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Research on the construction of scientific and technological achievements management index system

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Abstract

Analytic Hierarchy Process (AHP) is a comprehensive evaluation method combining qualitative and quantitative methods. Based on the original evaluation method of scientific and technological achievements, this paper uses AHP to construct a new evaluation management system for scientific and technological achievements in rail transit industry. Through the results of data analysis, it is found that the weight values of the four types of scientific and technological achievements in rail transit industry are different the four types of scientific and technological achievements have different evaluation focuses. Therefore, this paper constructs four kinds of scoring tables for evaluation of scientific and technological achievements, to promote the multi-category and full-life cycle development of rail transit industry, adapt to the reform of scientific and technological achievements, adapt to the development of socialist market economy, and help the national technology leapfrog development strategy.

Keywords: Analytic hierarchy process; Evaluation of scientific and technological achievements; Rail transit industry; Reform of scientific and technological achievements

1. Introduction

The Party Central Committee pointed out that in order to improve the evaluation system of scientific and technological achievements and give full play to the evaluation function of scientific and technological achievements, it is necessary to adhere to the basic principles of scientific classification and multi-dimensional evaluation. At the present stage, the national policies and regulations on the evaluation of scientific and technological achievements are mainly the Measures for the Evaluation of Scientific and Technological Achievements (for Trial Implementation), the Interim Measures for the Pilot Evaluation of Scientific and Technological Achievements and the Pilot Work Plan for the Evaluation of Scientific and Technological Achievements, and various provinces and cities have also issued relevant technical specifications. Policies and norms have been issued from the national level to the local level, which provide evaluation basis and operational norms for the transformation of scientific and technological achievements, making the evaluation of scientific and technological achievements gradually institutionalized and scientific. In recent years, there have been many researches on evaluation methods of scientific and technological achievements in China. For example, Anhui Sanxian Technology Consulting Co Ltd. has established a regional evaluation system of scientific and technological achievements, and established a localized database of scientific and technological evaluation by designing an evaluation index system.[1]1

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At present, there are some problems in the evaluation system of scientific and technological achievements, such as the evaluation index system is not classified, the evaluation quantitative index is not comprehensive and specific. The existing research has not reached an effective consensus on the evaluation purpose, evaluation subject, evaluation index, evaluation method and evaluation application of scientific and technological achievements, and because the evaluation of scientific and technological achievements is a complex system involving multiple objectives, multiple subjects, multiple stages and multiple ways, most of the existing research focuses on one or several aspects in the process of scientific and technological achievements transformation, which is not enough to reflect the overall level of scientific and technological achievements transformation. It is also difficult to monitor the weak links and policy blind spots in the evaluation of scientific and technological achievements from the macro and overall levels, which will also affect the improvement and improvement of the transformation level of scientific and technological achievements in the practical application of these theoretical achievements. [2] Therefore, it is of great theoretical and practical significance to construct a scientific and reasonable evaluation standard system of scientific and technological achievements. In this paper, by combing the related research on evaluation indicators of scientific and technological achievements, the existing evaluation methods and indicators are compared and analyzed, and a comprehensive and multi-level classified evaluation system is established. In order to evaluate the actual application of the index system in the rail transit industry, we analyze and test the data in the form of questionnaire, and promote the development of rail transit industry in multi-category and whole life cycle.

2. Introduction to Analytic Hierarchy Process

In AHP, pairwise comparison is often used to construct the judgment matrix between criteria or attributes. Paired comparison reflects the pairwise comparison of the importance between n criteria or schemes, and the values of these comparisons form an n ×n matrix, which is called the judgment matrix. [3] The judgment matrix consists of paired comparisons expressed by numerical values as elements, and the values of the elements are given by decision makers according to their own experience and professional knowledge, so convert qualitative attributes or criteria comparisons with different dimensions into measurable numbers. The multi-criteria decision-making method assigns the corresponding weights to these N items through this matrix, and finally ranks them.

If the potential "importance degree" of n criteria is $\boldsymbol{W}=(w_1,w_2,\cdots,w_n)$. When $\boldsymbol{W}$ is unknown, a judgment matrix given by the decision maker is recorded as $\boldsymbol{A}=(a_{ij})_{n\times n}$, in which the element a_{ij} represents the comparison between any two criteria i and j in n criteria, which can be understood as the multiple of criterion i being superior to criterion j. In other words, a_{ij} is an estimate of the ratio of w_i/w_j. The purpose of the paired comparison method is to solve an n-weighted weight vector $\boldsymbol{P}=(p_1,p_2,\cdots,p_{an})$, which is used to represent the estimation of the $\boldsymbol{W}$ vector, and then all the criteria are weighted according to the $\boldsymbol{P}$ vector. [4]

The value of pairwise comparison is assigned by decision makers according to their experience and domain knowledge. Satyr proposed to use a scale of 1 – 9 to measure the values compared with each other, thus forming the elements in the judgment matrix. In this way, qualitative attributes or standards can be transformed into measurable quantitative figures.

Table 1 Scale Assignment and Interpretation

scale	Scale meaning
1	It means that two factors are of equal importance compared with each other.
3	Compared with the two factors, the former is slightly more important than the latter
5	Compared with the two factors, the former is obviously more important than the latter
7	Compared with the two factors, the former is more important than the latter.
9	Compared with the two factors, the former is more important than the latter.
2,4,6,8	Represents the intermediate value of the adjacent judgment.
count backwards	If the ratio of the importance of factor I to factor J, then the ratio of the importance of factor J to factor I is =1/

The eigenvector method is often used to calculate the weight of each index in the judgment matrix. Because each element a_{ij} in the judgment matrix $\boldsymbol{A}$ represents the comparison of the relative importance between two criteria i and j, that is, a_{ij} is an estimate of the ratio w_i/w_j of the weight w_i of criterion i and the weight w_j of criterion j. If the decision-maker can accurately express the ratio of weights between criteria in the judgment matrix, there is the following relationship:

$$\boldsymbol{A}=\begin{pmatrix} a_{11} & a_{12} & \mathrm{L} & a_{1n} \\ a_{21} & a_{22} & \mathrm{L} & a_{2n} \\ \mathrm{M} & \mathrm{M} & \mathrm{O} & \mathrm{M} \\ a_{n1} & a_{n2} & \mathrm{L} & a_{nn} \end{pmatrix}=\begin{pmatrix} w_1/w_1 & w_1/w_2 & \mathrm{L} & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \mathrm{L} & w_2/w_n \\ \mathrm{M} & \mathrm{M} & \mathrm{O} & \mathrm{M} \\ w_n/w_1 & w_n/w_2 & \mathrm{L} & w_n/w_n \end{pmatrix} \tag{1}$$

In the above formula, both sides of the equal sign are multiplied by the column vector of the weight on the right, respectively,

to obtain:

$$\boldsymbol{A}w=\begin{pmatrix} w_1/w_1 & w_1/w_2 & \mathrm{L} & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \mathrm{L} & w_2/w_n \\ \mathrm{M} & \mathrm{M} & \mathrm{O} & \mathrm{M} \\ w_n/w_1 & w_n/w_2 & \mathrm{L} & w_n/w_n \end{pmatrix}\begin{pmatrix} w_1 \\ w_2 \\ \mathrm{M} \\ w_n \end{pmatrix}=n\begin{pmatrix} w_1 \\ w_2 \\ \mathrm{M} \\ w_n \end{pmatrix}=nw \tag{2}$$

Reorganize the above formula and write it as a matrix:

$$(\boldsymbol{A}-n\boldsymbol{I})w=0 \tag{3}$$

The maximum eigenvalue of the judgment matrix $\boldsymbol{A}$ is n, so its consistency index CI=0. This result also confirms the accurate judgment of a_{ij} on the weight ratio w_i/w_j. However, the weight vector w of the criterion and its intermediate ratio w_i/w_j are usually subjective, and its exact value is unknown, which means that it is almost impossible for decision makers to estimate a_{ij} completely accurately. We add perturbation to the weight vector according to the maximum eigenvalue of the judgment matrix, noting that $\boldsymbol{A}'$ is the judgment matrix given by the decision maker, and w' is the corresponding optimal weight. Then there are:

$$\boldsymbol{A}'w'=\lambda_{\max}w' \tag{4}$$

where $\lambda_{\max}$ is the maximum eigenvalue of the judgment matrix. The method of calculating the weight from the judgment matrix by the above formula is called the feature vector method. That is to say, the non-negative unit eigenvector corresponding to the maximum eigenvalue of a judgment matrix is its corresponding weight vector.

3.the preliminary screening of evaluation indicators of scientific and technological achievements

In order to better play the guiding role of the transformation of scientific and technological achievements, the selection of evaluation indicators of scientific and technological achievements should follow the principles of systematic, operable, objective, qualitative and quantitative. By consulting relevant literature and materials, drawing lessons from advanced evaluation indicators of scientific and technological achievements abroad, and on the basis of soliciting the opinions of relevant experts, it is determined to formulate diversified evaluation indicators of scientific and technological achievements from seven aspects: the degree of independent innovation, technological advancement, technical difficulty and complexity, popularization and application prospects, economic benefits, social benefits and achievement indicators. [5] Through expert consultation, the content validity and standard validity of the initial indicators were analyzed and demonstrated, and the secondary indicators were screened, and 23 secondary indicators were determined, and finally the following system structure was formed.

Table 2 Evaluation factor system of scientific and technological achievements

Primary index	Secondary index
Degree of independent innovation	Innovation and uniqueness of technical scheme
	The proportion of independent intellectual property technology
	Proportion of independent design and outsourcing work
Technological advancement	Percentage of performance indicators superior to related technologies at home and abroad
	The improvement ratio of performance index compared with the previous generation products.
	Percentage of economic indicators superior to relevant technologies at home and abroad
Technical difficulty and complexity	
Popularization and application prospect	Difficulty of achievement transformation
	Technical maturity and reliability
	Degree of technical commonality
	Technical life
	Potential market demand and promotion value
	Promotion risks such as intellectual property rights and market policies.
economic benefits	Cost-effectiveness ratio
	Return period of investment
	Technical financing ability
	New output value

	New profits and taxes
social benefit	Total energy consumption decreased.
	Carbon emissions
Outcome indicators	Number of papers
	Number of patents

4.the index system and weight under the classification evaluation of scientific and technological achievements

In this paper, using the method of literature analysis, the evaluation index of scientific and technological achievements evaluation is initially determined as a reference, and then combined with the questionnaire survey method, the questionnaire adopts Thomas Seti's "1-9 scale method", and the comparative judgment matrix model is used to distribute the questionnaire to experts. [6] Through the experts' scoring of different levels of indicators and the recognition of the relationship between indicators at the same level, the scientific and reasonable evaluation index is finally obtained. After designing the questionnaire, the questionnaire was distributed to the experts at the actual investigation point to investigate the experts' evaluation of the management system of scientific and technological achievements, thus obtaining the evaluation of four types of scientific and technological achievements.

In order to establish evaluation indexes for four different types of scientific and technological achievements, the weight of evaluation indexes for scientific and technological achievements in component product development is calculated as an example. According to the score of an expert, the first-level index judgment matrix for evaluating scientific and technological achievements of component product development is constructed, and a paired comparison matrix with incomplete information is formed. For this kind of judgment matrix, the maximum eigenvalue can't be solved, which leads to the failure of the feature vector method introduced above to solve the weight vector. In this paper, Harker's modified geometric averaging method (RGM) is used to construct a transformed matrix $R = (r_{ij})_{n*n}$ as follows [7]:

$$r_{ij}\begin{cases} a_{ij}, & \text{if } a_{ij} \text{ is not a missing value } i \neq j \\ 0, & \text{if } a_{ij} \text{ is a missing value }, i \neq j \\ 1+c_i, & i = j \end{cases} \tag{5}$$

where c_i is the number of missing in row i. The eigenvector $W = (w_1, w_2, \ldots, w_n)$ is associated with the maximum eigenvalue of the matrix R, so the principal eigenvector of matrix R is used as the weight vector of the judgment matrix. Similarly, we construct a secondary index weight judgment matrix according to the expert questionnaire, and calculate the corresponding index weights.

The above method is repeated, and the effective questionnaire scores of experts are calculated in turn, and the average weight of each type of scientific and technological achievement evaluation index is obtained. Then, the top 12 evaluation factors in the importance ranking are screened out, and four types of scientific and technological achievements evaluation index systems are formed: component product development, process, forward-looking foundation, and vehicle product development. Based on the results of analytic hierarchy, this paper constructs the evaluation system table of component product development. Through Table 2, it can be found that the top three evaluation indicators are technical difficulty and complexity, independent innovation degree, and achievement indicators. Rail transit manufacturing industry involves a variety of knowledge and technology, and needs to go through interconnected links to achieve the product production process, the support of professional and technical personnel team to manufacture products with quality that meet customer standards, so it has a high technical threshold. In recent years, electrification, networking, intelligence has become the future trend of the manufacturing industry, rail transit manufacturing industry widely use new technologies, new materials and new processes, in order to ensure that parts and components can be launched synchronously with the whole vehicle, synchronous upgrade, supporting parts products must also carry out corresponding technical updates and product upgrades, which requires rail transit manufacturing enterprises to have strong technological innovation capabilities. The number of patents is a business card of scientific research ability and can indicate the research direction of the topic.

Table 3 Results of Weight Value of Evaluation Factors of Scientific and Technological Achievements in Component Product Development

Target layer	Evaluation criterion layer	Evaluation factor layer	Weight value	Modified weight	ranking
Evaluation index system of scientific and technological achievements	Degree of independent innovation B1	Innovation and uniqueness of technical scheme B11	0.0729	0.1065	2
		The proportion of independent intellectual property technology B12	0.0528	0.0771	7
	Technical difficulty and complexity B3		0.0975	0.1423	1
	Popularization and	Technical maturity and reliability B42	0.0401	0.0585	12

A	application prospect B4	Potential market demand and promotion value B45	0.0403	0.0588	11
	economic benefits B5	Cost-effectiveness ratio B51	0.0445	0.0649	9
		Return period of investment B52	0.0570	0.0832	6
		New output value B54	0.0595	0.0869	4
		New profits and taxes B55	0.0407	0.0595	10
	social benefit B6	Total energy consumption decreased B61	0.0594	0.0867	5
		Carbon emissions B63	0.0483	0.0705	8
	Outcome indicators B7	Number of patents B72	0.0718	0.1049	3

5. Conclusion

Through the above analysis, it is found that the weight values of the evaluation factors of the four types of scientific and technological achievements are different, and it is found that the four types of scientific and technological achievements are basically consistent in the five first-level indicators of independent innovation degree, technical difficulty and complexity, promotion and application prospect, economic and social benefit. At the same time, the evaluation systems of scientific and technological achievements of component product development and vehicle product development are similar, but there are obvious differences between them and the evaluation systems of process and forward-looking foundation, which are as follows: first, the component product development and vehicle product development still retain the technological advancement as an important evaluation index, on the contrary, the evaluation index of technological advancement is deleted in process and forward-looking foundation; Secondly, component product development and vehicle product development only use the number of patents as the evaluation factor of achievement index, on the contrary, the number of papers and patents are still used as the evaluation factor of achievement index in technology and prospective basic classes. It is found that the advanced degree of technology has absolute influence on the evaluation of scientific and technological achievements in component product development and vehicle product development, which is also in line with the fact that advanced technology is an important foundation in the product development process. In addition, the number of papers has obvious weight advantage in the evaluation of technological and prospective basic scientific and technological achievements, which shows that papers can make the research achievements more perfect in technological and prospective basic scientific and technological achievements, thus improving the level and value of research achievements.

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