Research on the Input-output Evaluation of Power Grid Equipment Management Based on DEA Theory

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Abstract: The safe and stable operation of the power grid and the high-quality service play a solid role in ensuring the power supply. However, there are many professional management items of power grid equipment, and the quality and efficiency of professional coordination need to be improved. The quantitative production input and output cannot meet the development needs of lean management. It is urgent to establish a set of equipment input-output analysis methods to meet the lean management needs of enterprises. Therefore, this article combines the analysis of equipment management objectives for power grid enterprises, with the goal of achieving the minimum cost input and optimal output effect for power grid enterprises. A corresponding analysis and evaluation model is constructed, and empirical analysis is conducted using actual data from various units in a certain area of Fujian Power Grid Company, providing reference for cost saving and improving investment efficiency for power grid enterprises.

Key words: Grid equipment management; DEA; input-output evaluation

1. Introduction

Power grid enterprises as a typical "asset-intensive" enterprise, the current equipment management is still facing big but not strong, big but not optimal development bottleneck, old equipment base big hidden trouble, part of the key equipment quality problems, many equipment at both ends of the typical fault "bathtub curve", update demand increase, fault risk accumulation, maintenance costs rise. At the same time, there are many professional equipment management items, the quality and efficiency of professional coordination need to be improved, and the quantitative production input and output cannot meet the development needs of lean management.

In reference [1], in order to improve the decision-making level of project feasibility studies, an economic evaluation model for project feasibility studies was constructed from the perspective of the entire cost expenditure of the entire life cycle of power grid equipment. Starting from the analysis of the current stock of power grids, literature [2] delves into various prominent problems in the distribution network, and combines future economic and power grid construction needs to construct an evaluation and analysis model from the perspective of investment and development, thereby improving the scientific nature of power grid planning and construction. Reference [3] is based on the strategic goals of power grid enterprise distribution network development, combined with actual investment data, to analyze the

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correlation between investment and output in distribution networks, providing reference for improving investment output effectiveness. Reference [4] constructs an evaluation index system from the perspectives of investment in new and existing power grids, as well as investment effectiveness. Based on the sensitivity analysis results of indicator efficiency, it provides direction guidance for subsequent investments. Reference [5] divides power grid investment into two categories: rigid and elastic demand, and considers the differences in investment output effects of different types of investment. It constructs an investment benefit evaluation method to guide enterprises to reasonably allocate investment levels.

From the above, it can be seen that current scholars are more concerned about the investment effectiveness and output of power grid enterprises, but there is still a slight lack of research on evaluation methods. Therefore, this study has good necessity.

2. Establishment of Cost Input Effectiveness Evaluation Model

DEA is a linear programming model primarily used by enterprise managers to reduce inefficiencies. The DEA model is represented as the ratio of output to input. It is mainly a quantitative analysis method based on multiple input indicators and multiple output indicators, using the method of linear programming to evaluate the relative effectiveness of comparable units of the same type.

This article constructs the C^2R model. Assuming there are a total of r decision-making units, each with l types of investment types (I) and output types (O), with inputs and outputs $I_a = (I_{a1}, I_{a2}, ..., I_{al})^T$, $O_a = (O_{b1}, O_{b2}, ..., O_{bq})^T$, and $a, b = 1, 2, L, r$.

$$\begin{cases} \max \dfrac{f^T O_0}{e^T I_0} \\ s.t. \dfrac{u^T y_j}{v^T x_j} \le 1 \\ f \ge 0, e \ge 0 \end{cases} \quad (1)$$

Where, $e = (e_1, e_2, L, e_m)^T$ and $f = (f_1, f_2, L, f_l)^T$ is the weight coefficients of m inputs and s outputs respectively.

$$\begin{cases} \min \theta \\ s.t. \sum_{j=1}^{n} x_j \lambda_j \le \theta x_0 \\ \sum_{j=1}^{n} y_j \lambda_j \ge v_0 \\ \lambda_j \ge 0, j = 1,2,L,n, \theta \in E_1^+ \end{cases} \tag{2}$$

By processing the above model with infinitesimal (ε), it can be concluded that:

$$\begin{cases} \min \left[\theta - \hat{e}^{\mathrm{T}} S^- + \hat{e}^{\mathrm{T}} S^+ \right] \\ s.t. \sum_{j=1}^{n} x_j \lambda_j + S^- = \theta x_0 \\ \sum_{j=1}^{n} y_j \lambda_j - S^+ = y_0 \\ \lambda_j \ge 0, j = 1,2,L,n, \theta \in E_1^+, S^- \ge 0 \end{cases} \tag{3}$$

Where $\hat{e}^{T} = (1,1,L,1)^T$, if $\theta_0 = 1$, $S^- = 0$ and $S^+ = 0$ are met, DWU_{j0} is said to be DEA effective.

Let the optimal solution of the model be θ^0, λ^0, S^{0-}, S^{0+},if $\theta^0 = 1$, $S^{0-} = 0$ and $S^{0+} = 0$, call DMU DEA valid; if $\theta^0 = 1$, $S^{0-} \ne 0$ and $S^{0+} \ne 0$, call DMU weak DEA valid, if $\theta^0 < 1$, call DMU non-DEA valid.

3. Analysis and supervision of evaluation indicators based on cost-output optimization in power grid enterprises

The cost output effectiveness evaluation index system constructed by querying relevant information and combining with the suggestions of relevant experts from power grid enterprises is shown in Table 1:

Table 1. Cost output effectiveness evaluation index system.

Indicator category	metric
Enter the index	Total equipment value
	Equipment maintenance cost input

	Capacity to load ratio
	Proportion of Line Energy Loss
	Service life of equipment
Output indicators	Equipment failure rate reduction ratio

4. Empirical analysis

This article conducts empirical analysis on Fujian Power Grid Company as the research object. The relevant basic data collected through on-site research is shown in Table 2.

Table 2. Basic Data Table for Cost Output Effectiveness Evaluation Indicators.

a particular year	**DMU**	**(I) Total value of the equipment (RMB 100 million)**	**(I) Equipment maintenance cost input (ten thousand yuan)**	**(I) Number of equipment defects (years. Million units / times)**	**(I)** Proportion of Line Energy Loss	**(I) GDP growth rate(%)**	**(O) Equipment failure rate reduction ratio is (%)**
	FJA	289.73	35300.69	2.25	3.23	10.47	1.85
	FJB	162.95	19436.64	2.12	3.57	7.83	1.89
	FJC	199.65	25717.59	1.87	3.44	7.62	2.51
	FJD	66.80	7701.78	2.31	3.7	6.3	0.45
	FJE	188.80	21193.92	2.22	4.76	7.26	1.23
2020	FJF	159.23	16834.82	2.09	2.78	6.89	2.09
	FJG	68.30	8460.25	1.9	3.7	7.98	2.58
	FJH	92.40	14767.74	2.88	5.56	7.49	1.17
	FJI	110.98	13026.74	2.27	2.78	7.07	1.81
	FJJ	153.23	18003.55	2.07	5	7.29	2.51
	FJK	25.80	1497.28	3.24	5	6.32	0.82
	FJA	92.88	37756.17	2.41	3.03	11.2	1.98
	FJB	446.26	20381.31	2.22	3.45	8.21	1.98
	FJC	246.06	27950.73	2.03	3.13	8.28	2.73
	FJD	312.44	8197.16	2.46	3.45	6.7	0.48
	FJE	102.38	21897.93	2.29	4.55	7.5	1.27
2021	FJF	280.91	17390.58	2.16	2.7	7.12	2.16
	FJG	236.84	8841.54	1.99	3.57	8.34	2.7
	FJH	102.78	15366.81	3	5.26	7.79	1.22
	FJI	138.46	13487.84	2.35	2.7	7.32	1.87
	FJJ	165.46	19763.50	2.27	4.55	8	2.76
	FJK	242.21	1634.56	3.54	4.55	6.9	0.9

Based on the principle of the model, the evaluation results of the cost output effect of equipment operation and maintenance in various regions of Fujian Company are shown in Table 3:

Table 3. Evaluation Results of Operation and Maintenance Cost Output Effect.

a particular year	DMU	overall efficiency	pure technical efficiency	Scale efficiency	
2020	FJA	0.7569	0.9167	0.8326	irs
	FJB	0.72790	0.9210	0.7743	irs
	FJC	1	1	1	-
	FJD	0.2324	1	0.2250	irs
	FJE	0.4789	0.9654	0.5315	irs
	FJF	1	1	1	-
	FJG	1	1	1	-
	FJH	0.474	0.877	0.540	irs
	FJI	0.895	1	0.895	irs
	FJJ	1	1	1	-
	FJK	1	1	1	-
	averag e value	**0.781**	**0.970**	**0.801**	**-**
2021	FJA	0.749	0.895	0.837	irs
	FJB	0.731	0.937	0.780	irs
	FJC	1	1	1	-
	FJD	0.220	1	0.220	irs
	FJE	0.491	0.948	0.518	irs
	FJF	0.967	1	0.967	irs
	FJG	1	1	1	-
	FJH	0.474	0.894	0.530	irs
	FJI	0.8864	1	0.864	irs
	FJJ	1	1	1	-
	FJK	1	1	1	-
	averag e value	**0.772**	**0.970**	**0.792**	-

It can be seen from Table 3 ,it can be seen that the analysis of the evaluation results of operation and maintenance cost output effect is as follows:

(1) In 2020 and 2021, the input and output effects of power grid equipment operation and maintenance in regions FJC, FJG, FJJ, andFJ K were matched, and the cost application was optimal. However, in 2020 and 2021, regions FJA, FJB, FJD, FJE, FJH, and FJI had more cost inputs but lower output effects.

(2) As the scale of power grid construction continues to expand in the FJF region, its output effect will be higher. Therefore, the region should expand the scale of power grid inventory.

(3) In 2020 and 2021, the construction scale of power grids in the regions of FJA, FJB, FJD, FJE, FJH, and FJI was relatively small, while the investment in equipment operation and maintenance costs was relatively large, indicating that their asset size did not match the level of operation and maintenance investment. Therefore, cost investment control should be further strengthened to improve output effectiveness.

5. Conclusion

This article is guided by the improvement of equipment lean management needs in power grid enterprises, and constructs a cost-effectiveness evaluation analysis method from the perspective of matching cost input with output effects. This method is not only beneficial for enterprises to deeply analyze the current equipment asset inventory problems and development status, but also provides decision-making reference for enterprises to achieve "small investment, large output".

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