Research on the Line Selection of "Xubi Railway" Based on Analytic Hierarchy Process

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Abstract. This paper considers the various factors and different schemes that influence the direction of the railway line in Xubi, establishes the corresponding pairwise comparison matrix, analyses the line trend by using the analytic hierarchy process (Hereinafter referred to as AHP), and quantifies the comparison results of different schemes (east, middle and west lines) to provide reference and basis for the Xubi Railway line selection. It is necessary to fully demonstrate the relative importance of various factors affecting the railway’s direction to ensure the rationality of the judgment matrix. The AHP is intuitive to compare different approaches, making the results of railway line selection more scientific. The analysis results show that the mid-line scheme is far better than the east and west lines.

1. Introduction
The “Xubi Railway” starts with Xuyong and ends with Bijie (Chuandian Section), which is an important part of the Longchang-Huangtong Railway. It is located in the remote area at the junction of Sichuan and Yunnan. From the north of the line, there is the Longfeng Station of the Naxi-Xuyong Railway, to the south through Yibin City. Railway Line Scheme Optimal is a complicated systematic project, mainly because it is a general work with a global impact. In order to obtain an optimal line plan, many scholars have applied a variety of evaluation methods to railway line selection [1-4]. This research makes full use of the knowledge and experience of experts, and divides the factors affecting the route of the “Xubi Railway” into five, namely, engineering geological conditions and engineering reliability, key project angle and construction period, route length and investment angle, conducive to local economic development perspectives and planning, attracting local traffic and investment benefits along the line, and fully demonstrating the weight of each factor to ensure the rationality and scientificity of the relative matrix. For the three major macro-trend comparison schemes of East, Central and West, a hierarchical analysis model is established to determine the optimal railway trend plan.

2. Brief introductions to the route plan
The line route research determines the macro-direction plan of the line according to the location characteristics of the project, the status quo of the regional railway network and development planning and engineering conditions. This study combines the distribution of regional economic bases. The
Longfeng-Bijie section studies the three major macro-trends of the East, Central and West from the east to the west of Yunnan Province.

2.1 East Line Plan: Refers to the plan east of Yunnan Province. The line is drawn from the Longfeng Station of the existing cable line. It goes to the South Exhibition Line to Haiba Township of Xuyong County. It passes through Haizitang with a 14290m long tunnel to the Taiping. After the station is set up, continue to use the main span of 360m up-construction reinforced concrete arch across the Chishui River to Guizhou Province, and then the route to the east to avoid the Cover mountain nature reserve, after the Datang, Houchuan, and the muddy field, the comparative terminal Bijie station was introduced. The total length of the line within the comparison range of this scheme is 154.580km.

2.2 Mid-line plan: Refers to the plan between Yunnan Province and Chishui source. The line leads to Longfeng Station, westward to Jingui, Jingechichi and then to Gaofeng Temple. After the station is set up, the tunnel will enter the Territory of Weixin County of Yunnan Province with a 7525m tunnel. After the Majiaba and Xiaping Stations, the long tunnel will be 12670m to the Weixin Station where the railway will be built. At the Weixin Station where the Chenggui Railway was built, the line entered the Town of Zhenxiong County after passing through the Arroy in the southwest, and entered the Bijie City of Guizhou Province along the Chenggui Railway via the Guozhu and the Yile after the line. After the Heguantun and Degou, introduce the comparison terminal Bijie Station. The total length of the line within the comparison range of this scheme is 189.318km.

2.3 West Line Plan: Refers to the plan west of Chishui Source. The route from Longfeng to Guozhu is the same as the mid-line plan. After the fruit is out of the station, the line to the west through the Buwen, splashed and then turned to the east to access the mid-line program of Heguantun Station. The total length of the line within the scope of this scheme is 198.943km.

3. The specific application of AHP in the Xubi Railway

3.1 Building a hierarchical model
Taking the railway route plan from Xuyong North to Bijie East as the target layer Z, according to the location characteristics of the project, the existing railway network status and development planning, etc., the target layer is used as the solution layer B, and is decomposed into three major macro-strategies: East (B1), Middle (B2), and West(B3). Engineering geological conditions and engineering reliability (A1), key engineering angles and construction period (A2), route length and investment angle (A3), favourable local economic development perspective and planning (A4), attracting local traffic and investment along the route (A5). Five factors such are used as the criterion layer A, and the hierarchical structure model shown in Figure 1 is established.
Reconstruction to the comparison matrix

According to the characteristics of the railway engineering and the functional positioning characteristics of the Xubi Railway, combined with the influence of the route routing scheme on the entire line of the Longhuang Railway, considering the weight of the environmental impact on the route direction, fully discuss the factors of the criterion layer and the relative importance of the railway line in the target layer. Degree, described by a seven-level linear scale as follows:

\[
A = \begin{bmatrix}
1/4 & 1 & 1 & 1/2 & 2 \\
1/4 & 1 & 1 & 1/2 & 2 \\
1/4 & 1 & 1 & 1/2 & 2 \\
1/2 & 2 & 2 & 1/2 & 5 \\
1/7 & 1/2 & 1/2 & 1/5 & 1
\end{bmatrix}
\]

The advantages and disadvantages of each criterion are compared as follows:

3.2.1 From the analysis of engineering geological conditions and engineering reliability

The karst development in the area, the goaf is densely covered, and the bad geology has been reasonably avoided in the line selection design to reduce the engineering risks brought by bad geology. However, there are more line pressure mine on the east and west lines, which have a greater impact on the goaf. Therefore, from the analysis of engineering geological conditions and engineering reliability, the midline scheme is better, and the west and east routes are relatively poor.

3.2.2 From the perspective of key projects and construction period analysis

In terms of tunnels, the longest tunnel in the east line scheme is 14290m, and the tunnel is a single-faced steep slope tunnel. The longest tunnel in the middle line and west line scheme is 12670m, and the single slope in the tunnel. The longest length is 8830m. For the tunnel project, the east line scheme is relatively complicated, and the construction period is also increased by 12 months compared with the midline and west line schemes.

In terms of bridges, the main span of the Chishui River special bridge in the east line scheme is 360m upright reinforced concrete arch bridges, while the mid-line and west-line maximum span...
bridges are all 128m continuous rigid structures. For bridge engineering, the east line scheme is more complicated and the construction risk is relatively high.

3.2.3 From the line length and investment perspective
The mid-line scheme is 30.018km longer than the east-line scheme, and the project investment is increased by 1.588 billion. Compared with the west line plan, the line length is shortened by 9.625km, and the project investment is saved by 978 million. Therefore, from the line length and investment analysis, the engineering investment and future operating expenses of the East Line project are the most economical, and the mid-line plan is in the middle.

3.2.4 From the perspective of favourable local economic development and planning analysis
The eastern route scheme only distributes scattered villages, no large economic bases, resource development is lagging behind, except for G321, development is less; mid-line scheme and west line scheme attracting scope The Weixin and Zhenxiong counties in Zhaotong City, Yunnan Province have been added. The two counties are rich in mineral resources. They are an important window and business hub for the opening up of the northeastern part of Yunnan. The prestige is the location of the “Tashi” conference. Due to the limitations of road transport, the bulk of the goods such as coal in the territory is still unable to be transported in large quantities, which seriously restricts the resource development and economic development of the two counties.

The mid-line plan and the west line plan fully considered the local opinions and planning arrangements in the selection of relevant sites. The two programs can promote the economic development of Weixin and Zhenxiong two counties. At the same time, in the mid-line plan Both Weixin Station and Yile Station are well integrated with the relevant stations and local plans for the construction of the Chengdu-Guizhou Railway, which is more conducive to the passenger transportation of the Chengdu-Guizhou Railway and the Xubi Railway.

3.2.5 Analysis of the transportation volume and investment benefit from attracting along the route
The east, middle and west three-way plan mainly has certain differences in the local transportation volume (mainly coal transportation) attracting Yunnan Weixin and Zhenxiong County.

If the line adopts the east line plan, the local traffic volume of Yunnan Weixin and Zhenxiong County is considered to be used to construct part of the freight volume to the adjacent station by constructing the railway branch line or other transportation modes, and then transported through the line. If there is no special branch line or the road is introduced into the line, the long-distance traffic volume of the east line will be reduced by about 10 million tons.

After calculating the financial investment benefits of the three schemes, the financial internal rate of return of the west line program is 8.41%, the financial internal rate of return of the midline program is 8.33%, and the internal rate of return of the east line program is 8.12%. The midline plan is second, and the east line plan is the worst.

3.3 The advantages and disadvantages of the three routes of the east, middle and west are shown in Table 1.

Table 1 Comparison of Advantages and Disadvantages of Three Routes in East, Mid and West

| Program        | Engineering geological conditions and engineering reliability | Key project angle and construction period | Route length and investment angle | Conducive to local economic development perspectives and planning | Attract local traffic and investment benefits along the route |
|----------------|---------------------------------------------------------------|------------------------------------------|-----------------------------------|---------------------------------------------------------------|-------------------------------------------------------------|
| Eastern line   | Poor                                                         | Poor                                     | Better                            | worse                                                         | Poor                                                        |
| Mid-line       | Better                                                      | Better                                   | General                           | Well                                                          | General                                                     |
| West Line      | Poor                                                         | Better                                   | Poor                              | Better                                                        | Better                                                      |

According to Table 1, the scheme layer is pairwise comparison matrix, $B_{Ai/Bj}$ $(i = 1 ~ 5)$ respectively indicate the engineering geological conditions and engineering reliability of the east, middle and west.
schemes; the key engineering angle and construction period, the length of the route and the investment perspective, conducive to the local economic development perspective and planning and attracts the pairwise comparison matrix of five factors such as local traffic volume and investment benefit along the line.

\[
B_{A1/B} = \begin{bmatrix}
B1/B1 & B1/B2 & B1/B3 \\
B2/B1 & B2/B2 & B2/B3 \\
B3/B1 & B3/B2 & B3/B3
\end{bmatrix} = \begin{bmatrix}
1 & 1/3 & 1 \\
3 & 1 & 3 \\
1 & 1/3 & 1
\end{bmatrix}
\]

\[
B_{A2/B} = \begin{bmatrix}
B1/B1 & B1/B2 & B1/B3 \\
B2/B1 & B2/B2 & B2/B3 \\
B3/B1 & B3/B2 & B3/B3
\end{bmatrix} = \begin{bmatrix}
1 & 1/3 & 1/3 \\
3 & 1 & 1 \\
3 & 1 & 1
\end{bmatrix}
\]

\[
B_{A3/B} = \begin{bmatrix}
B1/B1 & B1/B2 & B1/B3 \\
B2/B1 & B2/B2 & B2/B3 \\
B3/B1 & B3/B2 & B3/B3
\end{bmatrix} = \begin{bmatrix}
1 & 2 & 2 \\
1/2 & 1 & 2 \\
1/2 & 1/2 & 1
\end{bmatrix}
\]

\[
B_{A4/B} = \begin{bmatrix}
B1/B1 & B1/B2 & B1/B3 \\
B2/B1 & B2/B2 & B2/B3 \\
B3/B1 & B3/B2 & B3/B3
\end{bmatrix} = \begin{bmatrix}
1 & 1/5 & 1/4 \\
5 & 1 & 2 \\
4 & 1/2 & 1
\end{bmatrix}
\]

\[
B_{A5/B} = \begin{bmatrix}
B1/B1 & B1/B2 & B1/B3 \\
B2/B1 & B2/B2 & B2/B3 \\
B3/B1 & B3/B2 & B3/B3
\end{bmatrix} = \begin{bmatrix}
1 & 1/2 & 1/3 \\
3 & 1 & 1/2 \\
3 & 2 & 1
\end{bmatrix}
\]

3.4 Weight calculation and hierarchical ordering

3.4.1 Hierarchical single sorting calculation

Determine the relative weight of each factor of the criterion layer to the target layer, and the weight vector is expressed as \(W_A^T = [0.459, 0.118, 0.118, 0.247, 0.058]\)

Determine the relative weight of the scheme layer in terms of engineering geological conditions and engineering reliability. The weight vector is expressed as \(W_{A1/B}^T = [0.2, 0.6, 0.2]\)

Determine the relative weight of the scheme layer in terms of key engineering angles and construction period. The weight vector is expressed as \(W_{A2/B}^T = [0.143, 0.429, 0.428]\)

Determine the relative weight of the scheme layer in terms of route length and investment angle. The weight vector is expressed as \(W_{A3/B}^T = [0.493, 0.311, 0.196]\)

Determine the relative weight of the program layer in terms of local economic development and planning. The weight vector is expressed as \(W_{A4/B}^T = [0.097, 0.57, 0.333]\)

Determine the relative weight of the program layer in attracting local traffic volume and investment benefit along the line. The weight vector is expressed as \(W_{A5/B}^T = [0.163, 0.297, 0.54]\)

3.4.2 Level total ranking calculation

Determine the weight of the plan level (the east, middle and west route plan) to the target level (the direction of the railway line). The weight of the east line plan for the direction of the Xubi Railway is 0.521. The weight of the plan for the Xubi Railway is 0.2, and the weight of the West Line for the track of the Xubi Railway is 0.279.

By comparison, it is found that after considering various factors, the weight of the midline strike scheme is significantly larger than that of the east and west schemes, indicating that the midline
scheme is superior to the east and west strike schemes, which is consistent with the expert argumentation and proves the scientific rationality of the analytic hierarchy process.

4. Conclusions
The use of analytic hierarchy process to compare and select the railway route plan of Xubi is not only avoiding the subjectivity of the qualitative analysis of the line selection, but also avoiding the demanding requirements of the data by simply using quantitative analysis, and is effective in solving multi-objective and multi-level problems in railway line selection.

At the same time, the tomographic analysis method quantifies each scheme, and uses scientific mathematical methods to determine the relative importance of each factor by establishing a pairwise comparison matrix, so that the results are more credible.

It is worth noting that the conclusions of the analytic hierarchy process are based on the pairwise comparison matrix. It is recommended to use the expert method to make full use of the experience and knowledge of the experts to ensure the scientificity and rationality of the pairwise comparison matrix. Studies have shown that the selection of the mid-line scheme for the Xubi railway line is far superior to the east and west lines.

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