Research on Highway Alignment Decision-making Based on Complex System Risk Analysis

ZHOU Zhi[1], CUI Xin-yuan[1], WANG Jing-ting[2]
1 School of Management, Chongqing Jiaotong University, P.R.China, 400074
2 School of Economic and Management, Tongji University , P.R.China, 200092

Abstract: Highway project construction is a complex system. The choice of highway route plan is the key job in decision-making and design phase before the construction of highway project. The highway alignment decision-making includes a lot of uncertain risk factors in the complex environment, the uncertain risk factors have characteristic of the dynamic change, the multiple risk factors action, cross-coupling effect , non-structural problem decision-making. For the traditional highway alignment decision-making is not adapt to sytematacially reflecting all kinds of risk factors in the complex system ,as well as the transmission relationship of the effect of the risk factors. In order to solve the Problem, a new method is put forward, which is based on fuzzy influence diagram theory. This paper constructs a fuzzy influence diagram model about the risk decision of highway alignment plan by the establishment of risk influence diagram and risk space. A case is given to illustrate to application of the model. The model is concise and clear in process of risk decision, and not only it is beneficial to construct information communication channels between risk analysts and decision makers by influence diagram ,but also it reduced the statistical data collection of the probability distribution in probability influence diagram evaluation, that is a rather difficult work in engineering practice. So it expanded the usable range of influence diagram and enhanced its practical applicability.

Keywords: complex system, risk analysis, highway alignment plan, risk decision-making, influence diagram

1 Introduction

Highway project construction is a complex system. The choice of highway alignment plan is the key job in project decision-making stage and design phase. Highway alignment plan decided the alignment directions of a Highway project, as well as mileage, highway alignment and the project scale etc..And, it decided the engineering quantity, construction period and engineering cost of the highway project. [1][2]So, in the construction of highway project, highway alignment plan has a decisive position. But the alignment plan decision-making is a very complex process , because the decision makers must have many subjects' professional knowledge, engineering technology, rich social practical experience, laws and regulations and other relevant knowledge. Especially, there are many uncertain factors which influence the alignment decision-making. So, it also needs an available scientific and effective decision-making method to deal with uncertain environment. Therefore, highway project construction is a complex system and highway alignment plan decision-making is the key link in the complex and dynamic system.[3] The highway alignment decision-making includes a lot of uncertain risk factors in the complex environment . The uncertain risk factors have characteristic of the dynamic change, the multiple risk factors action, cross-coupling effect, non-structural problem decision. [4]

Qualitative analysis is the major method in the traditional highway alignment decision-making, having a lack of theory support which is systemic and aims at complex system risk analysis. So in highway alignment decision-making neither does it reflect all kinds of uncertain risk factors and mutual influence of transitive relation correctly and entirely, nor lack for the objective data support based on the quantitative calculation. This makes the decision-making makers usually choose the complex system plans by subjective preferences in highway alignment plan selection. The errors of highway alignment decision-making could lead to very serious consequences, such as increasing investment, the major operation safe hidden troubles, geological hazard and environmental issues , as well as seriously restricts regional economic development. [5][6]This paper analyses the influence factors of highway alignment decision-making from a complex system risk analysis, then studies the uncertain risk factors existing in the decision-making and the mutual relationship. At last, the papper constructs alignment risk decision-making model based on fuzzy influence diagram and selected the alignment plan.[7]This paper combines a case of decision-making problems of the specific highway alignment plan, to illustrate application of the risk

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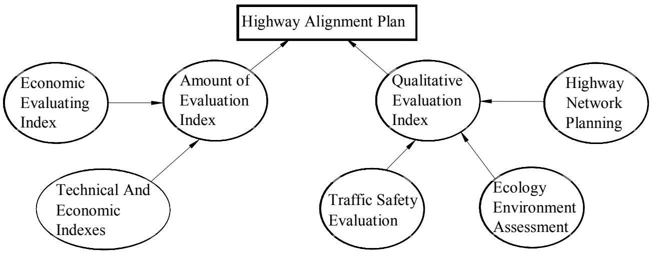

Fig.1 Level 1 risk goal influence diagram

decision-making process of the alignment plan. It has main reference value for the choice of selecting highway alignment plan, improving the scientific level of highway construction and improving the construction effect of a highway project.

2 Analysis of the uncertain risk factors and their relationship of highway alignment plan

2.1 Construct the level 1 risk target influence diagram

Highway alignment plan evaluation is divided into quantitative index and qualitative index, [8]because it is chosen mainly in planning and design stage. This paper gets the level 1 risk target influence diagram of highway alignment risk decision-making according to the compositional rules of influence diagrams Fig.1.

2.2 Construct level 2 and refining risk influence diagram

According to technological and economic characteristics of the highway alignment plan, decompose quantitative evaluation index and qualitative evaluation index of figure 1 and get level 2 risk goal.

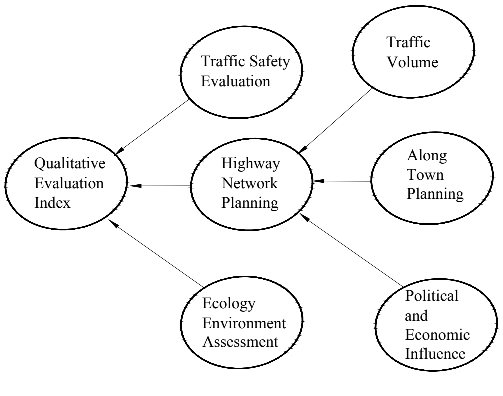

Fig.2 Qualitative evaluation index risk influence diagram

In Fig.2 foundation,make it refined according to technological and economic characteristics of the highway alignment plan. Fig.3 is traffic flow forecast risks influence diagram.

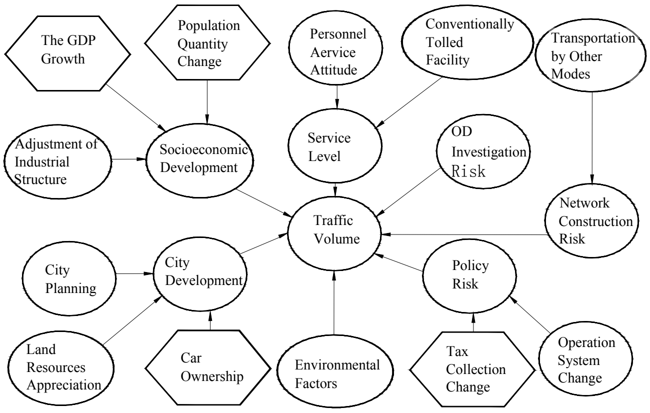

Fig.3 Traffic flow forecast risk influence diagram

According to the steps above, confirm the uncertainty factors' influence relationship of influencing the highway alignment plan and construct completed influence diagram of highway alignment plan about risk decision-making.

3 The fuzzy influence diagram model of highway alignment risk decision-making

Influence diagram is a new tool being developed over the last two decades to solve the issue of uncertain problems. As a toll for the analysis of decision-making R.A.Hward and his collaborators have already done the pioneering work. With the continuous improvement of the theory and the gradual expansion of its using, People are realizing its potential of development. As a toll for the analysis of decision-making, it links the two different areas that the analysis of decision-making and the artificial intelligence together, so does the personnel of the analysis of decision-making and the decision-making-makers. So it is a potential area. [9]Chinese scholars like professor Zhan yuanrui, Liu Jinlan, Sun Xiheng, Gu Changyue have done pioneering work in further theoretical research and practical application in the theories and methods of the influence diagram, making valuable achievements. The application in the field of highway alignment risk decision-making in China still needs further study and development.

Influence diagram is a network representation of the decision-making analysis model. [10]It is well defined in mathematical and graphics is intuitive to understand. The graphical representation of the influence diagram is appropriate for the thought process of decision-makers to understand the issues. The influence diagram can represent the probability of the relationships between risk variables and the flow of information clearly. It represents decision-makers' understanding of the issues and the graphical framework of experts' knowledge, so influence diagram is easy for the personnel of decision-making analysts , decision- makers and experts to exchange their ideas. At the same time, it is easy to create and modify a decision-making analysis model. What's more, it is also a framework of formal quantitative analysis of the decision-making problem. The form of the network of influence diagram is convenient for computer to calculate and is convenient for the communication between the personnel of decision-making analysis and computer workers.[11][12]

3.1 The evaluation method of probability influence diagram

In the use of influence diagram for decision-making analysis, there is a very big development study in foreign countries, mainly by two methods: one method is converting influence diagram into symmetric tree, but when it's used in dealing with large questions, the constructed decision-making tree is very big and the calculation is very complicated. Another method is based on such a kind of thinking that is from a influence diagram into another kind of influence diagram in the logical keep equivalence, such as Howard and Matheson points out that the equivalence based on two different influence diagram and says the state is drawing the information of the same. That suggests that the two may have the same relationship. The evaluation process of influence diagram is keeping the feasibility of influence diagram and not changing the optimal strategy or maximum effect under the condition of expectations. Making a series of transformation of influence diagram, this kind of logic equivalent transformation called keeping value. [13-15]

Shachter pointed out that if the joint probability or edge probability of influence diagram A' equal with influence diagram A, and the optimal strategy or maximum effect expectations of influence diagram A' is the same with influence diagram A, the operation from influence diagram A to influence diagram of A' was called as the influence diagram topological mapping. Influence diagram A and influence diagram A' logic equivalent. Arc to flip in Topology transformation method is to make the influence diagram flip through arc, delete redundant nodes, merger and decompose opportunity node. Therefore, dealing with the new diagram's data is easier. The basic steps of algorithm are as follows[16]:

(1) Remove redundant nodes

Redundant nodes is without the follow-up to opportunity node or decision-making node, because they have no effect on the value of the problem, so deleting the nodes will not change the value or joint probability distribution.

(2) Delete the opportunity node which enters into Value node

If the subsequent node of opportunity node is directly value node, then delete the node. To meet the conditions, it may need to flip the constraints of the arc between the nodes and other nodes, using the Bayes Rules to flip and deleting the node by looking for condition expected value.

(3) Delete decision-making node which enters into the value node

The conditions preface node of any value node in decision-making still not being observed (i.e. the subsequent node of decision-making node) should be deleted. Delete decision-making node by getting maximizing expected value. After all the preorder nodes before the value nodes are deleted, the whole process is over.

3.2 Fuzzy influence diagram model of highway alignment risk decision-making

3.2.1 Fuzzy influence diagram

The foundation of evaluation effect figure method of probability effect figure is that assuming the conditions probability and edge probability density contained in the analysis can be seeked out. The determination of non-independent variable conditions probability needs description for the combination of each state of its all conditions variable. This needs a cumbersome coding process whose workload will increase following the growth of effect figure node number, what's more, in highway alignment plan decision-making, there was also obvious difficulties to get the probability distribution of each risk variable. To overcome these limitations, this paper uses the influence diagram model to present the influence from various risk factors of the highway alignment plan selection, Using fuzzy set theory to solve influence diagrams so as to make full use of influence diagram to represent the influence of various risk variables. It can both do quantitative decision-making analysis and greatly simplifies solution of probability influence diagram.[17]

So-called fuzzy influence diagram is that, on the relationship layer, using graphical as representation, on function layer, using fuzzy sets to describe the relationships between variables, on the value layer, using fuzzy sets to describe the data structure of independent nodes. Different from the probability influence diagram, fuzzy influence diagram just uses language value to estimate the pairs relationship between the independent variables and variables, which will significantly shorten the process to solve influence diagrams.

Solution of fuzzy influence diagram begins from independent nodes, passing through the relationships between nodes, until projecting to the value node. It does not do influence diagram topological map and overcome the inconvenience to get optimum transformation sequence faults in probability influence diagram method.

3.2.2 Node release:

Fuzzy influence diagrams evaluation uses influence diagram to transfer frequency fuzzy sets, that is to say, using frequencies matrix of independent node and fuzzy relationship between predecessor and successor node to figure out the value node's frequence matrix. It would need to determine the frequency matrices of each condition node and all predecessor node of value node, figure out the frequency matrix of a node. It is considered to be free. Due to the need to figure out the frequence matrix of all predecessor node of each node, so it can only be released when its predecessor nodes are released. So on fuzzy influence diagrams, you must establish a release order. Firstly, calculate the frequency matrix for each independent variable. After all the independent node is released, calculate the frequency matrix of direct successor node of the independent variable and repeat the steps above until all nodes have been released.[18]

3.2.3 Fuzzy influence diagrams evaluation algorithm

Fuzzy influence diagrams evaluation algorithm is based on the relationship transitive principle of fuzzy synthesis.[19] Fuzzy influence diagram describes the relationship between the status frequency of nodes state by fuzzy theory. In determining the numerical layer and function layer of fuzzy influence diagram, it only needs to determine the status fuzzy sets of the independent variable, frequency fuzzy sets, non-State-space of the independent variable and fuzzy relationships between nodes. In effect, these data are generally relied on expert analysis to gain.

3.3 Node frequency matrix

3.3.1 Frequency matrix of independent nodes

Fuzzy quantifying of independent node status and frequency vector

Using fuzzy set theory to represent fuzziness and uncertainty is based on the quantification of language vocabulary. Establishment of fuzzy influence diagram needs three types of fuzzy sets: type one is used to describe the effects of each node in the graph, called the fuzzy set; type two is used to describe the independent variable (That is, without sequence nodes) frequency of each possible state, and may be referred to as frequency fuzzy sets; type three is used to describe the fuzzy relations between possible state of each node and possible state of it's predecessor and successor node.[20]

(1) The first type is determined by estimating possible state of each node and the possible state is often described by the words like "good, medium, bad","big, medium and small".

(2) The second type is determined by estimating the frequency of possible state of each node and the frequency is often described by words like "very high", "high" or "medium" and "low" and "very low".

(3) The third type is determined by estimating fuzzy relationship between possible state of each node and the possible state of its predecessor and successor. Calculated from the Cartesian product, the performance of fuzzy relation is fuzzy matrix which is a special form of fuzzy sets.

If X represents a node without predecessor, assume the node X possible state as:

$$P_x = \begin{Bmatrix} P_{x_1} \\ P_{x_2} \\ \cdots \\ P_{x_n} \end{Bmatrix} \tag{1}$$

$P_{x_1}, P_{x_2}, \cdots, P_{x_m}$ is state fuzzy set which defined by words.

The frequency vector of independent node X is:

$$f_x = \begin{Bmatrix} f_{x_1} \\ f_{x_2} \\ \cdots \\ f_{x_n} \end{Bmatrix} \tag{2}$$

$f_{x_1}, f_{x_2}, \cdots, f_{x_n}$ is one condition which is corresponding to frequence fuzzy sets about frequency vector of nodeX,frequency calculation of the node [21]:

$$F_x = \left(f_{x_1} \times P_{x_1}\right) \cup \left(f_{x_1} \times P_{x_1}\right) \cdots \cup \left(f_{x_n} \times P_{x_n}\right) \tag{3}$$

Operation symbol " × "is cartesian product,membership as following:

$$\mu R\left(f_{x_i}, P_{x_i}\right) = Min\left[\mu\left(f_{x_i}\right), \mu\left(P_{x_i}\right)\right] \tag{4}$$

3.3.2The independent node frequency matrix

① Ensure and all tight nodes before relation matrix

Establish One-to-one relationship Between nodes, This relationship may be a clear relationship between the number, such as function relation, Also may be fuzzy relations

② All the nodes of the matrix before tight frequency joint[22]

If X is by m random nodes $Y_1, Y_2, \cdots, Y_m$ as its previous node, No indirect previous node. F_{xp} is the coalition of all directly previous node's Frequency matrix of the node X.

$$F_{xp} = F_{Y_1} \cup F_{Y_2} \cdots \cup F_{Y_m} \tag{5}$$

Define the fuzzy relation of node to node is:

$$R_{XY_m} = \left(P_{Y_{m1}} \times P_{X_1}\right) \cup \left(P_{Y_{m2}} \times P_{X_2}\right) \cdots \cup \left(P_{Y_{mn}} \times P_{X_n}\right) \tag{6}$$

③ Calculate the frequency matrix of independent node

For example: make all the previous node of "technology index" complete relationship, Get all combination of previous node; then ensure the state of

Tab.1 Highway alignment comparison

Plans		Western	Middle	Eastern
Starting stake		K35+190	K35+190	K35+190
Ending stake		K228+327	K233+450	K222+498
Length(*km*)		193.137	198.26	187.308
Subline length(*km*)		40.5	26.5	16.5
Total construction scale (*km*)		233.637	198.26	203.808
The way of nantong line length		35.2	35.2	35.2
Grand bridge (*m*/*GL*)		17450/8	18550/9	18050/10
Highway overpass (*one location*)		10	10	9
Compare with each alignment Jinan	Beijing to Cangzhou	-22	-16	-15
	Beijing to Jinan	-44	-39	-48
Network layout analysis	Da Guang Highspeed	25	25	40
	Beijing -Shanghai Line	35	35	19

the combination of independent previous node, Finally get the state frequency matrix of the independent node:

$$F_{\text{qualification}} = F_{\text{qualification}\cdot \mathrm{P}} \otimes R_{\text{qualification}\cdot \mathrm{P}} \quad (7)$$

The operation is fuzzy transform, its algorithms is take small first " ∧ " ,then take big " ∨ ",namely

$$F_{\text{qualification}} = (f_{i1} \wedge r_{1j}) \vee (f_{i2} \wedge r_{2j}) \cdots (f_{in} \wedge r_{nj})$$

According to experts estimate the possible states of the independent node and Corresponding frequency and the relationship of node, Using the evaluation algorithm of Fuzzy image figure model to evaluate and calculate, According to the calculated value node, namely, Frequency matrix of Plan for the risk loss rate, combined the principle of the Maximum membership degree and Probability principle, Generation of state variable probability distribution:

$$P(x) = \frac{\mu_{x_1}}{\sum \mu_{x_i}} \quad (8)$$

According to Probability distribution Scheme decision-making, thus realize the highway alignment risk decision-making.

4 The case study

4.1 General situation

One highway in the northeast of china has three alignment plans, the engineering and technical characteristics follows as Tab.1.

4.2 Construe the fuzzy influence diagram model about highway alignment plan I

This paper has construe an implified model which only consider fuzzy influence diagram of highway alignment plan evaluation as Fig.4.

4.3 The frequency matrix calculation process of each node

The frequency matrix of " Road network planning 3" node

①Political and economic significance node status and frequency are following as Tab.2.

For the plan I could pull the endpoint of city development ability force small,sothe frequency matrix of the node 1=(Medium×Meaning Large) ∪ (High×Meaning Larger) ∪(Low×Meaning small), the result is following:

$$\left[\begin{array}{cccc} & I & L & B \\ 1 & 0.4 & 0.8 & 0.2 \\ 0.8 & 0.5 & 0.5 & 0,2 \\ 0.6 & 0.8 & 0.5 & 0 \\ 0.4 & 0.3 & 0.3 & 0 \\ 0.3 & 0 & 0.4 & 0.4 \\ 0.2 & 0 & 0.4 & 0.6 \\ 0.1 & 0 & 0.4 & 0.8 \end{array}\right] \begin{array}{c} SUM \\ 1.4 \\ 1.2 \\ 1.3 \\ 0.6 \\ 0.8 \\ 1.0 \\ 1.2 \end{array}$$

Note: I-Important;L-Less important;B-Bad.

The probability distribution of the political and economic significance:

P(Meaning Large)=0.4/1.4=28.57%,

P(Meaning Larger)=0.8/1.4=57.14%,

P(Meaning small)=0.2/1.4=14.29%

"Traffic flow forecast node2" of the state and frequency are following as Tab.3.

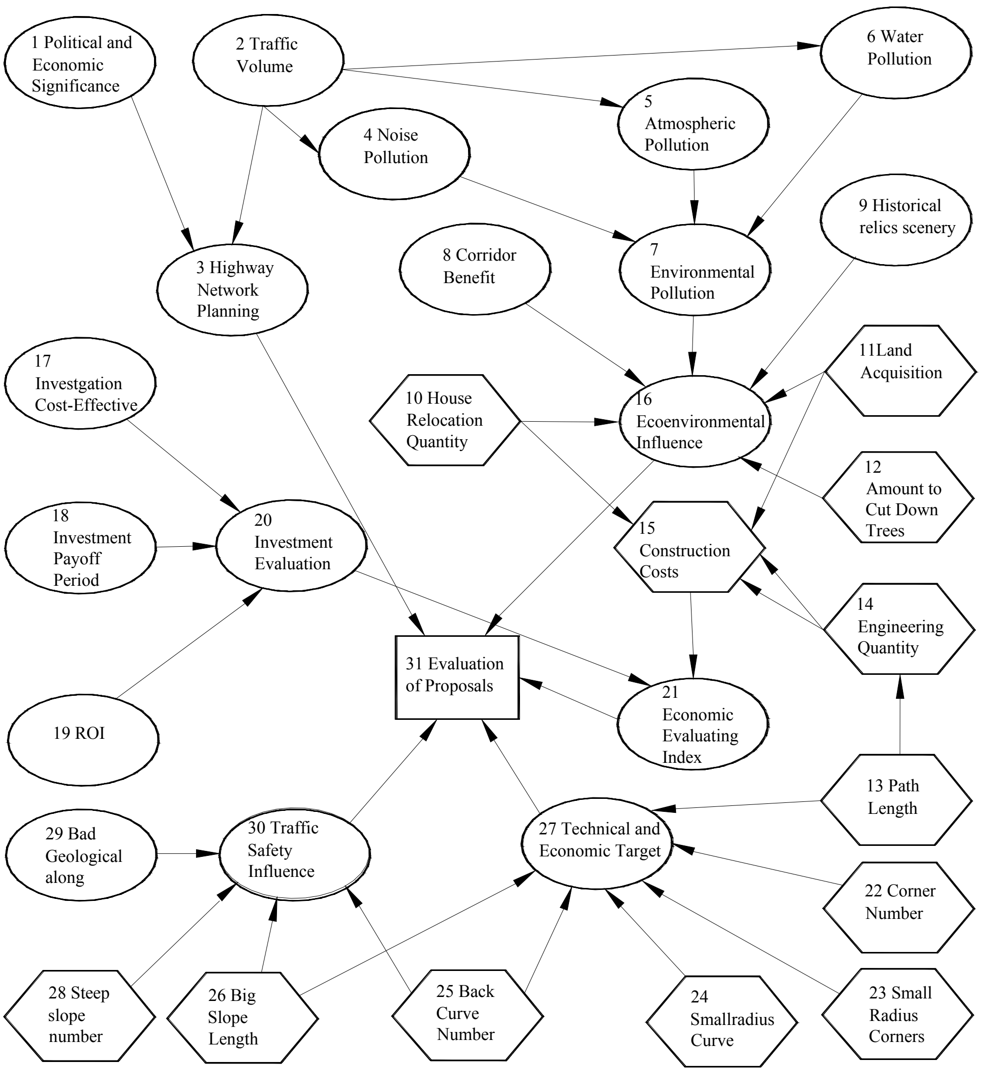

Fig.4 Risk influence diagram of highway alignment plan evaluation

Tab.2 Political and economic node status and frequency

State		Frequency	
Meaning Large	$\begin{pmatrix} \text{Important} \mid 1 \\ \text{Less important} \mid 0.5 \\ \text{Unimportant} \mid 0 \end{pmatrix}^T$	Medium	$\begin{pmatrix} 0.4 \mid 0.3 \\ 0.6 \mid 0.8 \\ 0.8 \mid 0.5 \end{pmatrix}^T$
Meaning Larger	$\begin{pmatrix} \text{Important} \mid 0.4 \\ \text{Less important} \mid 1 \\ \text{Unimportant} \mid 2 \end{pmatrix}^T$	High	$\begin{pmatrix} 0.6 \mid 0.4 \\ 0.8 \mid 0.6 \\ 0.1 \mid 0.8 \end{pmatrix}^T$
Meaning small	$\begin{pmatrix} \text{Important} \mid 0 \\ \text{Less important} \mid 0.4 \\ \text{Unimportant} \mid 0.9 \end{pmatrix}^T$	Low	$\begin{pmatrix} 0.1 \mid 0.8 \\ 0.2 \mid 0.6 \\ 0.3 \mid 0.4 \end{pmatrix}^T$

Tab.3 Traffic flow node of the state and frequency

State		Frequency	
Heavy traffic	[3.0|0.6, 3.5|0.8]	High	[0.6|0.4, 0.8|0.6, 1.0|0.8]
General traffic	[2.0|0.6, 2.5|0.8]	Medium	[0.4|0.3, 0.6|0.8, 0.8|0.5]
Small traffic	[1.0|0.8, 1.5|0.5]	Low	[0.1|0.8, 0.2|0.6, 0.3|0.4]

Note: The traffic has 1.015 million, 20000, 25.335 million, the unit is all vehicles/day.

The frequency matrix of the node 2=(Medium×general Traffic e) ∪(High×heavy traffic r) ∪(Low×small Traffic) , the result is following:

$$\begin{pmatrix} & 1.0 & 1.5 & 2.0 & 2.5 & 3.0 & 3.5 \\ 1.0 & 0 & 0 & 0 & 0 & 0.6 & 0.8 \\ 0.8 & 0 & 0 & 0.5 & 0.5 & 0.6 & 0.6 \\ 0.6 & 0 & 0 & 0.6 & 0.8 & 0.4 & 0.4 \\ 0.4 & 0 & 0 & 0.3 & 0.3 & 0 & 0 \\ 0.3 & 0.4 & 0.4 & 0 & 0 & 0 & 0 \\ 0.2 & 0.6 & 0.5 & 0 & 0 & 0 & 0 \\ 0.1 & 0.8 & 0.5 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{matrix} SUM \\ 1.4 \\ 2.2 \\ 2.2 \\ 0.6 \\ 0.8 \\ 1.1 \\ 1.3 \end{matrix}$$

The probability distribution of the node 2:

P(Traffic= thirty thousand pcu/d)=0.6/1.4=42.86%,

P(Traffic= thirty five thousand pcu/d)=0.8/1.4 =57.14%

Frequency matrix of "Transit planning"node:

(1)Synthetic node 3 that the node state joint of all predecessor $F_{3.P}$,the result is following:

$$F_{3.P}=\begin{bmatrix} & I & L & B & 1.0 & 1.5 & 2.0 & 2.5 & 3.0 & 3.5 \\ 1.0 & 0.4 & 0.8 & 0.2 & 0 & 0 & 0 & 0 & 0.6 & 0.8 \\ 0.8 & 0.5 & 0.5 & 0.2 & 0 & 0 & 0.5 & 0.5 & 0.6 & 0.6 \\ 0.6 & 0.8 & 0.5 & 0 & 0 & 0 & 0.6 & 0.8 & 0.4 & 0.4 \\ 0.4 & 0.3 & 0.3 & 0 & 0 & 0 & 0.3 & 0.3 & 0 & 0 \\ 0.3 & 0 & 0.4 & 0.4 & 0.4 & 0.4 & 0 & 0 & 0 & 0 \\ 0.2 & 0 & 0.4 & 0.6 & 0.6 & 0.5 & 0 & 0 & 0 & 0 \\ 0.1 & 0 & 0.4 & 0.8 & 0.8 & 0.5 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Note: I-Important;L-Less important;B-Bad.

(2)Synthetic node 3 that the node relationship joint of all predecessor $R_{3.P}$.

If 1 is important then 3 is "Network is very good",

If 1 is less important then 3 is "Network is good",

If 1 is unimportance then 3 is "Network is bad";

If 1 is heavy traffic then 3 is "Network is very good",

If 1 is general traffic then 3 is "Network is good",

If 1 is small Traffic then 3 is "Network is bad".

The relationship matrix between node 1 and node 3 is:

$R_{3.1}$=(Important×Verygood) ∪ (Less important×good) ∪(Unimportant×Bad)

$$=\begin{pmatrix} & Verygood & Good & Bad \\ \text{Important} & 0.9 & 0.6 & 0 \\ \text{Less important} & 0.4 & 0.8 & 0.1 \\ \text{Unimportant} & 0 & 0.3 & 0.8 \end{pmatrix}$$

The relationship matrix between node 2 and node 3 is:

$R_{3.2}$=(Heavy×Verygood) ∪ (Normal important×good) ∪(Small×Bad)

$$=\begin{pmatrix} & Verygood & Good & Bad \\ 1.0 & 0 & 0 & 0.9 \\ 1.5 & 0 & 0 & 0.8 \\ 2.0 & 0 & 0.6 & 0.3 \\ 2.5 & 0 & 0.8 & 0 \\ 3.0 & 0.8 & 0.6 & 0 \\ 3.5 & 1 & 0 & 0 \end{pmatrix}$$

Synthetic node 3 that the node relationship joint of all predecessor $R_{3.P}$:

$R_{3.P}= R_{3.1} \cup R_{3.2}$

$$=\begin{pmatrix} & Verygood & Good & Bad \\ I & 0.9 & 0.6 & 0 \\ L & 0.4 & 0.8 & 0.1 \\ B & 0 & 0.3 & 0.8 \\ 1.0 & 0 & 0 & 0.9 \\ 1.5 & 0 & 0 & 0.9 \\ 2.0 & 0 & 0.6 & 0.3 \\ 2.5 & 0 & 0.8 & 0 \\ 3.0 & 0.8 & 0.6 & 0 \\ 3.5 & 1 & 0 & 0 \end{pmatrix}$$

Note:I-Important;L-Less important;B-Bad.

The frequency matrix of the node 3:

$F_{3.P}= F_{3.P} \cup R_{3.P}$

$$=\begin{pmatrix} & Verygood & Good & Bad \\ 1.0 & 0.8 & 0.8 & 0.2 \\ 0.8 & 0.6 & 0.6 & 0.5 \\ 0.6 & 0.8 & 0.8 & 0.3 \\ 0.4 & 0.3 & 0.3 & 0.3 \\ 0.3 & 0.4 & 0.4 & 0.4 \\ 0.2 & 0.4 & 0.4 & 0.6 \\ 0.1 & 0.4 & 0.4 & 0.8 \end{pmatrix}$$

By such analogy to get frequency matrix of "16 the ecological environment" node, "15 economic evaluation index node ", "27 technical evaluation index" node, "30 traffic safety influence" node. The final value node 31 and the probability distribution of highway alignment plan 1 node risk decision-making is following:

$$R_{31.P} = R_{31.3} \cup R_{31.15} \cup R_{31.16} \cup R_{31.27} \cup R_{31.30}$$

$$=\begin{pmatrix} & G & B \\ \text{Good planning} & 1.0 & 0 \\ \text{Bad planning} & 0 & 1.0 \\ \text{Ecological influence serious} & 0.2 & 0.8 \\ \text{Ecological influence not serious} & 0.8 & 0.2 \\ \text{Good technology index} & 0.2 & 0.8 \\ \text{Bad technology index} & 0.8 & 0.2 \\ \text{Safety influence serious} & 0.9 & 0 \\ \text{Safety influence not serious} & 0.1 & 0.6 \\ \text{High cost} & 0.2 & 0.8 \\ \text{Low cost} & 0.8 & 0.2 \end{pmatrix}$$

Frequency matrix of node 31 is following :

$$F_{31}=F_{31.P}\cup R_{31.P}=\begin{array}{c}\begin{array}{ccc} G & B & SUM\end{array}\\ \left(\begin{array}{ccc|c} 1.0 & 1.0 & 0.6 & 1.6\\ 0.8 & 0.8 & 0.6 & 1.4\\ 0.6 & 0.8 & 0.9 & 0.8\\ 0.4 & 0.8 & 0 & 0.8\\ 0.2 & 0.6 & 0 & 0.6\end{array}\right)\end{array}$$

Thus, obtain the probability distribution of plan1,that just is the risk evaluation of planI:

P(PlanIis good)=1.0/1.6=62.5%,

P(PlanIis bad)=0.6/1.6=37.5%,

Similarly, obtain the frequency matrix of node 31 of plan Ⅱ:

$$F_{31}'=F_{31.P}'\bigcup R_{31.P}'=\begin{array}{c}\begin{array}{ccc} G & B & SUM\end{array}\\ \left(\begin{array}{ccc|c} 1.0 & 0.8 & 0.8 & 1.6\\ 0.8 & 1.0 & 0.6 & 1.6\\ 0.6 & 0.6 & 0.4 & 1.0\\ 0.4 & 0.4 & 0.2 & 0.8\\ 0.2 & 0.2 & 0 & 0.2\end{array}\right)\end{array}$$

And get the probability distribution of plan 2, that just is the risk evaluation of plan 2

P(PlanⅡis good)=0.8/1.6=50%,

P(PlanⅡis bad)=0.8/1.6=50%,

4.4 The risk decision-making of highway alignment

According to the probability distribution of the highway alignment plan 1 and plan 2, the plan decision-making:

P(Plan I is good)=1.0/1.6=62.5%

>P(Plan II is good)=0.8/1.6=50%

To sum up, highway alignment plan should be plan I.

5 Conclusion

For technology and economy characteristics of highway project construction, it determines that highway alignment plan decision-making is a complex system risk decision-making problem. In this paper, based on complex system risk analysis, authors studied the characterization of the risks and their relevance, and illustrated risk influence, transmission and cross-coupling process, in highway alignment plan decision-making. And on this basis, authors constructed a model on fuzzy influence diagram to characterize the risk of highway alignment plan and to make the risk decision. The model is able to enhanced the application of influence diagram in engineering, for it avoids a large amount of the work to obtain the probability distribution to collect statistical data in probability influence diagram evaluation, which is a very difficult work in engineering practice. So the model also expanded the usable range of influence diagram and enhanced its practical applicability. A case has been given to illustrate the application of the model in highway alignment plan decision-making.

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