Feasibility Study of Soil and Water Conservation Project in a Small Watershed Based on Analytic Hierarchy Process

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Abstract. Aiming at the problem of soil and water loss, the multi-objective feasibility analysis of the soil and water conservation construction project was carried out. The analytic hierarchy process was used to establish a feasibility study comprehensive evaluation hierarchy analysis structure model, and the multi-indicator and feasibility of the research project were analysed. The conclusions have a wide range of applicability, which can well guide the planning and implementation of the project, and ensure that the problem of soil erosion is properly managed.

1. Introduction
With the rapid increase of the world's population, human demand for natural resources is increasing, and the contradiction between humans and the natural environment is getting worse. Soil and water loss is one of the direct manifestations of ecological environment damage[1]. Land caused by soil and water loss Problems such as degradation and sediment have become global environmental and disaster problems [2]. Severe soil erosion has led to more and more sandstorms and floods in China. Therefore, it is of great significance to conduct feasibility studies on soil and water conservation projects.

Feasibility studies abroad usually focus on investment in construction projects [3-4]. Especially the investment in public infrastructure construction projects [5-6]. Regarding the ecological environment, the British economist Schumacher proposed that the development model of ecological economy should be a miniaturized economy with the characteristics of freedom, efficiency, creativity and endurance. In our country, the feasibility study still uses the economic demonstration methods of the former Soviet Union. These methods were not carried out in the early stage of investment, so they have major limitations [7-8].

This paper conducts a feasibility study on the multi-objective of a soil and water conservation construction project in a small watershed area. Based on the analytic hierarchy process, it analyzes the multi-indicator and feasibility of the research project and obtains the feasibility study conclusion of the project. The conclusions have a wide range of applicability, which can well guide the planning and implementation of the project, and ensure that the problem of soil erosion is properly managed.

2. Analytic hierarchy process and calculation steps

2.1 Concept
Analytic Hierarchy Process (AHP) is an evaluation method that is suitable for multi-objective, multi-criteria, and effective combination of quantitative analysis and qualitative analysis. This method divides the indicators of the problem to be resolved into several related and Order of hierarchy. The
importance of the indicator is reflected in a quantitative form. The indicator values are compared and judged in pairs. The greater its impact is, the greater the weight of the indicator values. Finally, it is reflected in the hierarchical structure. Through the combination of the relative importance weights of each layer, the importance weights of all indicators relative to the target are obtained. This method converts past experience into quantitative data, which is suitable for incomplete and more complex projects [9]. The specific analysis process is shown in Table 1:

| Table 1: AHP analysis flow chart |
|----------------------------------|
| Determine evaluation indicators  |
| Establishing a hierarchical analysis structure |
| Constructing a judgment matrix |
| Hierarchical single ordering and consistency check |
| Calculate the consistency index of the judgment matrix CI |
| Calculate the value of the random consistency ratio CR |
| Hierarchical total ordering |

### 2.2 AHP calculation steps

**Determine the evaluation index system:** Select several important and necessary analysis targets to form a comprehensive evaluation index system.

**Establishing a hierarchical analysis structure model:** According to the upper-lower relationship of the selected target, the levels are divided, so that different targets form a multi-level progressive model in different levels to which they belong.

**Construct the judgment matrix:** In the tomographic analysis structure model, the targets at the same level are compared pair by pair, and the importance of the two is judged.

**Hierarchical ordering and consistency check:** Hierarchical single sort is to sort the weights of different targets belonging to the same level. This process requires the calculation of its judgment matrix to obtain the ranking weight of the relative importance of each factor in the same target layer to a certain target at a higher level. Method for calculating maximum characteristic root $\lambda_{max}$ of judgment matrix:

$$\lambda_{max} = \sum_{i=1}^{n} \left( \frac{A W_i}{n W_i} \right)$$

Calculate the consistency index of the judgment matrix CI:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Then calculate the random consistency ratio CR:

$$CR = \frac{CI}{RI}$$

$RI$ can be found from the table below.

| Order | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  |
|-------|----|----|----|----|----|----|----|----|
| RI    | 0  | 0  | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 |

Perform consistency check on the judgment matrix. If it is calculated that $CR < 0.10$, it is considered to meet the consistency requirements, otherwise, the judgment matrix needs to be adjusted.
Hierarchical total ordering: The results of hierarchical single-ranking are further calculated to obtain the combined weight of the bottom target to the total target.

3. A Feasibility Study Based on Analytic Hierarchy Process

3.1 Project summary
The Fenghuangling small watershed management project is located in the south of Changle County. The selected watershed area is specifically located at 118°39′15.90″～118°44′06.81″ east longitude, 35°56′29.97″～36°00′55.35″ north latitude, and the area is 16.06 km². The shape of the watershed is irregular rhombus, with a longest 5.65km from north to south and 4.22km from east to west. The overall terrain is high in the middle and low in the periphery. The geological rocks in this basin are mainly sandstone, and the weathering fissure layer of the bedrock is thick, without other geological disasters. According to the division of soil erosion types, the project area is located in the northern rocky mountainous area. The degree of soil erosion is serious. The type of erosion is mainly water erosion, and the form of erosion is mainly surface erosion [10]. After field survey and analysis of the plot, the existing area of light and above soil erosion in the basin is 1314.89hm², of which 102.995hm² is mild erosion, 284.94hm² is moderate erosion, and the average erosion modulus for many years is 780t / km²·a.

3.2 Project feasibility study comprehensive evaluation index system
The feasibility study of this project starts from the three target levels of technical solutions, economic benefits and social benefits, and is specifically detailed into project planning level, project governance, internal rate of return, project payback period, per capita income growth rate in the project area, and promotion. Comprehensive evaluation of seven small goals include regional economic development level, resources and environmental impact. But it includes both quantitative evaluation indicators and qualitative evaluation indicators. The feasibility of the water and soil conservation project in Fenghuangling small watershed was evaluated through comprehensive qualitative evaluation and quantitative calculation analysis.

The comprehensive evaluation indicators of the feasibility study of this project are shown in the table. Among them, \( P_1 \) is the achievement degree of each sub-indicator of the project, and \( P_2 \) is the industry benchmark or construction project specification. The project governance is mainly taken from the national soil and water conservation construction specification. Intermediate and third-level standards. The internal rate of return of the project is taken as the benchmark value of the soil and water conservation project investment industry, and the growth rate of per capita income is also taken as the benchmark value of the growth rate of per capita income brought by the soil and water conservation project to the project area.

| Serial number | Feasibility study sub-indica \( (P_1) \) | Industry benchmark \( (P_2) \) |
|---------------|---------------------------------|-----------------|
| \( C_1 \) Planning level | | |
| \( C_2 \) Governance | 94.27% | 80% |
| \( C_3 \) Internal Rate of Return | 16.92% | 13% |
| \( C_4 \) Payback period | 3.52 | 5 |
| \( C_5 \) Growth rate of per capita income | 342.06% | 120% |
| \( C_6 \) Promote regional development effects | | |
| \( C_7 \) Resources and environmental impact | | |

Table 3. Indicators for Feasibility Study of the Project.
3.3 Feasibility study comprehensive evaluation hierarchy analysis structure model
Based on the actual situation of the soil and water conservation project in the Fenghuangling small watershed and combined with the multiple comprehensive evaluation indicators previously determined, the following hierarchical analysis model is constructed as shown in the figure:

Table 4. Structural model diagram of comprehensive evaluation hierarchy analysis for feasibility study.

In the above model, the first layer (layer B) has three evaluation indicators: ① technical solution (B1), ② economic benefits (B2), ③ social benefits (B3); the second layer includes seven indicators: ① project planning level (C1), ② Project governance (C2), ③ Project internal rate of return (C3), ④ Project payback period (C4), ⑤ Per capita income growth rate (C5), ⑥ Promoting regional economic development effects (C6), ⑦ Resources and Environmental impact (C7).

First, judge the importance of indicators in layer B by comparing the importance of indicators with ten experts in the industry, and then rank according to their importance, and get the importance ranking of the three evaluation indicators in layer B as B2 > B3 > B1. At the same time, the indicators are scored according to the above ratio scaling method. The scores of B1, B2, B3 are 1, 5, and 3 respectively.

3.4 Construct a judgment matrix and perform comprehensive ranking
According to the calculation result of single-level ranking, one by one calculation is performed to obtain the sorting combination weight of the lowest layer (scheme) to the highest layer (target), and then the result analysis is performed. Write the three goals of layer B into the form of a judgment matrix:

\[
A_{\text{B}} = \begin{bmatrix}
1 & 1/5 & 1/3 \\
5 & 1 & 3 \\
3 & 1/3 & 1 \\
\end{bmatrix}
\]

By analyzing the relationship between the B1 layer and the Clayer, it is found that B1 not only has a very important relationship with C1, C2, but also has a close relationship with C3, C4, C5, C6, C7. For the evaluation indicators of layer C, through the comparison of the importance of the indicators by dozens of experts in the industry, the importance ranking is as follows: C2 > C1 > C3 > C4 = C7 = C6 > C5. Scoring and writing the judgment matrix:

...
By analyzing the relationship between $B_2$ and C layer, the analysis shows that $B_2$ is not only closely related to $C_3$ and $C_4$, but also has an important relationship with $C_5$. According to the evaluation of experts in the industry, the order of importance is: $C_3 > C_4 > C_5$, and the relevance is scored to obtain a judgment matrix:

$$\begin{bmatrix}
1 & 0.333 & 0.333 & 0.333 & 0.2 & 0.111 & 0.143 \\
3 & 1 & 1 & 1 & 0.333 & 0.143 & 0.2 \\
3 & 1 & 1 & 1 & 0.333 & 0.143 & 0.2 \\
3 & 1 & 1 & 1 & 0.333 & 0.143 & 0.2 \\
5 & 3 & 3 & 3 & 1 & 0.2 & 0.333 \\
9 & 7 & 7 & 7 & 5 & 1 & 3 \\
7 & 5 & 5 & 5 & 3 & 0.333 & 1 \\
\end{bmatrix}$$

By analyzing the relationship between $B_2$ and C layer, the analysis shows that $B_2$ is not only closely related to $C_3$ and $C_4$, but also has an important relationship with $C_5$. According to the evaluation of experts in the industry, the order of importance is: $C_3 > C_4 > C_5$, and the relevance is scored to obtain a judgment matrix:

$$\begin{bmatrix}
1 & 0.333 & 0.2 \\
3 & 1 & 0.333 \\
5 & 3 & 1 \\
\end{bmatrix}$$

Analyzing the relationship between $B_3$ and C, it can be seen that $B_3$ is only closely related to $C_5$, $C_6$, and $C_7$. More than a dozen experts in the industry have scored the importance of their indicators. The importance ranking is: $C_7 = C_6 > C_5$, written as judgment matrix is:

$$\begin{bmatrix}
1 & 0.333 & 0.333 \\
3 & 1 & 0.333 \\
3 & 3 & 1 \\
\end{bmatrix}$$

For each of the above different judgment matrices, transform them into a matrix form, and find the corresponding feature root $\lambda$, the corresponding feature vector $w$, and the maximum feature root of the matrix. The CI value, the average random consistency index $RI$ value, and the random consistency ratio $CR$ value which are used to evaluate the above matrix deviation consistency are calculated.

1) $A-B$:

$$W = \begin{bmatrix} 0.105 \\ 0.637 \\ 0.258 \end{bmatrix}$$

$$\begin{cases}
\lambda_{max} = 3.038 \\
CI = 0.019 \\
RI = 0.58 \\
CR = 0.033
\end{cases}$$

2) $B_1-C$:

$$W = \begin{bmatrix} 0.0269 \\ 0.0574 \\ 0.0574 \\ 0.1304 \\ 0.4287 \\ 0.2420 \end{bmatrix}$$

$$\begin{cases}
\lambda_{max} = 7.2542 \\
CI = 0.0424 \\
RI = 1.32 \\
CR = 0.032
\end{cases}$$

3) $B_2-C$:

$$W = \begin{bmatrix} 0.121 \\ 0.144 \\ 0.735 \end{bmatrix}$$

$$\begin{cases}
\lambda_{max} = 3.046 \\
CI = 0.023 \\
RI = 0.58 \\
CR = 0.0396
\end{cases}$$

4) $B_3-C$:

$$W = \begin{bmatrix} 0.186 \\ 0.407 \\ 0.407 \end{bmatrix}$$

$$\begin{cases}
\lambda_{max} = 3.104 \\
CI = 0.052 \\
RI = 0.58 \\
CR = 0.0892
\end{cases}$$

To ensure the rationality of the calculation results, the CR values calculated by the above four sets of judgment matrices are checked for consistency. The CR values of the judgment matrices $A-B$, $B_1-C$, $B_2-C$, $B_3-C$ are 0.033, 0.032, 0.0396, and 0.0892, all of which are <0.10. It can be obtained that the consistency of all matrices meets the requirements and no adjustment is required.
Sort the total weights of the project indicators, as shown in Table 3:

Table 5. Multi-objective Weight Table of the Project.

| Level C  | Level B | Total hierarchical weight |
|---------|---------|---------------------------|
|         | B₁      | B₂       | B₃      |                         |
| C₁      | 0.428   | 0        | 0       | 0.045                 |
| C₂      | 0.242   | 0        | 0       | 0.025                 |
| C₃      | 0.130   | 0.735    | 0       | 0.482                 |
| C₄      | 0.057   | 0.144    | 0       | 0.098                 |
| C₅      | 0.027   | 0.121    | 0.186   | 0.128                 |
| C₆      | 0.057   | 0        | 0.407   | 0.111                 |
| C₇      | 0.057   | 0        | 0.407   | 0.111                 |

Further compare the indicators of this project with industry standard values, compare the total ranking results of the two, and analyze the feasibility of the project.

C₁-P=|1 0.5 0.5 2 |
C₂-P=|1 1 1 1 |
C₃-P=|1 0.5 0.5 1 |
C₄-P=|2 2 2 1 |
C₅-P=|1 0.5 0.5 2 |
C₆-P=|1 1 1 1 |
C₇-P=|1 1 1 1 |

The importance ranking and importance scoring results of the indicators of layer B have been obtained by the industry experts' scoring above. The A-B matrix is:

A-B=|1 1/5 1/3 |
    |5 1 3  |
    |3 1/3 1  |

Through matrix operations, the final comprehensive ranking of P₁ and P₂ is obtained as:

Table 6. Comprehensive Evaluation Scores for this Project and Industry Benchmark Values.

| A   | B₁     | B₂     | B₃     | Total sorted results |
|-----|--------|--------|--------|----------------------|
| P₁  | 0.105  | 0.637  | 0.258  | 6.12                 |
| P₂  | 3.72   | 4.84   | 1.85   | 3.88                 |

From the above calculation results, it can be seen that the comprehensive evaluation score of this project is far greater than the comprehensive evaluation score of the industry benchmark value, which shows that this project is feasible.

4. Conclusion:
This article evaluates multiple targets in a small watershed soil and water conservation project, integrates their multiple targets to build an evaluation matrix, analyzes the weight ratio of different targets, and compares the comprehensive score with industry benchmarks to determine that Fenghuang Ridge is feasible. This conclusion can better guide the planning and implementation of the project, and ensure that the problem of soil and water loss in the project area is properly managed.

References
[1] Shan, L., Yin, M., Sun, X.H. (2010) The art of writing a scientific article. J. Sci. Commun., 163: 51–59.
[2] Xiao, H. (2013) Research on Countermeasures for Soil and Water Loss Control in Hunan Province Based on Game Perspective [D]. Hunan University of Science and Technology, The Hunan.
[3] Pan, L. (2018) Technology and Economic Feasibility Study of County AWastewater Treatment Plant Extension Project [D]. Anhui University of Science and Technology, The Anhui.
[4] Ziara, M., Nigin,K., Enshassi,A. (2012) Strategic implementation of infrastructure priority projects: case study in Palestine [J]. Journal of infrastructure systems., 8(1): 2-9.
[5] Cao, S.P. (2019) Feasibility Study of Reconstruction and Expansion Project of Company B's
Insulation Resin [D]. Nanjing University of Science and Technology, The Nanjing.

[6] Zhang, Y. (2009) Research on Evaluation of Investment Projects for Power Projects under Partial Weight Conditions [D]. North China Electric Power University (Hebei), The Hebei.

[7] Li, H.T. (2014) Feasibility analysis and research on the reconstruction project of Tuha Petroleum Building in Urumqi [D]. Southwest Petroleum University, The Chengdu.

[8] Masahiro, T. (1984) Theory and Practice of Feasibility Study of Engineering Projects. Tsinghua University Press, The Beijing.

[9] Liu, X., (2015) Study on the feasibility management mode of commercial landmark construction in Qinhuangdao City [D]. Yanshan University, The Hebei.

[10] Li, R. (2012) Research on Ecological Restoration Evaluation Based on BP Neural Network [D]. Fujian Normal University, The Fujian.

[11] Xu, X.X. (2017) Soil and Water Loss of Xiaqingshui River and Its Control Measures [J]. Henan Water Resources and South-to-North Water Diversion., 45 (07): 8-9.