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EVALUATION SYSTEM FOR THE INVESTMENT EFFICIENCY OF DISTRIBUTION NETWORK: IMPROVED DATA ENVELOPMENT ANALYSIS MODEL APPROACH

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Abstract. *The investment for distribution network is an important part of power grid construction. The establishment of the analytical model for the investment efficiency of the distribution network construction is able to ensure the efficiency and reliability of the power system and is one of important means to realize the intensification of the grid construction. This paper has established a data envelopment analysis model to assess the investment efficiency of grid enterprises. For less objectivity of the original model, an entropy weight method has been introduced to determine the weight of each index. At the same time, a normalization method has also been brought in the model establishment to achieve the standardization of the index value so that the model is more scientific and accurate and its practicality has been proved by the analysis of examples.*
Keywords: Distribution network, Investment efficiency, Data envelopment analysis model, Entropy weight method, Normalization method

1. **Introduction.** With the growth of the demand for electricity, the investment for distribution network has been growing during the past few years [1,2]. Therefore, the costs of network maintenance and operation have been maintained at a relatively high level. Meanwhile, problems on the lower utilization rate of the distribution network investment have become increasingly prominent, and seriously affected the economic operation of the power grid so that the investment returns are difficult to achieve. Therefore, it has become an important research topic that the investment benefit of the distribution network construction is evaluated by using a data model so as to guide the power grid company's investment planning of the distribution network [3-5].

At present, the research of distribution network investment mainly focuses on the stability and economy of the power grid to be enhanced from the technical level [6]. Reference [7] has proposed a new technique using discrete wavelet transform and fuzzy logic in order to identify the fault types on transmission systems. Reference [8] has investigated efficient network investment for smart distribution grids and obtained variations of locational distribution-pricing to reduce investments. Reference [9] has examined the electric generation expansion plans with Smart Grid technologies in order to improve the performance of the distribution system as well as reduce the cost and emissions. From the existing research content, there is still a blank in the research related to the investment efficiency of the distribution network, which cannot effectively reflect the overall situation of the investment and construction of China's distribution network. Meanwhile, during the past decade, the theory of data envelopment analysis has developed in a variety of directions. Reference [10] has proposed a dynamic DEA model involving network structure in each period within the framework of a slacks-based measure approach. This approach has been applied to a dataset of US electric utilities and compared the result with that of DSBM. Reference [11] has proposed and tested a DEA-centric Decision Support System that aims to assess and manage the relative performance of organizations. Nowadays, data envelopment analysis method is always employed as a tool to assess the efficiency or productivity of organizations [12-14]. In addition, data envelopment analysis also performs as a benchmarking process to improve the performance of enterprises [15-17]. However, to date, none of the data envelopment analysis methods developed is perfect and all are far from ready to be used in the assessment for the investment efficiency of distribution network. Based on the study on the distribution network investment efficiency and the DEA model in recent years, the data envelopment analysis model has been designed and improved in this paper to evaluate China's investment efficiency of the distribution network according to the needs of China's power grid enterprises.

The novelty of the paper is as follows. First, both the normalization method and the entropy method are introduced to the establishment of the data envelopment analysis model to provide a simple solution for this complex problem of the investment efficiency evaluation of the distribution network. Weights between indexes can be scientifically allocated and calculated by using the entropy method. At the same time, the value of each index is standardized by the normalization method.

Second, a complete and rigorous system of the investment efficiency evaluation is built in this paper under full consideration of the characteristics of China's distribution network construction and indexes are divided into two categories: input index and output index so as to meet the requirements of the DEA model.

Finally, the revised DEA model is first used in the research of the investment efficiency of the distribution network in this paper, and compared with the model built in References [11-17], this model in the paper is more applicable in the assessment of the investment and construction of China's electric distribution network.

This paper proceeds as follows. Section 2 gives an evaluation system of the investment efficiency of distribution network investment and the definition as well as calculation method of every index. In Section 3, we built the methods used in this paper: data envelopment analysis, the entropy method and normalization method. Section 4 presents the experimental results of the proposed method. Finally, the conclusions and suggestions are contained in Section 5.

2. **Investment Efficiency Evaluation System.**

2.1. **The establishment of investment efficiency evaluation system.**

For different levels of the investment effectiveness of the distribution network branch reflected, a set of more perfect evaluation index system of the distribution network investment has been established in this paper [18-20]. In accordance with China's distribution network investment characteristics, the indexes in this paper are divided into two parts: input index and output index, as shown in Table 1 [21-23]. At the same time, the classification also meets the requirements of the DEA model, in the calculation process of DEA model, input index values are compared with output index ones, and the final result of comparison is the investment efficiency.

2.2. **Index definitions and calculation methods.**

(1) Line loss rate. The line loss rate refers to loss of the electrical energy in the transmission process of the distribution network and is an important index to reflect economic and technical characteristics of the investment and construction of the distribution network.

Table 1. Investment efficiency evaluation system for distribution network

The type of indicators	Code of indicators	Indexes
Input indicators	I_1	Line loss rate
	I_2	Capacity-load ratio
	I_3	Power supply per unit substation capacity
	I_4	Line utilization rate
	I_5	Load forecasting accuracy
	I_6	Predicted deviation rate of electricity sales
Output indicators	I_7	Increased power supply per unit investment
	I_8	Gross margin of new fixed assets
	I_9	Increased power supply per unit new substation capacity
	I_{10}	Completion rate of productive maintenance costs
	I_{11}	Control rate of overhauling costs
	I_{12}	Operation and maintenance costs per unit grid assets
	I_{13}	Completion rate of power grid construction and renovation Project investment plan

Its calculation method is shown in Formula (1).

$$I_1 = \frac{G - S}{G} \tag{1}$$

G is the annual power supply and S is the annual electricity sales amount.

(2) Capacity-load ratio. The capacity-load ratio is a comparative index of the supply capacity at each voltage grade of the power grid to the actual load, describes whether the substation capacity margin is appropriate or not, and is used for guiding the reasonable control of the investment scale of power grid enterprises [24]. Its calculation method is shown in Formula (2).

$$I_2 = \frac{Q_{\max day}}{L_{\max day}} \tag{2}$$

$Q_{\max day}$ stands for substation capacity during the day which reaches the maximum load. $L_{\max day}$ represents the maximum load at that day.

(3) Power supply per unit substation capacity. This index refers to the utilization efficiency of the substation equipments. The higher the power supply per unit substation capacity is, the higher the substation equipment efficiency is. Its calculation method is demonstrated in Formula (3).

$$S_7 = \frac{G}{Q} \tag{3}$$

G stands for an annual power supply and Q is substation capacity.

(4) Line utilization rate. This index reflects the line utilization level in the distribution network and is one of the important indexes necessary for reference that reflect the utilization of the grid lines, develop grid investment decisions and build a strong smart grid in the future. Its calculation method is demonstrated in Formula (4).

$$I_4 = \frac{N_{Line_A}}{N_{Line_{Total}}} \tag{4}$$

N_{Line_A} stands for the number of lines conforming to the following two cases: lines whose annual maximum load rate is less than 50% and the annual average load rate is less than

30%; lines whose annual maximum load rate is more than 70% and the annual average load rate is more than 50%. $N_{Line_{Total}}$ is a total number of lines.

(5) Load forecasting accuracy. Load forecasting accuracy is an index to measure the load forecasting accuracy, in addition, the power load forecasting is an important basic work to ensure the safe and stable operation of the power grid as well as the economic operation. Therefore, it is of great significance to improve the load forecasting accuracy. Its calculation method is shown in Formula (5).

$$I_5 = 1 - \frac{(L_{FOR_{\max}} - L_{PRA_{\max}})}{L_{FOR_{\max}}} \tag{5}$$

$L_{FOR_{\max}}$ stands for the predicted maximum load and $L_{PRA_{\max}}$ represents the actual maximum load.

(6) Predicted deviation rate of electricity sales. This index refers to the difference between the forecast sales and the actual electricity sales. This index is influenced by the forecast of electricity sales and line loss rate. Its calculation method is shown in Formula (6).

$$I_6 = \frac{S_{FOR} - S_{PRA}}{S_{FOR}} \tag{6}$$

S_{FOR} stands for the forecast of electricity sales, and S_{PRA} represents the actual electricity sales.

(7) Increased power supply per unit investment. I_7 reflects the growth of power supply which was created by the distribution network investment. Its calculation method is shown in Formula (7).

$$I_7 = \frac{G_{NEW}}{I_{LY}} \tag{7}$$

G_{NEW} stands for the annual new power supply and I_{LY} means last year's total investment.

(8) Gross margin of new fixed assets. This index reflects the revenue of power enterprises brought by new assets of distribution network. Its calculation method is shown in Formula (8).

$$I_8 = \frac{M_{NEW}}{F_{ANEW}} \tag{8}$$

M_{NEW} stands for the contribution margin brought by new assets, and F_{ANEW} represents the value of new assets.

(9) Increased power supply per unit new substation capacity. This index reflects the utilization efficiency of the new substation capacity. Its calculation method is shown in Formula (9).

$$I_9 = \frac{G_{NEW}}{Q_{NEW}} \tag{9}$$

G_{NEW} stands for the annual new power supply and Q_{NEW} means the annual new substation capacity.

(10) Completion rate of productive maintenance costs. This index is the ratio between actual maintenance costs and the planned maintenance costs. This index reflects the present situation of preventive and scheduled maintenance. Its calculation method is shown in Formula (10).

$$I_{10} = \frac{F_{PMF}}{F_{PMP}} \tag{10}$$

F_{PMF} stands for actual maintenance costs, and F_{PMP} represents the planned maintenance costs.

(11) Control rate of overhauling costs. I_{11} is the ratio between actual overhauling costs and the planned overhauling costs. This index reflects the present situation of overhauling

costs for distribution network equipments. Its calculation method is shown in Formula (11).

$$I_{11} = \frac{F_{OP}}{F_{OPlan}} \tag{11}$$

F_{OP} stands for actual overhauling costs, and F_{OPlan} represents the planned overhauling costs.

(12) Operation and maintenance costs per unit grid assets. I_{12} shows the present situation of operation and maintenance costs of distribution network. Its calculation method is shown in Formula (12).

$$I_{12} = \frac{F_{MAO}}{V_{FA_{ave}}} \tag{12}$$

F_{MAO} stands for the operation and maintenance costs of distribution network, and $V_{FA_{ave}}$ means the original value of fixed assets of the distribution network..

(13) Completion rate of power grid construction and renovation project investment plan. This index states the implementation situation of investment plans. Its calculation method is shown in Formula (13).

$$I_{13} = \frac{I_{FP}}{I_{Plan}} \tag{13}$$

I_{FP} stands for the amount of completed project investment within the plan, and I_{Plan} represents the amount of the annual investment plan.

3. Modeling of Improved Data Envelopment Analysis.

Data envelopment analysis is a nonparametric method that uses mathematical tools to evaluate the effectiveness of the production frontier of economic system and applies to the performance evaluation for multi-input, multi-output and multi-objective decision making units [25-27]. Based on relative efficiency, this method is used to evaluate the relative effectiveness of the same type of decision making units as per the value of multi-input indexes and multi-output indexes. The evaluation can be made from the point of view which is most conducive to the decision by using data envelopment analysis, but the calculation result objectivity of the data envelopment analysis will be affected accordingly due to defects in the weight calculation [28,29].

3.1. Initial modeling of data envelopment analysis.

In the data envelopment analysis, it is assumed that a total number of decision making units is t, each decision making unit has m input variables and n output variables, among which, x_{ik} stands for the input of decision making unit k to input variable i, y_{jk} is the output of k to output variable j. o_i means the weight of input variable i, q_j refers to the weight of output variable j, e is the investment efficiency necessary to be solved. Each decision making unit has its own efficiency index, as shown in Formulae (14) and (15).

$$e_k = \frac{q^T y_k}{o^T x_k} = \frac{\sum_{j=1}^{n} q_j y_{jk}}{\sum_{i=1}^{m} o_i x_{ik}}, \ k = 1, 2, \cdots, t \tag{14}$$

$$\text{s.t.} \begin{cases} \frac{q^T y_k}{o^T x_k} \leq 1, \ k = 1, 2, \cdots, t, \\ q \geq 0, o \geq 0, \ q \neq 0, \ o \neq 0. \end{cases} \tag{15}$$

Using Charnes-Cooper transformation, $v = \frac{1}{o^T x_0} > 0$, $\gamma = v \cdot o$, $\sigma = v \cdot q$, original problems can be converted into their equivalent linear programming problems, as shown in the following formulae.

$$\max e_{k_0} = \sigma^T y_0 \tag{16}$$

$$\text{s.t.} \begin{cases} \gamma^T x_k - \sigma^T y_k \geq 0, \ k = 1, 2, \cdots, t, \\ \gamma^T x_0 = 1, \\ \gamma \geq 0, \ \sigma \geq 0. \end{cases} \tag{17}$$

The above functions are turned into corresponding dual programming and slack variables are introduced as shown in the formulae below.

$$\min \varepsilon \tag{18}$$

$$\text{s.t.} \begin{cases} \sum\limits_{k=1}^{t} \lambda_k x_k + r^- = \varepsilon x_0 \\ \sum\limits_{k=1}^{t} \lambda_k y_k - r^+ = \varepsilon y_0 \\ r^-, r^+ \geq 0 \\ \lambda_k \geq 0, \ k = 1, \cdots, t \end{cases} \tag{19}$$

The linear planning model is solved and ε, the investment efficiency is obtained. When value ε taken is $0 \leq \varepsilon \leq 1$, the smaller value ε is, the lower investment efficiency is. At the same time, the higher value ε is, the higher investment efficiency is. When $\varepsilon = 1$, efficiency of investment reaches the maximum, which means the optimization of investment.

3.2. **Index standardization through the normalization method.** In order to eliminate the difference between different index dimensions, it is necessary to standardize the index values of evaluation objects. Different dimensional indexes are converted into standardized dimensionless indexes by appropriate transformation, which is called the standardization of indexes [30].

In this model, the relationship between indexes should be reflected, therefore the normalization method is the best practice to realize the index standardization. In the decision matrix $X = (x_{ij})_{m \times n}$, the number of decision indexes is n, meanwhile, the number of units to be evaluated is m. The standardization processes are shown in the formula below.

$$y_{ij} = \frac{x_{ij}}{\sum\limits_{i=1}^{m} x_{ij}} \quad (1 \leq i \leq m, 1 \leq j \leq n) \tag{20}$$

If $x_{ij} < 0$, index values can be converted to positive ones using $x'_{ij} = x_{ij} - \min\limits_{1 \leq i \leq m} x_{ij}$, and are standardized as per the following formula:

$$y_{ij} = \frac{x'_{ij}}{\sum\limits_{i=1}^{m} x'_{ij}} \quad (1 \leq i \leq m, 1 \leq j \leq n) \tag{21}$$

Matrix $Y = (y_{ij})_{m \times n}$ is the standardized matrix after normalization.

3.3. **Weight calculating through the entropy method.** The objectivity of these weights is affected because the evaluated decision making units obtain their weights respectively from the most favorable angle so that the characteristics of each decision making unit are lack of effective comparability [31]. Therefore, the entropy weight method is introduced in this paper to calculate the weight of each index.

In information theory, entropy is a way to measure the uncertainty of different indexes. The greater the uncertainty is, the smaller entropy is. According to the characteristics of entropy, the randomness and the disorder of an event can be judged by entropy method, this method can also be used to determine the discrete degree of a index, the greater the degree of discrete is, the greater the influence of the index of comprehensive evaluation is. Taking input variable as an example, its solving process is as follows.

(1) z_{ik} stands for the input amount of decision making unit k to input variable i, and the matrix of raw index data $Z = (z_{ik})_{m\times t}$ is formed.

(2) Calculate the specific gravity p_{ij} of index value of project j under index i, $p_{ij} = z_{ij} \Big/ \sum_{i=1}^{m} z_{ij}$.

(3) Calculate entropy c_i of index i, $c_i = -h \sum_{i=1}^{m} p_{ij} \cdot \ln p_{ij}$, hereinto $h = 1/\ln m$.

(4) Calculate entropy w_i of index i, $w_i = (1 - c_i) \Big/ \sum_{i=1}^{m} (1 - c_i)$.

4. **Analysis of Examples.**

4.1. **Raw data.**

In this paper, the investment data of distribution network is derived from two provinces in the north China during 2008-2012. All data were obtained through field data collection. The raw data from Province A and Province B are shown in Table 2 and Table 3.

TABLE 2. Data of investment (1)

Province	Year	I_1 (%)	I_2	I_3 (thousand kW·h/MVA)	I_4 (%)	I_5 (%)	I_6 (%)	I_7 (kW·h/RMB)
A	2008	3.2	2.1	1676.2	94.22	97.25	1.55	2.9
	2009	3.3	2.2	1314.9	96.36	98.12	3.39	1.0
	2010	3.3	2.4	1892.6	98.69	97.55	2.80	6.3
	2011	3.4	2.8	1791.5	97.62	96.28	1.06	7.1
	2012	3.3	2.5	1264.6	91.93	98.36	3.48	2.7
B	2008	3.5	2.9	1762.7	87.36	95.39	1.59	2.1
	2009	3.7	2.6	1056.2	81.52	94.58	5.21	4.3
	2010	3.4	2.6	1343.7	79.15	96.02	4.67	5.7
	2011	3.6	2.3	978.0	76.22	94.30	3.02	0.7
	2012	3.5	2.0	1440.8	82.63	95.55	2.20	3.1

TABLE 3. Data of investment (2)

Province	Year	I_8	I_9 (thousand kW·h/MVA)	I_{10} (%)	I_{11} (%)	I_{12}	I_{13} (%)
A	2008	1.57	3416.0	100.00	100.00	0.23	98.36
	2009	1.60	2613.8	100.00	100.00	0.79	99.21
	2010	0.67	3567.9	100.00	100.00	0.52	100
	2011	0.79	2386.4	98.52	100.00	0.46	97.55
	2012	0.92	1639.1	89.33	100.00	0.36	98.23
B	2008	1.05	1344.7	89.93	99.32	0.30	100
	2009	1.26	2503.3	96.63	99.69	0.49	99.23
	2010	0.97	1245.8	98.83	97.86	0.39	100
	2011	0.37	−569.3	87.01	95.02	0.38	95.26
	2012	0.96	1982.0	100.00	100.00	0.36	100

TABLE 4. The result of data envelopment analysis

Province	Year	Investment Efficiency
A	2008	0.8557
	2009	0.9705
	2010	0.9211
	2011	0.9543
	2012	0.9783
B	2008	0.8783
	2009	0.8830
	2010	0.7996
	2011	0.8648
	2012	0.8234

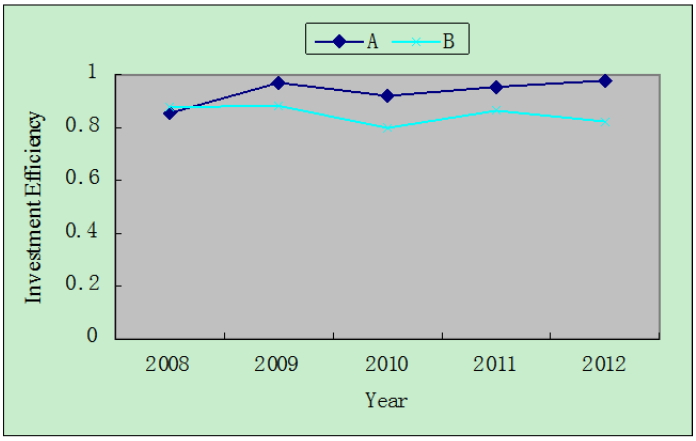

FIGURE 1. The trends of investment efficiency for distribution network from A and B

4.2. **Calculated results of initial model of data envelopment analysis.** According to the above modeling, data from Table 2 and Table 3 are taken in the model, and through the optimization calculation, results are shown in Table 4.

Besides, the trends of investment efficiency are illustrated in Figure 1.

From the results, an investment efficiency gap between two cities was not large but it could be seen that the investment efficiency of the distribution network in Province B was not high and its level of investment efficiency was under Province A for a long time while the efficiency of investment in the two provinces reached the highest in 2009.

As we can see in Table 2 and Table 3, it was necessary to compare the data of Province B in 2011 with the data of Province B in other years. It can be seen from the raw data table that compared the data of Province B in 2011 with those in other years, investment efficiency was not obviously high. However, after a model calculation, the investment efficiency of Province B in 2011 still remained in a uniform level with those in other years, which was caused by the subjectivity of the weight calculated with the data envelopment analysis, hence, there were deviations in calculation results. Below were calculations with the improved data envelopment analysis.

4.3. **Results of the improved data envelopment analysis.** First, index values are standardized and shown in Table 5 and Table 6 after standardization (there may be errors due to rounding).

Table 5. Data after standardization (1)

Province	Year	I_1 (%)	I_2	I_3 (thousand kW·h/MVA)	I_4 (%)	I_5 (%)	I_6 (%)	I_7 (kW·h/RMB)
A	2008	0.094	0.086	0.115	0.106	0.101	0.054	0.081
	2009	0.096	0.090	0.091	0.109	0.102	0.117	0.028
	2010	0.096	0.098	0.130	0.111	0.101	0.097	0.175
	2011	0.099	0.115	0.123	0.110	0.100	0.037	0.198
	2012	0.096	0.102	0.087	0.104	0.102	0.120	0.075
B	2008	0.102	0.119	0.121	0.099	0.099	0.055	0.058
	2009	0.108	0.107	0.073	0.092	0.098	0.180	0.120
	2010	0.099	0.107	0.093	0.089	0.100	0.161	0.159
	2011	0.105	0.094	0.067	0.086	0.098	0.104	0.019
	2012	0.102	0.082	0.099	0.093	0.099	0.076	0.086

Table 6. Data after standardization (2)

Province	Year	I_8	I_9 (thousand kW·h/MVA)	I_{10} (%)	I_{11} (%)	I_{12}	I_{13} (%)
A	2008	0.155	0.154	0.104	0.101	0.054	0.100
	2009	0.157	0.123	0.104	0.101	0.185	0.100
	2010	0.066	0.160	0.104	0.101	0.121	0.101
	2011	0.078	0.114	0.103	0.101	0.107	0.099
	2012	0.091	0.086	0.093	0.101	0.084	0.099
B	2008	0.103	0.074	0.094	0.100	0.070	0.101
	2009	0.124	0.119	0.101	0.101	0.114	0.100
	2010	0.095	0.070	0.103	0.099	0.091	0.101
	2011	0.036	0.000	0.091	0.096	0.089	0.096
	2012	0.094	0.099	0.104	0.101	0.084	0.101

Table 7. The weight of indicators

The code of indicators	Indicators	Weight
I_1	Line loss rate	0.0914
I_2	Capacity-load ratio	0.1369
I_3	Power supply per substation capacity	0.0794
I_4	The rate of line utilization	0.0669
I_5	Load forecasting accuracy	0.0806
I_6	Sales forecast deviation	0.0489
I_7	The growth of power supply from investment	0.1022
I_8	Contribution gross profit of new fixed assets	0.0824
I_9	The growth of power supply per the growth of substation capacity	0.0526
I_{10}	Completion rate of productive maintenance costs	0.0865
I_{11}	Control rate of the cost for heavy repair	0.0384
I_{12}	Operation and maintenance costs of grid asset	0.0685
I_{13}	Completion rate of investment plans for power grid construction and renovation project	0.0653
The sum of the weights		1

Second, the weight is calculated using the entropy method. According to the calculation process of the entropy weight method, the weight of each index is determined and shown in Table 7.

(1) Calculated results of Province A. Investment efficiency of the distribution network of Province A calculated with the improved data envelopment analysis is shown in Table 8 and Figure 2.

TABLE 8. The result of improved data envelopment analysis (Province A)

Year	Before Improvement	After Improvement
2008	0.8557	0.9102
2009	0.9705	0.9603
2010	0.9211	0.9191
2011	0.9543	0.9392
2012	0.9783	0.9801

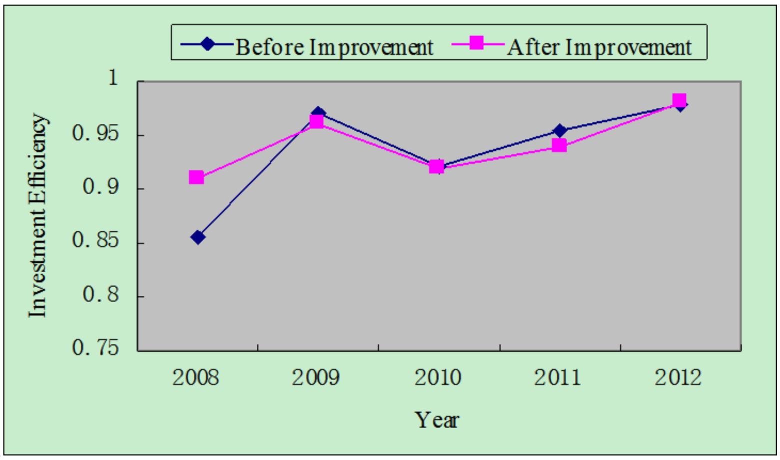

FIGURE 2. The trends of investment efficiency in Province A (make a comparison between models improved before and after)

TABLE 9. The result of improved data envelopment analysis (Province B)

Year	Before Improvement	After Improvement
2008	0.8783	0.8821
2009	0.8830	0.8792
2010	0.8696	0.8531
2011	0.8648	0.7728
2012	0.8534	0.8437

It can be seen from Table 6 and Figure 2 that a result gap calculated with models improved before and after is not large, which has further proved that the improvement of the model does not affect the effectiveness of the model.

(2) Calculated result of Province B. The calculated result of Province B is demonstrated in Table 9 and Figure 3.

Based on calculated results, there is not a large gap between the result calculated with the improved model and that with the original model except 2011. It can be seen from the raw data that the investment efficiency is significantly low in 2011 in Province B

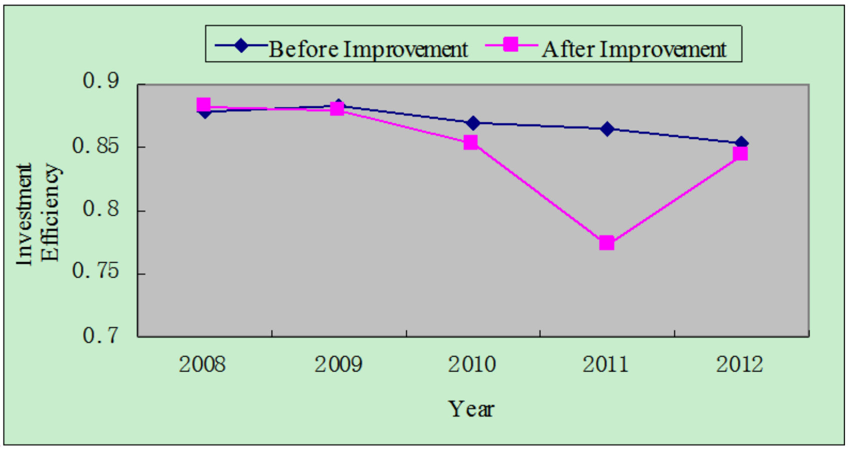

FIGURE 3. The trends of investment efficiency in Province B (before and after improvement)

and results calculated with the improved model conform to actual situations, which have proved that compared with the original model, calculations with the improved model are more accurate and reasonable.

4.4. **The analysis of the results.** As shown in the calculation results, the power network investment efficiency of Province B is lower. On the contrary, the power network investment efficiency of Province A is higher than that of province B for a long time. As we can see from the examples, the results of the improved model are more scientific. The reason for this improvement has the following three points:

(1) Scientific weight determination. Compared with the original model, the entropy method has been introduced to the establishment of the data envelopment analysis model, which has made the weight determination process more scientific. The scientific allocation of index weight can clear important degree of each index during the evaluation process. Besides, the combination of entropy method and data envelopment analysis will not affect the practicality of the model.

(2) Accurate index standardization. The normalization method has been introduced to standardize index value. According to the requirements of data envelopment analysis model as well as the characteristics of raw data, the relationship between the indexes should be reflected. Besides, normalization method will make the indexes more comparable between each other. Therefore, normalization method is the most suitable way to realize the accurate index standardization.

(3) Accurate raw data. The data of the examples in Table 2 and Table 3 were obtained through field data collection in Province A and Province B. Accurate results were derived from accurate data. Meanwhile, the accurate data has further proved the practice of the model.

5. **Conclusions.** Electricity demand increases gradually with the development of economic society. Therefore, it is of important significance that both the planning and investment of China's power grid construction are for the future development of the whole electric power industry. Based on the improved data envelopment analysis, the investment efficiency evaluation model of distribution network for power grid enterprises is designed in this paper and both the entropy method and the normalization method are introduced to the model building of data envelopment analysis to assign the weight and standardization to the indexes. The investment efficiency is evaluated by the input and output data for measuring the distribution network investment. Through example analysis, the results

evaluated with the model are accurate and objective, with certain practicality and can be used for the evaluation of investment efficiency of the distribution network for power grid enterprises.

With the continuous development of reform, Chinese electric power market and the electric power industry have gradually turned to the planning on both supply and demand sides from a single supply side in the past. Simultaneously, a large amount of renewable energy integration will affect the reliability and security of the power distribution network. Therefore, in future studies, we will continue to modify the existing model and consider the demand side management and renewable energy generation in the model building.

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