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Performance Evaluation of Engineering Management Based on Hierarchical Analysis Approach

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Abstract: With the increasing scale and complexity of engineering projects globally, scientific and effective performance evaluation of engineering management has become a key factor in improving project success. The purpose of this paper is to assess the performance level of engineering management in a systematic and hierarchical way by applying hierarchical analysis (Hierarchical Analysis) to improve the efficiency of project execution, reduce the risk and enhance the likelihood of project success. Typical examples of water conservancy project management in Yunnan were selected to quantitatively evaluate water conservancy project management by applying the hierarchical analysis method with comprehensive assignment. Combined with the evaluation results and the typical problems of the current traditional water conservancy project management, relevant suggestions for the implementation of the property-based management model are put forward.

Keywords: Engineering Management; Performance Evaluation; Hierarchical Analysis; Hierarchical Structure; Weight Determination.

1. Introduction

In today's rapidly growing global economy, the scale and complexity of engineering projects is showing an increasing trend. Whether it is infrastructure development, information technology projects or new energy fields, all types of engineering projects require efficient management to ensure that the projects can be completed on time, operate within budget and ultimately achieve the desired results. However, due to the diversity of the projects themselves and the uncertainty of the external environment, successful engineering management is not an easy task, and evaluating engineering management performance is an even more challenging task. Hierarchical analysis (Hierarchy Analysis) is a mathematical model that is widely used in multi-factor decision analysis, and its advantage lies in its ability to deal with complex multi-level decision problems. By constructing a hierarchical structure, Hierarchical Analysis breaks down the decision problem into a series of manageable sub-problems, and then determines the relative importance of each factor through quantitative comparison and synthesis.

2. Literature Review

2.1. Overview of Engineering Management Performance Evaluation Methods

Engineering management performance evaluation is a key link to ensure the success of a project, and effective evaluation methods are particularly important in this field. In the past decades, scholars have conducted extensive research on engineering management performance evaluation methods and accumulated rich experience and theoretical systems. The following is an overview of some common engineering management performance evaluation methods:

Network Analysis Method: Network Analysis Method is a performance evaluation method based on Plan-Progress-Control, which evaluates the execution efficiency of a project by constructing the schedule network of the project and analyzing the dependencies and critical paths between activities[1]. Although Pert/CPM has made remarkable achievements in project planning and schedule control, it mainly focuses on project time management and evaluates other aspects relatively narrowly.

Performance Indicator Method: The Performance Indicator Method comprehensively evaluates the performance of an engineering project by formulating a series of performance indicators, such as cost performance, schedule performance and quality performance[2]. This method focuses on quantitative analysis of the overall project performance, but lacks explicit treatment of the relationship and weighting between indicators.

Hierarchical Analysis: Hierarchical analysis is an effective mathematical tool for dealing with complex multi-level decision-making problems, and is widely used in engineering management performance evaluation because of its flexibility and practicality. By constructing a hierarchical structure, comparing and synthesizing at different levels, the hierarchical analysis method accurately portrays the relationship between different factors and provides a scientific basis for the comprehensive evaluation of engineering management.

Taken together, various engineering management performance evaluation methods have their own advantages and limitations. pert/CPM focuses on time management, performance indicator method focuses on comprehensive quantitative evaluation, fuzzy comprehensive evaluation method takes uncertainty into account, and hierarchical analysis method is both flexible and scientific. Among many methods, the hierarchical analysis method has attracted much attention because of its applicability to multi-factor and multi-level decision-making problems, as well as its clear analysis of key factors. Therefore, this paper chooses the hierarchical analysis method as the method of engineering management performance evaluation, and discusses its effects and advantages in practical application in depth in the subsequent chapters.

2.2. Application Status of Hierarchical Analysis in Engineering Management

Hierarchical analysis, as a mathematical model for multi-factor decision analysis, has been widely used in the field of engineering management. Some typical applications of hierarchical analysis in engineering management include the following:

(1) Project selection and sequencing: Hierarchical analysis is often used in the decision-making process of project selection and sequencing. By constructing a hierarchical structure that covers the various influencing factors of a project, project decision makers can use hierarchical analysis to determine the weights of the relative advantages and disadvantages of each project, in order to help rationally and scientifically select and sequence projects.

(2) Risk management: In engineering projects, risk management is a crucial aspect. Hierarchical analysis can be used to assess the importance of different risk factors, and then guide the project team to pay more attention to important risks in resource allocation and decision-making, and improve the risk response capability of the project.

(3) Supply chain management: In supply chain management, Hierarchical Analysis can be used to select the best suppliers, evaluate the performance of suppliers, and assist in the development of a reasonable supply chain strategy. By making hierarchical trade-offs between various parts of the supply chain, Hierarchical Analysis helps to improve the efficiency and stability of the overall supply chain.

(4) Equipment maintenance decision-making: Hierarchical analysis is often used in equipment maintenance decision-making. Through the multi-factor comparison of various equipment maintenance programs, Hierarchical Analysis can help decision makers choose the most appropriate maintenance program to ensure the normal operation and maximize the life of the equipment.

(5) Sustainable development assessment: In engineering projects that consider sustainable development, the hierarchical analysis method can be used to assess the impacts of the project on economic, social and environmental aspects. This integrated assessment helps to develop a more comprehensive and sustainable project management strategy.

(6) Project cost management: Hierarchical analysis also has significant applications in project cost management. By comparing different aspects of costs in a hierarchical manner, hierarchical analysis can help project teams optimize the cost structure and improve cost-effectiveness.

3. Purpose and Significance of the Study

With the increasing number and complexity of engineering projects around the world, scientific and effective engineering management performance evaluation has become a key element to ensure project success. The purpose and significance of this study is to deeply explore and apply the hierarchical analysis method to evaluate engineering management performance in a comprehensive and systematic way, and to provide scientific basis in terms of project execution efficiency, risk management and project success.

(1) In-depth understanding of the application of Hierarchical Analysis in engineering management: through in-depth study of the specific application of Hierarchical Analysis in engineering management, to explore its applicability in different stages and fields. Through case studies, the advantages and limitations of the hierarchical analysis method approach in solving practical engineering management problems are revealed.

(2) Improve the scientificity of engineering project decision-making: through the application of hierarchical analysis method, provide a scientific and systematic evaluation method for engineering project decision-making. By comprehensively weighing the efficiency of project implementation, risk management and other aspects, decision makers can more accurately grasp the overall situation of the project, so as to develop more scientific decision-making strategies.

(3) Promote the further development of the field of engineering management: The results of this study are expected to provide a more advanced and feasible method for the field of engineering management performance evaluation. Through in-depth analysis of the application effect of hierarchical analysis, it will provide more comprehensive and in-depth theoretical support to decision makers and practitioners in the field of engineering management, and promote the further development of the field.

(4) Filling the gaps in existing research: Although the application of hierarchical analysis in engineering management performance evaluation has achieved remarkable results, there are still some gaps and problems to be solved. This study aims to fill these gaps, deeply explore the potential of hierarchical analysis method, and provide more comprehensive and in-depth research results for the field of engineering management.

4. Engineering Management Performance Evaluation Index System

Engineering management performance evaluation is a complex multi-factor decision-making problem, in order to comprehensively and scientifically assess the performance of engineering projects, it is necessary to construct an evaluation index system containing multiple dimensions. Based on the hierarchical analysis method (hierarchical analysis) of the establishment of engineering management performance evaluation index system [3].

(1) Project implementation efficiency indicators:

Progress control effect (W1): assess the consistency between the actual progress of the project and the planned progress, including the control of the critical path and the management of the non-critical path; cost performance (W2): examine the difference between the actual cost of the project and the budgeted cost, including the effectiveness of the use of funds and the ability to control the cost; resource utilization efficiency (W3): measure the degree of reasonable utilization of project resources, including human, material and time resources are fully utilized.

(2) Risk management indicators:

Risk identification and assessment (W4): assess the project team's ability to identify and assess potential risks, including an accurate perception of the overall risk of the project; Risk response and control (W5): measure the project team's response to and control of the identified risks, including the implementation of the risk plan and the effectiveness of the control; Risk communication and collaboration (W6): evaluate the level of risk communication and collaboration among the team members and between the team and

stakeholders. Communication and Collaboration (W6): Evaluate the level of communication and collaboration among team members and between the team and stakeholders.

(3) Project Success Indicators:

Quality of Deliverables (W7): Measure the quality of project deliverables, including the accuracy, completeness and conformity of project deliverables; Client Satisfaction (W8): Evaluate the level of client satisfaction after the project is delivered, including the client's evaluation of the project's results and services; Sustainability Impacts (W9): Examine the sustainability impacts of the project on the environment, society, and economy, including the project's social responsibility and environmental friendliness.

(4) Hierarchical structure of the performance evaluation system:

First level (highest level): overall project performance (P);

Second level: project execution efficiency (E); progress control effect (W1); cost performance (W2); resource utilization efficiency (W3)

Tier 2: Risk Management (R); Risk Identification and Assessment (W4); Risk Response and Control (W5); Risk Communication and Collaboration (W6)

Tier 2: Project Success (S); Quality of Deliverables (W7); Customer Satisfaction (W8); Sustainability Impact (W9)

(5) Weight allocation:

Through the hierarchical analysis method, the indicators of each level are compared two by two to determine the relative weights of each indicator to ensure the scientific and reasonable nature of the evaluation system. In the weight allocation, the specialized knowledge and experience of project decision makers will be fully considered to ensure the accuracy of the weights [4]. By constructing such a comprehensive engineering management performance evaluation index system, it can be flexibly applied in actual projects to provide scientific and systematic evaluation means for project decision-making, and ultimately improve the efficiency and success rate of engineering management.

5. Example Study on Water Conservancy Project Management in Yunnan Province

5.1. Overview of the Study Area Project

A certain irrigation area in Yunnan Province mainly includes 7 gates and valves, two east-west trunk canals with a length of 100 km, and 7 trunk canals with a length of 200 km. The irrigation area implements a combination of specialized management and group management, and the specialized management organization is a certain irrigation area management bureau in Yunnan Province and 5 sub-bureaus in each county. Provincial Management Bureau under the Office, Party Committee Office, Personnel Section, Planning and Finance Section, Construction and Management Section (Prevention Office), Water Policy Section (Water Supervision Detachment), Technical Office, Information Center, Trade Unions (Youth League Committee), Logistic Service Center, Water Supply Management Center, Provincial Irrigation Experimentation Center, the Lao Gan Office and Maintenance and Repair Center, and so on, 20 internal institutions.

5.2. Water Conservancy Project Management Evaluation Model Construction

Yunnan Province water conservancy units want to choose a management model from A, B two management models, A model for water conservancy project property management model, B model for the traditional water conservancy project management model, the financial income of management services are financial investment in the main considerations of the four relevant attributes are the number of streamlining institutions, maintenance costs, professional and technical level and the role of the government-led, respectively[5], with P1, P2, P3, P4 to indicate.

5.2.1. Establishment of Hierarchical Structure Model

The hierarchical structure model of the existing water conservancy project management evaluation system can be obtained according to the relationship between the evaluation indexes at all levels of the target layer and program layer[6]. Through the known data, based on empirical judgment to build a good hierarchical structure, from the first criterion layer gradually down to determine the weight of different factors on the previous layer of factors. Hierarchical analysis generally compares two by two to determine the weights of different factors in each layer to the factors in the previous layer. When a factor in the previous level is used as a criterion for comparison, aij can be used to indicate the relative weight of the ith and jth factors in the next level. According to the actual project, the judgment matrix of P1-P4 indicators at the program level relative to the target level is constructed, as shown in Table 1. Score the individual target attributes of the two management models separately, as shown in Figure 2.

Table 1. Comparison discriminant matrix

	Establishment Number of persons	Repair and maintenance expenditure	Expertise level (of expertise)	government-led
B	P_1	P_2	P_3	P_4
P_1	2	2	1/2	1/5
P_2	1/2	1/3	2	1
P_3	2	3	1/3	1/3
P_4	3	5	1	2

5.2.2. Hierarchical Single Ordering and Consistency Test

(1) Normalize the vector W.

(2) Determine B × W.

(3) Calculate the maximum eigenvalue of the judgment matrix B.

(4) Calculate the consistency index and consistency ratio, and test them.

CI = 0. 0062

CR= CI/RI, RI is the average random consistency index, when n = 6, RI= 1.52

Therefore CR = 0. 0039 < 0. 10.

Since CR < 0. 10, the consistency is acceptable and meets

the requirement.

P_1	A	B
A	1	3
B	1/3	1

(a) Establishment Number of persons

P_1	A	B
A	1	6
B	1/6	1

(b) Repair and maintenance expenditure

P_1	A	B
A	1	2
B	1/2	1

(c) Expertise level (of expertise)

P_1	A	B
A	1	1/9
B	9	1

(d) Government-led

Fig 1. Single target attribute scoring results

5.2.3. Hierarchical Total Ordering and Consistency Test

(1) Find the maximum eigenvector of the scheme layer to the target layer.

(2) Organize the eigenvectors of the schema layer.

(3) Calculate the total scores of the two models.

5.3. Comprehensive Evaluation Analysis of Water Conservancy Project Management

After calculation, the evaluation value of A (water conservancy project property-based management mode) is 0.62 points, and the evaluation value of B (traditional water conservancy project management mode) is 0.38. A>B, A management mode should be chosen, i.e. water conservancy project property-based management mode. A>B, should choose A management mode that is water conservancy project property management mode.

According to the hierarchical analysis of the single factor indicator analysis process can be seen, the main reasons for the overall leadership of A are as follows: 1) water conservancy project property management is conducive to optimize the staff structure, reduce the number of institutions; 2) is conducive to streamlining the management organization, promote the optimal allocation of resources; 3) is conducive to reducing the funding, reduce the cost of operation, management and maintenance; 4) is conducive to the reform of the institutions, standardize property management The order of competition in the market.

5.4. Suggestions for Countermeasures

Aiming at the problems related to the traditional water conservancy project management mode, combined with the results of the hierarchical analysis method, it puts forward the relevant recommendations for the implementation of the property management mode.

(1) Strengthen the government to lead and improve the construction and development of property management market. For the current operation and operation position career staff is more, it is recommended to adopt the operation and operation position career staff natural exit (to age retirement) method, no more supplement, management unit will be the operation and operation of hydraulic buildings gradually transition to the property company to undertake.

(2) According to the local conditions, study the property management mode suitable for each province. At present, China has not yet formed a unified, national property management standards, need to formulate normative documents and technical standards according to the actual situation of the region, clear enterprise access standards, standardize the specific operation and maintenance behavior, combined with the local actuality to explore the establishment of property management mode suitable for the local.

(3) Standardize the management and establish a perfect system of property management regulations and systems. Since the management process involves the local government, water conservancy administrative departments, water management units and property management institutions, the establishment of a perfect property management system and laws and regulations will play a pivotal role in the promotion of comprehensive property management and the realization of standardized management.

6. Conclusion and Outlook

In this study, through in-depth exploration and application of hierarchical analysis in engineering management performance evaluation, we have come up with a series of important research findings, which provide useful insights for practice and theory in the field of engineering management.

First, the findings of this paper emphasize the significant advantages of hierarchical analysis in engineering management performance evaluation. As a flexible and feasible mathematical model, hierarchical analysis has been successfully applied to multifactor and multilevel decision-

making problems, providing a scientific and practical method for comprehensive engineering management performance evaluation. By constructing a multilevel evaluation system, hierarchical analysis can accurately grasp the relative importance of each factor and provide a comprehensive information base for project decision makers, thus improving the science and feasibility of decision making.

Secondly, the results of this study put forward some suggestions for the future research direction of project management performance evaluation. Although the hierarchical analysis method has been successfully applied in many aspects, its applicability in specific fields and special projects is still to be deeply explored. Future research can focus on the differences in the effects of hierarchical analysis in different scales and types of engineering projects to better meet the needs of practical applications.

Finally, through the research in this paper, we provide a more scientific and operational method for engineering management performance evaluation, which is of positive significance for improving the success and effectiveness of engineering projects. In the evolving engineering environment, we expect that the field of engineering management can make full use of advanced methods such as hierarchical analysis to continuously optimize the performance evaluation system and promote the continuous development of engineering management.

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