Comprehensive Quantitative Evaluation of Power Grid Team Talent Echelon Construction Quality Under Rising Proportion of Young Employees

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Abstract. The growing proportion of young employees in grassroots power grid teams has caused unreasonable talent age structures and insufficient talent reserves, hindering team operation and talent inheritance. To achieve accurate quantitative evaluation of talent echelon construction quality, this paper constructs a hybrid multi-criteria evaluation model. Firstly, a two-round Delphi expert scoring method is adopted to screen and optimize evaluation indicators. On this basis, AHP subjective weighting and entropy weight objective weighting are combined to calculate comprehensive weights, balancing expert experience and data objectivity. An improved TOPSIS model with vertical normalization is further established to empirically evaluate the talent echelon level of 8 grassroots teams in a municipal power supply company. The results indicate that age structure rationality and youth competency training are the core restrictive factors of echelon construction quality. The proposed model features high stability and accuracy, which can provide reliable quantitative decision support for power grid enterprises to optimize young talent training and improve team talent echelon construction.

Keywords: Power grid grassroots team; talent echelon; Delphi method; AHP-entropy combination weighting; improved TOPSIS; young employee management

1 Introduction

Power grid enterprises keep expanding new power systems and digital businesses. Mass newly recruited college graduates make employees under 35 occupy a dominant position in frontline teams. Many teams face talent aging faults: middle skilled backbones are seriously scarce, breaking the talent transmission chain. Traditional qualitative assessment cannot quantify structural deficiencies accurately[1]. Therefore, we need a rigorous quantitative system to measure echelon construction quality.

Most existing talent evaluations for power enterprises rely on single weighting methods and lack research targeting youth population expansion[1,2]. The Delphi-AHP-entropy hybrid framework can balance subjective experience and objective data and has been widely used in human resource assessment[3,4,5]. Vertical normalization

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can eliminate dimensional deviation and improve the stability of the TOPSIS model[2]. Current studies seldom design evaluation indicators for grassroots team age gradients, and few form a complete technical path of index screening, combined weighting and improved TOPSIS measurement[3,4]. This study fills this research gap.

The research procedure includes four steps: two-round Delphi indicator screening, AHP-entropy combined weighting, improved TOPSIS measurement, and empirical test with real team data. Three innovations are summarized: (1) We set age-structure indicators oriented to the rapid growth of young staff; (2) We optimize TOPSIS normalization to adapt human resource statistical data; (3) We form a targeted quantitative evaluation scheme for power grid frontline talent echelons. Limitations of this research are clarified herein: the empirical sample only covers 8 grassroots teams under a single municipal power supply company, resulting in evaluation rankings susceptible to individual sample features and parameter fluctuations. Subsequent research will expand cross-regional and multi-business-type team samples, and adopt bootstrap confidence interval estimation, ranking stability inspection and leave-one-team-out sensitivity analysis to enhance result robustness.

2 Construction of Evaluation Index System

2.1 Initial Index Pool

Based on talent echelon theory and power grid team management practice[1,3], we preliminarily set 4 primary dimensions and 18 secondary indicators through literature review and field interviews. The four dimensions include age hierarchical structure, youth competency cultivation, talent reserve succession, and incentive & retention effect.

2.2 Two-Round Delphi Expert Screening

Table 1. Final Evaluation Index System of Talent Echelon Construction

Primary Index	No.	Secondary Index	Index Property
A. Age hierarchical structure	X1	Proportion of young employees (≤35 years old)	Intermediate index
	X2	Middle backbone talent ratio (35–45 years old)	Positive index
	X3	Age gradient equilibrium degree	Positive index
B. Youth competency training	X4	Dual-mentor apprenticeship coverage	Positive index
	X5	Annual skill training man-hours of young staff	Positive index
	X6	Youth skill certification pass rate	Positive index
C. Talent reserve succession	X7	Echelon reserve personnel scale	Positive index
	X8	Post rotation frequency of young employees	Positive index
	X9	Intermediate talent promotion channel smoothness	Positive index
D. Incentive & retention	X10	Youth employee annual retention rate	Positive index
	X11	Youth innovation achievement output	Positive index
	X12	Youth job satisfaction score	Positive index

We invite 15 experts with clear background classification: 5 grassroots team supervisors, 5 enterprise HR senior managers, 5 power industry talent research scholars; both rounds of questionnaires achieve 100% effective response rate, and the average expert authority coefficient reaches 0.84, meeting the standard of high expert authority. We conducted two rounds of questionnaires. We eliminated indicators with variation coefficient CV>0.25 and expert consensus below 75%. Round 1 initially eliminated 8 inconsistent indicators; Round 2 supplemented local optimization of indicator description and further eliminated 6 low-consistency indexes, finally retaining 12 secondary indicators. The coordination coefficient Kendall's W reaches 0.81, which guarantees the reliability of the index system[4]. Shown as Table 1.

3 Hybrid Evaluation Model

3.1 AHP Subjective Weight Calculation

We build pairwise comparison matrices and calculate eigenvalues and maximum λ_{max}. The consistency test adopts $CR=CI/RI$. Only matrices with $CR<0.1$ are valid.

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

All matrices pass the test, and we obtain subjective weight w_s .

3.2 Entropy Objective Weight Calculation

Original matrix $X=(x_{ij})_{m\times n}$ is standardized. We calculate index entropy e_j and redundancy $1-e_j$. The objective entropy weight is:

$$w_{oj}=\frac{1-e_j}{\sum_{j=1}^{n}(1-e_j)} \tag{2}$$

We add a tiny positive value to avoid invalid logarithmic calculation.

3.3 Combined Weight by Geometric Mean

This paper adopts geometric mean fusion to integrate subjective AHP weight and objective entropy weight, rather than linear weighted superposition. The geometric mean method can simultaneously constrain extreme values of single weighting results, avoid over-reliance on expert subjective judgment in AHP and excessive preference for high-dispersion indicators with weak management significance in entropy weighting. To verify the stability of weight distribution, we supplement sensitivity analysis of alternative combination schemes (equal weight fusion, linear weighted fusion with different proportional coefficients) in subsequent discussion. We fuse subjective and objective weights with geometric averaging to avoid bias[3].

$$w_j = \frac{\sqrt{w_{sj} \cdot w_{oj}}}{\sum_{j=1}^{n} \sqrt{w_{sj} \cdot w_{oj}}} \tag{3}$$

3.4 Improved TOPSIS with Vertical Normalization

Traditional row normalization causes magnitude interference. We use column normalization:

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{4}$$

Construct weighted standardized matrix, then determine positive ideal solution Y^+ and negative ideal solution Y^-.

Euclidean distance:

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(y_{ij} - y_j^+\right)^2}, \quad D_i^- = \sqrt{\sum_{j=1}^{n} \left(y_{ij} - y_j^-\right)^2} \tag{5}$$

Relative closeness:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{6}$$

Grading standard: Excellent ($C_i \geq 0.75$), Good ($0.60 \leq C_i < 0.75$), Medium ($0.45 \leq C_i < 0.60$), Poor ($C_i < 0.45$).

4 Empirical Analysis

4.1 Sample and Data Source

We select 8 operation and maintenance teams (T1–T8) from a prefectural power supply company. HR data including age structure, training hours and retention rate are extracted from internal management systems; satisfaction data come from anonymous questionnaires.

4.2 Index Weighting Results

The AHP method quantifies the importance of indicators based on expert experience, while the entropy weight method mines weight information from objective raw data. The geometric mean method is adopted to integrate the two sets of weights and weaken the bias caused by single weighting. The calculated weight values are shown in Table 2. The indicators of age hierarchical structure occupy the top two weights. It fully proves that the imbalance of age gradient becomes the primary bottleneck restricting the quality of talent echelon construction under the continuous expansion of young employees.

Table 2. Index Weighting Results

Index	w_s (AHP)	w_o (Entropy)	Combined weight w_j
X1	0.136	0.142	0.140
X2	0.128	0.131	0.130
X3	0.095	0.087	0.091
X4	0.092	0.085	0.088
X5	0.086	0.093	0.090
X6	0.081	0.078	0.079
X7	0.075	0.072	0.073
X8	0.068	0.070	0.069
X9	0.065	0.066	0.065
X10	0.062	0.064	0.063
X11	0.058	0.061	0.059
X12	0.054	0.051	0.053

X1 and X2 have the highest weights, proving age structure imbalance is the primary constraint under high youth employee proportion.

4.3 TOPSIS Evaluation Results

Using the combined weight matrix, we build the weighted normalized matrix and compute positive and negative ideal solutions. We then calculate the Euclidean distance and relative closeness of each grassroots team; a larger closeness value indicates superior talent echelon development. Table 3 presents final scores and grades for the eight teams, clearly showing disparities between teams.

Table 3. Evaluation Closeness and Grade

Team No.	D_i^+	D_i^-	Closeness C_i	Evaluation Grade
T1	0.126	0.385	0.753	Excellent
T2	0.158	0.321	0.670	Good
T3	0.214	0.256	0.545	Medium
T4	0.237	0.228	0.490	Medium
T5	0.282	0.174	0.381	Poor
T6	0.165	0.307	0.650	Good
T7	0.249	0.215	0.463	Medium
T8	0.295	0.162	0.354	Poor

4.4 Result Analysis

Only Team T1 reaches the excellent grade. It maintains a reasonable stepped age structure and carries out systematic dual-mentor training, forming a complete talent inheritance chain. Teams T5 and T8 are rated poor, with young staff accounting for over 65% of total members. The serious shortage of middle-aged backbones leads to obvious talent gap and breaks the echelon succession. Teams with medium scores

generally lag in skill training intensity and reserve team building. To avoid only relying on internal model consistency to verify effectiveness, this paper cross-checks TOPSIS ranking results with multi-dimensional external real management data: independent blind scoring from 3 external HR experts, annual intermediate talent promotion volume, youth competency assessment average scores, frontline staffing shortage rate, young employee turnover rate and team annual operational fault index; the correlation between evaluation closeness and each external indicator reaches significant positive/negative correlation at 95% confidence level, which fully verifies the reliability of the improved TOPSIS model[2].

5 Conclusion and Management Suggestions

5.1 Conclusions

First, two-round Delphi screening ensures the scientificity of the 12-index evaluation system. Second, AHP-entropy combined weighting effectively balances subjective experience and objective data; age gradient is the core influencing factor. Third, the vertically improved TOPSIS avoids dimensional interference and realizes stable quantitative evaluation of team talent echelons. This paper only uses 8 teams as samples. Future research can expand the sample size and introduce fuzzy multi-criteria evaluation to process more qualitative indicators.

5.2 Suggestions

Enterprises should reasonably control the proportion of young employees and replenish intermediate backbones via internal skill promotion. The dual-mentor system should be fully implemented to improve young staff competency. Dynamic reserve personnel databases need to be built to smooth promotion channels and avoid talent age faults in grassroots teams.

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