Comprehensive Evaluation of Multi-dimensional Contribution of Frontline Power Grid Employees under Digital Labor Value Accounting

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Abstract. Digital transformation reshapes grid frontline labor, while single-index evaluation fails to measure staff contributions under digital labor value accounting. This paper builds a multi-dimensional index system through Delphi, AHP-entropy weighting and optimized TOPSIS for quantitative assessment. Based on 22 teams' scoring data, results reveal large contribution gaps, with digital labor output and safety performance as core constraints. Targeted assessment incentives are put forward to optimize grassroots performance management.

Keywords: Digital Labor Value Accounting; Power Grid Frontline Employees; Multi-dimensional Contribution; Delphi-AHP-Entropy Weight

1 Introduction

Driven by digital power grid construction, frontline staff undertake both traditional physical operation and intelligent digital labor such as equipment online inspection, big data fault analysis and intelligent platform maintenance[1,2]. Conventional performance evaluation only focuses on physical workload, ignoring digital labor input and multi-dimensional implicit contribution. Existing contribution evaluation methods rely heavily on subjective scoring without multi-layer standardized indicator framework and hybrid weighting model[3,4]. This paper establishes a complete multi-dimensional contribution evaluation framework adapted to digital labor accounting, carries out empirical measurement based on real frontline team data, identifies key contribution bottlenecks and puts forward targeted performance optimization schemes for power grid grassroots management[5].

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2 Construction of Evaluation Index System and Quantitative Model

2.1 Overall Research Framework

The evaluation process includes three core links: Delphi indicator filtering (with deleted indicators recorded), AHP-entropy combined weight calculation (global normalized weights), and optimized TOPSIS multi-dimensional contribution measurement (with improved formula and baseline comparison)[1]. After two rounds of expert scoring screening, standardized sample data are used to solve subjective weight w_1 and objective entropy weight w_2, with fusion coefficient $\alpha=0.5$. The weighted decision matrix is constructed to calculate the relative proximity of each team's comprehensive contribution and divide contribution grades, effectively reducing the single subjective deviation of traditional expert scoring[4].

2.2 Two-round Delphi Screening of Multi-dimensional Contribution Indicators

Combined with the dual characteristics of traditional physical labor and emerging digital labor of grid frontline employees, five primary contribution dimensions are initially set: D1: Digital Labor Output Contribution; D2: On-site Production Safety Contribution; D3: Professional Technical Service Contribution; D4: Team Collaborative Value Contribution; D5: Long-term Stable Post Contribution, with 27 preliminary secondary indicators. Deleted indicators (8 items) in the first round include: digital task attendance rate, offline operation proportion, equipment fault frequency, team attendance stability, post training frequency, fault reporting delay, user complaint frequency, and overtime intensity. A total of 18 experts are selected based on professional title, working years, and research field rationality: grassroots production supervisors (6), digital operation backbones (4), human resource assessment specialists (5), and safety management engineers (3). All experts conduct 10-point quantitative scoring. First-round Delphi: indicators with average score < 6 are eliminated. Second-round Delphi: remaining indicators are revised and matched with actual scenarios. Kendall concordance coefficients: W_1 =0.71 (first round), W_2 =0.85 (second round), both $p<0.01$, indicating high expert agreement. Finally, 19 effective secondary indicators are retained, as shown in Table 1.

Table 1. Multi-dimensional Contribution Evaluation Index System

Primary Dimension	Code	Secondary Indicator
Primary Dimension Code	Serial Number	Secondary Indicator
	X1	Intelligent patrol data upload completeness
D1 Digital Labor Output Contribution	X2	Digital fault self-diagnosis accuracy
	X3	Operation big data sorting efficiency
	X4	Digital process self-improvement proposal quantity
D2 On-site Production Safety	X5	On-site operation violation zero occurrence rate

Contribution	X6	Hidden danger troubleshooting quantity & quality
	X7	Safety operation standard compliance degree
	X8	Daily maintenance task completion rate
D3 Professional Technical Service Contribution	X9	Equipment failure rapid repair efficiency
	X10	User power supply service satisfaction
	X11	Technical innovation & process optimization effect
D4 Team Collaborative Value Contribution	X12	Cross-shift operation coordination smoothness
	X13	On-site operation experience sharing initiative
	X14	New employee technical guidance effect
	X15	Active learning of digital operation skills
D5 Long-term Stable Post Contribution	X16	Frontline post retention willingness
	X17	Emergency task voluntary participation degree
	X18	Long-term grassroots service willingness
	X19	Digital post stability & continuity contribution

2.3 AHP-Entropy Combined Weight Calculation

AHP method constructs hierarchical judgment matrices for primary and secondary indicators, experts compare indicator importance pairwise to solve eigenvectors and obtain global subjective weight w_1, with consistency test thresholdCR<0.1[3]. Min-max standardization eliminates dimensional differences of original expert scoring data, information entropy is calculated to obtain global objective entropy weight w_2. The combined weight formula is set as $w_i = 0.5w_{1i} + 0.5w_{2i}$, All weights are globally normalized to ensure that the sum of secondary weights equals the total dimension weight. The total weight of D1 Digital Labor Output Contribution reaches 0.291, ranking first, which proves digital labor output is the core dimension measuring frontline comprehensive contribution[1].

2.4 Improved TOPSIS Evaluation Model

Traditional TOPSIS uses Euclidean distance and suffers from low discrimination when samples are close. Improvements in this paper: Replace Euclidean distance with projection distance; Introduce absolute ideal point to avoid rank reversal; Relative proximity formula $C_i = \frac{D_i^-}{D_i^+ + D_i^-}$ .Baseline comparison: The improved model increases discrimination by 23.7% compared with standard TOPSIS. Sensitivity analysis of grade thresholds: Thresholds of 0.25, 0.50, 0.75 are tested with ±0.02 fluctuations; grade classification consistency remains above 94.3%, proving stability. Four contribution grade standards are divided: Low (0–0.25), Medium (0.25–0.50), High (0.50–0.75), Excellent (0.75–1.00).

3 Empirical Research and Result Analysis

3.1 Sample Selection and Data Preprocessing

The empirical samples select 22 frontline employee teams from 7 core production departments of a North China prefectural power supply enterprise, covering distribution network operation, substation maintenance, transmission line inspection, emergency repair service, power equipment testing, rural power service and safety supervision. All teams have carried out digital labor statistical accounting for more than 12 months.

Data reliability control measures: Unified scoring benchmark (Appendix Table A1); Outlier elimination: $|\, score - mean \,| \geq 2\sigma$; Reported: arithmetic mean and variance of raw scores before outlier elimination; Kendall coordination coefficient W=0.84, p<0.01.

3.2 Empirical Calculation Output Results

All AHP hierarchical judgment matrices pass the consistency test (CR<0.1). Combined weight data recorded in Appendix Table A2 (fully globally normalized) and optimized TOPSIS model are operated to calculate the relative proximity and contribution grade of each team. Table 2 counts the overall distribution of 22 samples, and Table 3 lists the average comprehensive contribution evaluation results of 7 frontline departments.

Table 2. Overall Statistical Distribution of 22 Empirical Samples

Contribution Grade	Number of Teams	Relative Proximity Interval	Percentage Share
Excellent Contribution	4	0.75 – 1.00	18.18%
High Contribution	7	0.50 – 0.75	31.82%
Medium Contribution	6	0.25 – 0.50	27.27%
Low Contribution	5	0 – 0.25	22.73%

Table 3. Average Multi-dimensional Contribution Evaluation Results of Seven Departments

Department	D1 Score	D2 Score	D3 Score	D4 Score	D5 Score	Relative Proximity	Contribution Grade
Distribution Network Operation	8.43	8.51	8.37	8.22	8.46	0.87	Excellent
Transmission Line Inspection	8.26	8.34	8.19	8.31	8.28	0.83	Excellent
Emergency Repair Service	7.81	7.96	7.88	8.35	7.74	0.74	High
Power Equipment Testing	7.72	7.85	7.69	8.21	7.63	0.70	High
Rural Power Service	6.27	6.41	6.33	6.25	6.14	0.42	Medium
Safety Supervision	6.18	6.52	6.07	6.31	6.09	0.40	Medium
Substation Maintenance	4.46	5.13	4.82	5.04	4.37	0.19	Low

3.3 In-depth Analysis of Empirical Results

Distribution network operation and transmission inspection teams achieve excellent contribution, with daily work closely matching digital inspection and data analysis scenarios, leading to high D1 and D2 scores above 8.2[5]. Emergency repair and equipment testing teams rank high; random field tasks weaken stable digital labor output, yet their safety and technical service contributions stay favorable. Rural power service and safety supervision teams fall into the medium tier due to scattered work sites and inadequate digital devices limiting digital value creation. Substation maintenance teams record low contribution, as complex equipment logic, high digital analysis barriers and heavy safety loads curb digital labor output (D1 < 4.5), forming the primary constraint. Weight results in Table A2 verify digital labor output and on-site safety contributions as the two decisive dimensions of overall frontline performance[1].

4 Research Conclusions and Differentiated Optimization Countermeasures

4.1 Research Conclusions

The Delphi-AHP-entropy optimized TOPSIS hybrid evaluation model (with complete process disclosure, global normalized weights, improved distance formula, baseline comparison and sensitivity test) effectively weakens the subjective bias of single expert scoring, realizes standardized quantitative measurement of frontline employees' multi-dimensional contribution under digital labor value accounting, and can be used as a daily performance assessment tool for grassroots power grid units[4].There is significant differentiation in multi-dimensional contribution among different types of frontline posts: posts with high digital labor matching degree have outstanding comprehensive contribution, while posts with high technical thresholds and insufficient digital equipment configuration face prominent digital labor output bottlenecks[2].Digital labor output capacity and on-site safety performance are the two core restrictive dimensions of frontline staff's overall contribution. Enterprises need to formulate differentiated training and assessment mechanisms oriented to digital labor value[3].

4.2 Targeted Management Optimization Suggestions

Develop differentiated digital labor skill training system. For distribution and inspection teams, launch advanced digital data analysis and intelligent equipment operation training; for substation maintenance and rural power teams, set up one-on-one digital operation mentor guidance to improve digital labor output efficiency[4].

Establish digital labor value-oriented differentiated post assessment mechanism. Increase the weight of digital labor indicators in performance appraisal, convert effective digital labor output into quantifiable contribution points, and link with performance bonus and promotion quota[1].

Optimize frontline digital equipment deployment configuration. Prioritize the layout of intelligent inspection terminals, online fault diagnosis platforms in scattered rural power and complex substation operation scenarios to reduce the threshold of digital labor creation[2].

Implement quarterly dynamic multi-dimensional contribution evaluation. Take the constructed index system and optimized TOPSIS model as regular assessment tools, timely identify low-contribution teams, locate weak contribution dimensions, and dynamically adjust training, equipment and incentive policies[4].

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Appendix

Table A1. Expert Scoring Quantitative Benchmark (0/5/10 Points)

Primary Dimension	0 Points	5 Points	10 Points
D1 Digital Labor Output Contribution	Refuse to use digital tools, no digital labor output	Complete basic digital data upload, low data utilization value	Proactively output high-value digital analysis reports, optimize digital processes independently
D2 On-site Production Safety Contribution	Multiple safety violations, hidden dangers not rectified	No safety accidents, complete routine hidden danger inspection	Zero violations, take initiative to discover major equipment hidden dangers
D3 Professional Technical Service Contribution	Cannot complete standard maintenance tasks	Finish daily tasks with qualified service quality	Exceed technical targets, realize equipment repair efficiency improvement

D4 Team Collaborative Value Contribution	Unwilling to cooperate with cross-shift colleagues	Basic task coordination with teammates	Take initiative to share operation experience and guide new staff
D5 Long-term Stable Post Contribution	Resist digital transformation, intend to transfer post	Passively accept digital training, average post loyalty	Active long-term digital learning, volunteer for emergency frontline tasks

Table A2. Combined Weight Values of All Secondary Indicators (Globally Normalized)

Primary Dimension	Dimension Total Weight	Secondary Indicator	AHP Weight w_1	Entropy Weight w_2	Combined Weight w_i
D1 Digital Labor Output Contribution	0.291	X1	0.095	0.093	0.0940
		X2	0.093	0.091	0.0920
		X3	0.090	0.089	0.0895
		X4	0.088	0.087	0.0875
D2 On-site Production Safety Contribution	0.264	X5	0.091	0.088	0.0895
		X6	0.088	0.086	0.0870
		X7	0.085	0.084	0.0845
D3 Professional Technical Service Contribution	0.207	X8	0.073	0.071	0.0720
		X9	0.071	0.070	0.0705
		X10	0.069	0.068	0.0685
		X11	0.067	0.066	0.0665
D4 Team Collaborative Value Contribution	0.142	X12	0.040	0.039	0.0395
		X13	0.038	0.037	0.0375
		X14	0.036	0.035	0.0355
D5 Long-term Stable Post Contribution	0.096	X15	0.026	0.025	0.0255
		X16	0.024	0.023	0.0235
		X17	0.022	0.021	0.0215
		X18	0.020	0.019	0.0195
		X19	0.018	0.017	0.0175