Research on Risk Evaluation in Urban Rail Transit Project

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Abstract

Methods combining fuzzy evaluation theory and network analysis is utilized to establish risk evaluation system and evaluation model, and to completely state application of fuzzy ANP in project risk evaluation by taking urban rail transit in a certain city for example, which shall provide decision reference for effectively controlling risks of urban rail transit project.

Keywords: Urban Rail Transit Project; Risk Evaluation; Fuzzy Analytic Network Process

1. Introduction

There will be larger risks in implementation of urban rail transit due to long construction period, large investment scale, wide coverage and complex technology. In Recent years, many scholars have made researches on risks of urban rail transit project, for example: Sock-Yong Phang (2007), Jinghua Li (2007), Lei Xie (2008) and etc respectively analyzed and evaluated the risk of urban rail transit project under PPP financing mode, and proposed corresponding risk aversion strategy from qualitative point of view [1-3]; Li Hou (2009), taking urban rail transit project in Vietnam for example, carried out research on financing risks of BOT projects respective from time dimension, logic dimension and knowledge dimension by taking use of Hall three-dimension model analysis methods [4]; Yaodong Zhou and Minglu Shi (2009), analyzed the risk factors and the degree of risk effects of rail transit project by AHP model [5]; Yujun Wen (2010), taking urban rail transit in Shanghai for example, systemically stated countermeasures of risk control and management in project construction [6].

Seen from documentary search, researches related to risks of urban rail transit project are still in qualitative analysis stage at present, lack of accurate measurement and evaluation on risks. Risks in urban rail transit projects are various and of complex relationship. Many risk factors are complex and of mutual independence and mutual influence; in addition, risk factors also have problems like difficulty in accurate description of risks degree and unclear borders. Therefore, based on existing research results [7-8], the author made quantitative analysis and evaluation on risks in urban rail transit projects by taking use of fuzzy network analysis.

2. Evaluation Methods

2.1. Establishment of risk evaluation indicator system

Referring to [9], this paper established risk evaluation indicator system for urban rail transit projects, and three structures of target level A, standard level B and factors level C as shown in Table 1.
Table 1 Risk evaluation indicator system for rail transit projects

<table>
<thead>
<tr>
<th>Target level A</th>
<th>Standard level B</th>
<th>Factors level C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk evaluation A in Urban</td>
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<td></td>
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<tr>
<td>Rail transit projects</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Political risks $B_1$</td>
<td></td>
<td>Permission risks $C_{11}$</td>
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<tr>
<td></td>
<td></td>
<td>Policy risks $C_{12}$</td>
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<td></td>
<td></td>
<td>Nationalization risks $C_{13}$</td>
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<tr>
<td>Economic risks $B_2$</td>
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<td>Market risks $C_{21}$</td>
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<tr>
<td></td>
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<td>Interest rate risks $C_{22}$</td>
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<td></td>
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<td>Exchange rate risks $C_{23}$</td>
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<tr>
<td></td>
<td></td>
<td>Inflation risks $C_{24}$</td>
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<tr>
<td>Legal and contractual risks $B_3$</td>
<td></td>
<td>Legal risks $C_{31}$</td>
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<tr>
<td></td>
<td></td>
<td>Contractual risks $C_{32}$</td>
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<tr>
<td>Environmental risks $B_4$</td>
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<td>Natural Environmental risks $C_{41}$</td>
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<tr>
<td></td>
<td></td>
<td>Economic, social and human</td>
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<tr>
<td></td>
<td></td>
<td>Environmental risks $C_{42}$</td>
</tr>
<tr>
<td>Completion risks $B_5$</td>
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<td>Engineering design and construction</td>
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<td>technical scheme risks $C_{51}$</td>
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<td>Organization and management risks of</td>
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<td></td>
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<td>engineering construction $C_{52}$</td>
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<td></td>
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<td>Capital risks $C_{53}$</td>
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<tr>
<td>Operation and maintenance risks $B_6$</td>
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<td>Operation conditions risks $C_{61}$</td>
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<td>Operation management risks $C_{62}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation technology risks $C_{63}$</td>
</tr>
</tbody>
</table>

2.2. Establishment of ANP model

Considering mutual influence between factors and based on risk evaluation indicator system listed in Table 1, An ANP network structure is constructed, which is shown in Figure 1.

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**Figure 1 ANP network structure**
Indirect dominance comparison on factors in factor set $B_i$ is carried out according to their influence on $C_j$ by considering factor set $B_i$ ($i=1,2,\ldots,6$) as primary standard and factor set $C_j$ ($j=1,2,\ldots,6$) as secondary standard, that is, to construct judgment matrix. Then maximum eigenvalue and characteristic vector is calculated and judged by adopting eigenvalue methods. Relative weights of factors under certain standard are calculated and consistency check is carried out according to judgment matrix. If consistency rate $C.R. < 0.10$, it proves that such comparison judgment matrix possesses a satisfactory consistency; if consistency rate $C.R. > 0.10$, adjustment is required to be carried out. To obtain super matrix $W$:

$$W = \begin{bmatrix}
    w_{11} & w_{12} & w_{13} & w_{14} & w_{15} & w_{16} \\
    w_{21} & w_{22} & w_{23} & w_{24} & w_{25} & w_{26} \\
    w_{31} & w_{32} & w_{33} & w_{34} & w_{35} & w_{36} \\
    w_{41} & w_{42} & w_{43} & w_{44} & w_{45} & w_{46} \\
    w_{51} & w_{52} & w_{53} & w_{54} & w_{55} & w_{56} \\
    w_{61} & w_{62} & w_{63} & w_{64} & w_{65} & w_{66}
\end{bmatrix}$$

(1)

If factors in $B_i$ are of no influence on factors in $B_j$, $w_{ij} = 0$ ($i=1,2,\ldots,6$; $j=1,2,\ldots,6$). $w_{ij}$ block in super matrix is normalization in column, but $W$ is not normalization in column. Corresponding characteristic vector $K_{ij}$ of maximum eigenvalue in $W$ (i=j) shall be respectively calculated.

Weighting matrix is obtained by carrying out comparison on importance of factors in each group to standard $B_j$ ($j=1,2,\ldots,6$):

$$b = \begin{bmatrix}
    b_{11} & b_{12} & \cdots & b_{16} \\
    \cdots & \cdots & \cdots & \cdots \\
    b_{61} & b_{62} & \cdots & b_{66}
\end{bmatrix}$$

(2)

$W = (w_{ij})$ is obtained by carrying out weighting on factors in super matrix $W$, thereinto, $w_{ij} = b_i(w_{ij})$ (i=1,2,3,4,5,6), and $W$ is weighting super matrix with a column sum of 1, which is called random matrix:

$$W = \begin{bmatrix}
    b_{11}w_{11} & b_{12}w_{12} & b_{13}w_{13} & b_{14}w_{14} & b_{15}w_{15} & b_{16}w_{16} \\
    b_{21}w_{21} & b_{22}w_{22} & b_{23}w_{23} & b_{24}w_{24} & b_{25}w_{25} & b_{26}w_{26} \\
    b_{31}w_{31} & b_{32}w_{32} & b_{33}w_{33} & b_{34}w_{34} & b_{35}w_{35} & b_{36}w_{36} \\
    b_{41}w_{41} & b_{42}w_{42} & b_{43}w_{43} & b_{44}w_{44} & b_{45}w_{45} & b_{46}w_{46} \\
    b_{51}w_{51} & b_{52}w_{52} & b_{53}w_{53} & b_{54}w_{54} & b_{55}w_{55} & b_{56}w_{56} \\
    b_{61}w_{61} & b_{62}w_{62} & b_{63}w_{63} & b_{64}w_{64} & b_{65}w_{65} & b_{66}w_{66}
\end{bmatrix}$$

(3)

Normalization characteristic vector $K$ of $W$ can be further obtained, which is the final weighting defined by this model.

2.3. Establishment of fuzzy consistency judgment matrix

Firstly, evaluation factor set $U = \{U_1, U_2, \ldots, U_n\}$ shall be confirmed, thereinto, $U_u$ is each factor incident in factor level. Judgment set $V = \{V_1, V_2, \ldots, V_m\}$ involving m factors shall be established. The author will establish evaluation set by adopting five grades risk judgment methods: {High risks, relative high risks, medium risks, relative low risks, low risks}, and obtain judgment matrix according to marks given by experts and property of fuzzy consistency matrix:

$$R_i = \begin{bmatrix}
    r_{i1} & r_{i2} & \cdots & r_{im} \\
    r_{21} & r_{22} & \cdots & r_{2m} \\
    \vdots & \vdots & \cdots & \vdots \\
    r_{ni} & r_{n2} & \cdots & r_{nm}
\end{bmatrix} = (r_{ij})_{mn}$$

(4)
2.4. Confirmation of risk level

\( M(\otimes) \) model shall be adopted for composition operator of comprehensive evaluation, that is, weighted average operator, since additive operator is suitable for comprehensive evaluation giving overall consideration to overall factors. Calculation result is as shown in the below:

\[
B = KR
\]

Risk level shall be confirmed based on maximum membership principle.

3. Example Analysis

Subway engineering in a certain city, with an investment of RMB 11,900 million in total, will arrange 19 stations along the line, time of which is 5 years. After completion, such project will well improve transit congestion situation in the city. Indicators system shall be established based on Table 1.

The author invited 20 project managers and experts familiar with this project to give a mark on risk evaluation indicators in the manner of questionnaire survey, and takes use of aforesaid risk evaluation model to carry out analysis and handle on collected data through collection, arrangement and statistics of questionnaire, in order to confirm risk level of each risk factor.

3.1. Establishment of factor level super matrix

In \( B_{1} \) (political risks), indirect dominance comparison shall be carried out respectively considering \( C_{11} \) permission risks, \( C_{12} \) policy risks, \( C_{13} \) nationalization risks as standard, weighting vector shall be obtained by taking use of eigenvalue method, so as to form judgment matrix:

\[ w_{11} = \begin{bmatrix} 0.637 & 0.258 & 0.258 \\ 0.258 & 0.637 & 0.105 \\ 0.105 & 0.105 & 0.637 \end{bmatrix} \]

Similarly, we can prove that: \( W_{12}, W_{13}, W_{14}, W_{15}, W_{16}, W_{21}, W_{22}, W_{23}, W_{24}, W_{25}, W_{26}, W_{31}, W_{32}, W_{33}, W_{34}, W_{35}, W_{36}, W_{41}, W_{42}, W_{43}, W_{44}, W_{45}, W_{46}, W_{51}, W_{52}, W_{53}, W_{54}, W_{55}, W_{56}, W_{61}, W_{62}, W_{63}, W_{64}, W_{65}, W_{66} \), thus, unweighted factor level super matrix can be established:

\[
W = \begin{bmatrix} 0.637 & 0.258 & 0.258 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 \\ 0.258 & 0.637 & 0.105 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 \\ 0.105 & 0.105 & 0.637 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 & 0.333 \\ 0.167 & 0.167 & 0.095 & 0.657 & 0.100 & 0.076 & 0.100 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 \\ 0.500 & 0.500 & 0.250 & 0.076 & 0.700 & 0.191 & 0.100 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 \\ 0.167 & 0.167 & 0.560 & 0.076 & 0.100 & 0.657 & 0.100 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 \\ 0.167 & 0.167 & 0.191 & 0.100 & 0.076 & 0.700 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 & 0.250 \\ 0.500 & 0.500 & 0.250 & 0.833 & 0.500 & 0.500 & 0.750 & 0.250 & 0.250 & 0.250 & 0.750 & 0.750 & 0.750 & 0.833 & 0.750 & 0.750 \\ 0.500 & 0.500 & 0.750 & 0.167 & 0.500 & 0.500 & 0.250 & 0.250 & 0.250 & 0.750 & 0.750 & 0.750 & 0.250 & 0.250 & 0.167 & 0.250 \\ 0.250 & 0.500 & 0.500 & 0.500 & 0.500 & 0.500 & 0.500 & 0.500 & 0.833 & 0.167 & 0.500 & 0.500 & 0.500 & 0.500 & 0.750 & 0.750 \\ 0.750 & 0.500 & 0.500 & 0.500 & 0.500 & 0.500 & 0.500 & 0.500 & 0.167 & 0.833 & 0.500 & 0.500 & 0.500 & 0.250 & 0.250 & 0.250 \\ 0.333 & 0.333 & 0.333 & 0.200 & 0.333 & 0.333 & 0.258 & 0.200 & 0.200 & 0.637 & 0.600 & 0.258 & 0.258 & 0.333 & 0.333 & 0.200 \\ 0.333 & 0.333 & 0.333 & 0.200 & 0.333 & 0.333 & 0.105 & 0.600 & 0.600 & 0.200 & 0.105 & 0.200 & 0.637 & 0.105 & 0.333 & 0.333 & 0.200 \\ 0.334 & 0.334 & 0.334 & 0.600 & 0.334 & 0.334 & 0.637 & 0.200 & 0.200 & 0.600 & 0.258 & 0.200 & 0.105 & 0.637 & 0.334 & 0.334 & 0.600 \\ 0.333 & 0.333 & 0.333 & 0.188 & 0.333 & 0.333 & 0.188 & 0.200 & 0.200 & 0.333 & 0.429 & 0.200 & 0.333 & 0.637 & 0.200 & 0.258 \\ 0.333 & 0.333 & 0.333 & 0.081 & 0.333 & 0.333 & 0.081 & 0.600 & 0.200 & 0.333 & 0.142 & 0.200 & 0.333 & 0.200 & 0.105 & 0.600 & 0.105 \\ 0.334 & 0.334 & 0.334 & 0.731 & 0.334 & 0.334 & 0.731 & 0.200 & 0.600 & 0.334 & 0.429 & 0.600 & 0.334 & 0.600 & 0.258 & 0.200 & 0.637 \end{bmatrix} \]
3.2. Establishment of standard level super matrix

Respectively considering $B_1$, $B_2$, $B_3$, $B_4$, $B_5$, and $B_6$ as standard, judgment matrixes are established, and corresponding characteristic vector of maximum eigenvalue of these matrixes are calculated. Standard level weighting matrix $\mathbf{b}$ is formed after composite of the aforesaid characteristic vector:

$$
\mathbf{b} = 
\begin{bmatrix}
0.125 & 0.069 & 0.125 & 0.125 & 0.125 & 0.125 \\
0.125 & 0.419 & 0.125 & 0.125 & 0.125 & 0.125 \\
0.125 & 0.069 & 0.375 & 0.125 & 0.125 & 0.375 \\
0.125 & 0.187 & 0.125 & 0.125 & 0.375 & 0.125 \\
0.375 & 0.187 & 0.125 & 0.125 & 0.125 & 0.125 
\end{bmatrix}
$$

3.3. Establishment of fuzzy evaluation matrix

Fuzzy relationship $R (U \rightarrow V)$ is established through statistics analysis on evaluation mark of risk factors, so as to obtain fuzzy evaluation matrix:

$$
R = 
\begin{bmatrix}
0 & 0 & 0 & 0.50 & 0.50 \\
0 & 0.4 & 0.5 & 0.1 & 0 \\
0 & 0.25 & 0.25 & 0.25 & 0.25 \\
0 & 0 & 0.5 & 0.25 & 0.25 \\
0 & 0.25 & 0.25 & 0.5 & 0 \\
0.5 & 0.2 & 0.2 & 0.1 & 0 \\
0.75 & 0.25 & 0 & 0 & 0 \\
0 & 0.2 & 0.15 & 0.15 & 0.5 \\
0 & 0.25 & 0.25 & 0.2 & 0.3 \\
0 & 0.25 & 0.25 & 0.5 & 0
\end{bmatrix}
$$

3.4. Evaluation results

Weighting super matrix can be obtained based on equation (3):
Corresponding characteristic vectors of maximum eigenvalue of matrix $\tilde{W}$ can be obtained:

$$\tilde{K} = \begin{bmatrix}
0.064 & 0.035 & 0.034 & 0.035 & 0.043 & 0.0370 & 0.036 & 0.188 & 0.098 & 0.071 & 0.065 & 0.040 & 0.053 & 0.053 & 0.044 & 0.047 & 0
\end{bmatrix}$$

Value in matrix $B$ reflects risk influence degree of each risk factor in factor level. Legal risks and contractual risks exert a large influence on the project, while nationalization risks exert a relatively small influence on the project.

Risk level of each risk factor in standard level as well as target level can be confirmed according to equation (5) and maximum membership principle:

- **Political risks:** $B_{11} = [0.2022, 0.1462, 0.3539, 0.2978]$, belonging to relative low risk.
- **Economic risks:** $B_{22} = [0.289, 0.214, 0.229]$, belonging to medium risks.
- **Legal and contractual risks:** $B_{33} = [0.400, 0.375, 0.175, 0.050, 0]$, belonging to high risks.
- **Environmental al risks:** $B_{44} = [0.250, 0.400, 0.250, 0.100]$, belonging to medium risks.
- **Completion contractual risks:** $B_{55} = [0.576, 0.235, 0.159, 0.030, 0]$, belonging to high risks.
- **Operation and maintenance risks:** $B_{66} = [0.230, 0.210, 0.299, 0.260]$, belonging to relative low risks.
- **Project overall risks:** $B = [0.181, 0.261, 0.235, 0.199, 0.125]$, belonging to relative high risks.

Therefore, project managers shall adopt proper ways to prevent and control risks after balancing risk loss and risk control costs according to risk level and influence degree of each risk factor obtained by aforesaid calculation.

4. Conclusions

Due to complexity of risks in urban rail transit project, this paper proposes to take use of fuzzy ANP for carrying out evaluation on project risks. Network analysis, as a method combining qualitative method and quantitative method, possesses obvious advantages on handling complex problems influence, factors of which possess feedback and relevancy. Introduction of fuzzy evaluation theory can carry out effective handle on risk factors which are hard to accurately describe and of unclear borders, so as to improve effectiveness of model evaluation. It is proved by example analysis results that, evaluation method of urban rail transit based on fuzzy ANP is scientific and effective, which can provide decision reference for project risk management.

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References