Decision Model Research on Engineering Project Arrangement of Power Grid Enterprise Group Based on Input and Output Efficiency Evaluation

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ABSTRACT: The engineering project arrangement of a large-scale Power Grid Enterprise Group confronts optimization problems on how to achieve efficient investment, how to achieve overall balance. This paper presents a general analytical framework, and establishes appropriate quantitative analysis models from the development of general control scale, input and output efficiency evaluation, index optimization of engineering project input of a single subsidiary, and balance optimization of engineering project arrangement of subordinate units of the Group, and so on. Simulated calculation examples show that this method is more practical, which can flexibly solve such problems.

Keywords: Power Grid Enterprise Group; engineering project arrangement; input and output; balance optimization

1 INTRODUCTION

How to scientifically arrange the engineering project by the Power Grid Enterprise Group has a significant impact on the implementation of enterprise strategy and development planning of Power Grid, overall planning and coordination of the development speed, quality and structure of subordinate units. Currently, the academic circle pays closer attention to the assessment of specific projects in the research of engineering project arrangement of Power Grid [1-4]. The engineering project arrangement and optimization at the level of the large-scale Power Grid Enterprise Group is the lack of systematic quantitative model method, with fewer practical application cases and limited lean level of management. For the large-scale Power Grid Enterprise Group, the Enterprise develops and invests a great number of engineering projects with greater funds every year, throughout the headquarters of the Group and all levels of grassroots units, involving in the balance and collaboration among subordinate units, and proposing relatively high requirements on the predictability, accuracy and overall plan of the management decisions. Broadly speaking, the scientific optimization of the engineering project arrangement is also a difficult issue commonly confronted by other large-scale enterprise groups. The approach and tool to develop the engineering project arrangement of the large-scale Power Grid Enterprise Group also have important theoretical and practical value.

Based on the arrangement and optimization problems on the engineering project of the large-scale Power Grid Enterprise Group, this paper will establish a systematic general analytical framework, and develop appropriate quantitative analysis models from the development of general control scale, input and output efficiency evaluation, index optimization of engineering project input of a single subsidiary, and balance optimization of engineering project arrangement of subordinate units of the Group, and so on, so as to provide an effective method to solve such problems.

2 ANALYTICAL FRAMEWORK

The Power Grid Enterprise Group scientifically determines which engineering project should be put into operation by subordinate units, mainly involving in the following issues: First, there is a need to ensure efficient implementation of the plan within the enterprise competence scope, to satisfy the most important needs by limited funds, and to scientifically and quantitatively determine the general control scale of engineering project input, which is the upper limit of a total amount of engineering projects putting into production by the subordinate units; Second, the limited funds shall be put into the optimal engineering project to achieve optimum input and output; Third, there is a need to strive to ease key index declining in the poor management and development units, and achieve balanced development of each unit. In general, it is to research and determine the optimal strategy for overall distribution of general control scale of engineering project among subordinate units.

For this reason, this paper establishes a general analytical framework shown in Figure 1, basically covering all key links in the plan arrangement of engineering projects of the Power Grid Enterprise Group. Wherein the decision model of general control model determines the upper limit of the investment of engi-
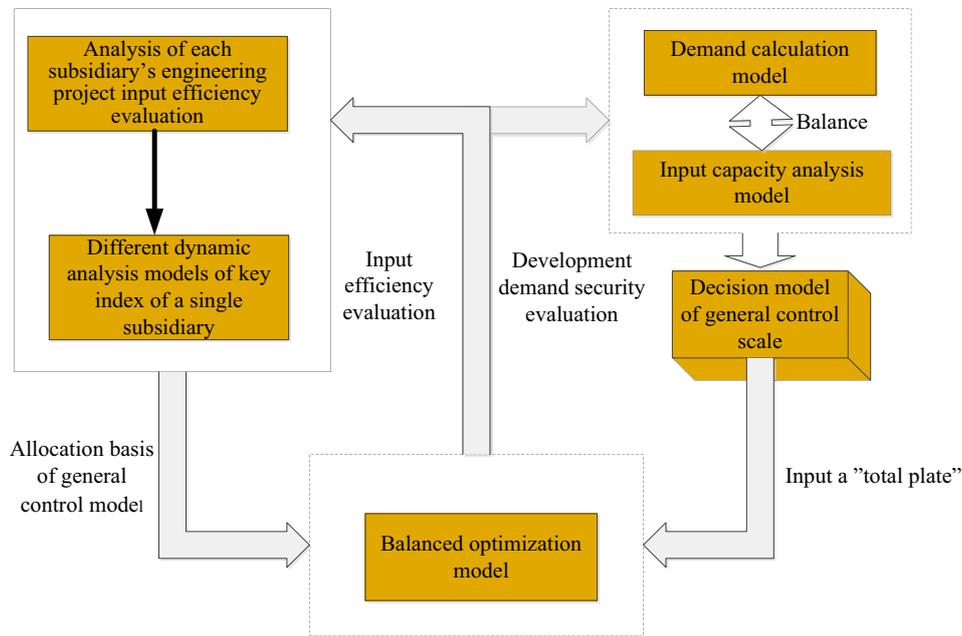
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Figure 1. Analytical framework of balanced optimization of engineering project arrangement of Power Grid Enterprise Group

neering projects by subordinate units, and explicitly states the size of a "total plate"; the subsidiary's input and output efficiency evaluation model will explicitly state an overall strategy for an overall judgment of the efficiency of engineering projects putting into operation by subordinate units, and further adjustment of input scale of subordinate units; different dynamic analysis models of the key index of a single subsidiary provide a method for analyzing relatively tight or loose strategy on the engineering project input by a specific subsidiary. The above three sub-models determine constraint conditions for balance optimization of the decision on engineering projects of the Group headquarters, and provide a more targeted basis for the overall optimization strategy.

3 MODEL

Four quantitative analysis models are successively constructed according to the analytical framework above in Figure 1.

3.1 *Dual-factor decision model of general control scale of engineering project construction input*

First, an annual input scale shall be scientifically judged from the level of Group. The so-called dual-factor decision model of general control scale refers to the realization of effective matching between the actual input of the enterprise and the construction development needs of the engineering project through

calculation of engineering construction input required by the achievement of development goals under consideration of the enterprise development and input capacity and other constraint conditions based on the external environment and strategic planning goals of the enterprise management and development.

(1) Calculation of infrastructure investment demand.

The infrastructure of Power Grid is affected by many factors, involving regional economic level, population, area, scale of Power Grid, electricity consumption level in the society and other types of indexes. The infrastructure demand of Power Grid can be basically reflected from the following three aspects: social economic level (population of power supply, GDP), scale of Power Grid (power transformation capacity of Power Grid under different voltage classes), and load power level (total electricity consumption, regional maximum load). The development trend of indexes can be predicted via the Grey Theory GM (1, 1) model and GM (1, N) model to obtain the development target value of indexes by the end of planning year; the relationship between the index and investment can be analyzed via Analytic Hierarchy Process (AHP) to obtain index influence coefficient; infrastructure investment calculation model of Power Grid is established based on both combination to obtain an infrastructure investment scale value of Power Grid that meeting the development needs of Power Grid in the planning year. The specific calculation model can refer to the Reference [5]. Combined with a
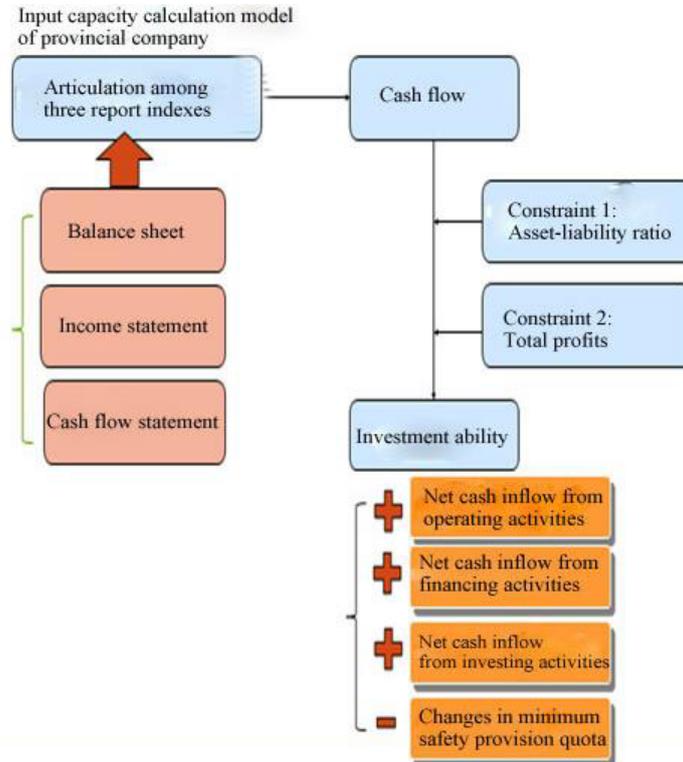
Figure 2. Input capacity calculation model of provincial company

key method of special structure analysis, a total demand on the infrastructure input of Power Grid can be calculated according to the proportion of infrastructure of Power Grid in the general control target by the use of historical data.

(2) Calculation of engineering construction input capacity.

The implementation of engineering construction plan needs to be safeguarded by the input capacity. The maximum limit of input capacity for integral development of the Group can be obtained through calculation of input capacities of each subsidiary. On the basis of a balance sheet, an income statement and a cash flow statement, the input capacity of subsidiaries constructs an input capacity calculation model shown in Figure 2 through articulation among three report indexes. Combined with development planning of a subsidiary, from the perspective of the cash flow of the subsidiary, according to historical financial data, with total profits and asset-liability ratio as boundary conditions, net cash flow from operating activities, net cash flow from investing activities, net cash flow from financing activities, and minimum safety provision quota can be measured to determine the maximum annual investment quota of provincial company.

(3) Calculation of general control scale.

The general control scale shall be adjusted in combination of development needs and input capacity. When the construction development need exceeds the input capacity, the input capacity is an upper limit to guarantee the general control scale, thus requiring to determining the general control scale based on the input capacity; when the development need is less than the input capacity, the need is guaranteed, thus developing a reference base of general control scale based on the development need.

3.2 *Subsidiary's engineering construction input and output efficiency evaluation model*

An index system covering the subsidiary's engineering construction development input and output efficiency can be constructed based on the viewpoint of input and output analysis. On this basis, the subsidiary's input and output efficiency can be calculated through key indexes selected from the index system by the further use of envelopment analysis model, and then the subsidiary's efficiency calculation value shall be classified and ranked. The data envelopment analysis model is a method to research efficiency evaluation of the "production department" with multiple inputs and multiple outputs, which can calculate and compare with the relative efficiency values of multiple decision-making units in given samples. On the whole, the data envelopment analysis is applicable for multiple inputs and multiple outputs, which can avoid human interference in setting up the index weight, and conduct comparison with various types of input and

output efficiency.

(1) Selection of input and output indexes.

The engineering project construction development input index aims at reflecting input conditions, while the output efficiency index is used to measure the output results, including not only electricity sales amount, total profit and other efficiency indexes, reliability of Power Grid and other safety indexes, but also including the indexed related to social responsibility. The following three indexes, that is, total investment in fixed assets, total investment proportion of infrastructure of Power Grid in the total investment of fixed assets, and total investment proportion of distribution network in the total investment of infrastructure of Power Grid, can be selected as input analysis indexes of the subsidiary's efficiency evaluation; the following two indexes, that is, the investment increased electricity sales amount of unit grid in recent three years and the property electricity sales amount of unit grid in 2014 can be selected as output analysis indexes of the subsidiary's efficiency evaluation.

(2) Evaluation model.

The input and output efficiency of 27 subsidiaries is analyzed by the use of data envelopment analysis C^2R model. Wherein, the decision-making units are 27 subsidiaries, and then n = 27; each subsidiary has m ($m = 3$) kinds of input (s) $x_j = (x_{1j}, x_{2j}, L, x_{mj})^T$ and s ($s = 3$) kinds of output (s) $y_j = (y_{1j}, y_{2j}, L, y_{sj})^T$, $j = 1, 2, L, n$:

$$\begin{cases} \max \dfrac{u^T y_0}{v^T x_0} \\ s.t. \dfrac{u^T y_j}{v^T x_j} \leq 1 \\ u \geq 0, v \geq 0 \end{cases} \quad (1)$$

Where $v = (v_1, v_2 ... v_m)^T$ and $u = (u_1, u_2, \cdots, u_s)^T$ respectively indicate the weight coefficient of m kinds of input (s) and s kinds of output (s). An equivalent linear programming model can be converted from the conversion of Charnes-Cooper via the formula (1):

$$\begin{cases} \min \theta \\ s.t. \sum_{j=1}^{n} x_j \lambda \leq \theta x_0 \\ \sum_{j=1}^{n} y_j \lambda_j \geq v_0 \\ \lambda_j \geq 0, j = 1, 2, \cdots n, \theta \in E_1^+ \end{cases} \quad (2)$$

After non Archimedes infinitesimal process, the model can be converted into:

$$\begin{cases} \min[\theta - \hat{e}^T S^- + \hat{e}^T S^+] \\ s.t. \sum_{j=1}^{n} x_j \lambda + S^- = \theta x_0 \\ \sum_{j=1}^{n} y_j \lambda_j - S^+ = y_0 \\ \lambda_j \geq 0, j = 1, 2, \cdots n, \theta \in E_1^+, S^- \geq 0 \end{cases} \quad (3)$$

Where, $\hat{e}^T = (1, 1, L, 1)^T$, if it meets $\theta_0 = 1$, $S^- = 0$, $S^+ = 0$, then the envelopment analysis of the decision-making unit is effective.

Assuming that the optimal solution of the model is θ^0, λ^0, S^{0-}, S^{0+}, if $\theta^0 = 1$, and $S^{0-} = 0$, $S^{0+} = 0$, then the envelopment analysis of input and output efficiency of the provincial company is effective; if $\theta^0 = 1$, and $S^{0-} \neq 0$, $S^{0+} \neq 0$, then the weak envelopment analysis is effective; if $\theta^0 < 1$, then the non-envelope analysis is effective.

3.3 Arrangement and optimization decision vector model of a single subsidiary's engineering project input

The model constructed in Section 3.2 is an overall principle with definite distribution of general control scale. On this basis, the current management situation can be further considered for the arrangement of the single subsidiary's engineering project input. Special focus shall be given to key variables that affect the specific input scale, such as the subsidiary's asset-liability ratio, total profit, depreciation rate and other indexes. For this reason, this paper constructs an optimization decision vector model of the subsidiary's development input with linkage analysis of key variables as a core, also constructs a typical situation of different dynamic articulations related to asset-liability ratio, total profit, depreciation rate and other key indexes, and proposes corresponding optimization strategies.

(1) Different dynamic analysis is carried out on the key variables that affect the scale of the subsidiary's engineering project construction input, to specify special subsidiaries required with special focus. The key variables that affect the scale of the subsidiary's project input mainly include asset-liability ratio, profit, electricity price, electricity sales amount, depreciation rate and other indexes. Wherein, the asset-liability ratio and profit target are the most critical indexes, the asset-liability ratio reflects the company's debt level, and the profit reflects the company's profit and loss situation, which are key indexes that directly affect the scale of project construction input in the next year. In addition, the electricity price, electricity sales amount, depreciation rate, controllable costs and other indexes also affect the scale of future development input of the provincial company.

(2) The decision vector matrix is established. The decision vector matrix is established based on the asset-liability ratio, profit, electricity price, property electricity sales amount of the unit, investment increased electricity sales amount of the unit, depreciation rate and other key indexes. Combined with three kinds of scenario assignments of each variable, each key variable is divided into different partitions (for example, the asset-liability ratio has three partitions: "low, medium, high"; the profit has three partitions: "accumulated losses, expectation to reverse losses, general level"); around the typical situation constructed based on the different dynamic articulations of key variables, an in-depth analysis is given to the provincial company, and the optimization strategy of the provincial Company's development input is proposed to form a decision vector matrix.

3.4 Balance optimization model of engineering project construction arrangement among subsidiaries

Many domestic scholars have researched the enterprise input problems by the use of data mining, multi-objective fuzzy evaluation and other methods [6-10]. The Paper [10] constructs a balance optimization model based on the comprehensive planning of dual-objective programming. The balance optimization model of engineering project construction arrangement among subsidiaries is constructed based on the Reference [10].

Where, assuming that the total investment scale of the Power Grid Enterprise Group in the next year is I, the funds are allocated to n subordinate units, and then the input of j (serial number) unit is expressed as X_j. According to the characteristics of the Power Grid Enterprise Group, there are two optimization goals. First, it's to achieve the maximization of enterprise profit of each subordinate unit under certain conditions. Assuming that the profit of each unit is a function of input, $f_j(X_j)$, then the company's total profit is $\sum_{j=1}^{n} f(X_j)$. Second, it's to achieve the maximization of asset scale of each subordinate unit under certain conditions. Therefore, the first objective function is:

$$\max \quad \sum_{j=1}^{n} f_j\left(X_j\right) \qquad (4)$$

The second objective function is:

$$\max \quad \sum_{i=1}^{n} x_j \qquad (5)$$

Constraint conditions are as follows:

Constraint 1: $\sum x_j \leq I$ indicates that the sum of cost input of all subordinate units should be less than or equal to the total cost input scale of the enterprise.

Constraint 2: $x_j \leq I_j, j = 1, 2 \ldots n$ indicates that the sum of special project input of all subordinate units should be less than the upper limit of the input of all units, I_j.

Constraint 3: $x_j = c_j, \quad 1 \leq j \leq n$ indicates that input amount of some special projects is a specified amount, which must be guaranteed beyond the adjustment range. For example: the public welfare input must be guaranteed.

In addition to common constraints above, the following constraint conditions are established based on the results of input and output efficiency evaluation model and decision vector model:

Constraint 4: $x_{j,t} \leq x_{j,t-1}$ indicates that the engineering project input in t year (s) shall be less than that of the previous year, in the event of the subsidiary with low input and output efficiency based on the input and output efficiency evaluation model, or strict control of the input based on the decision vector model.

Constraint 5: $x_{j,t} \geq x_{j,t-1}$ indicates that the engineering project input in t year (s) shall be more than that of the previous year, in the event of the subsidiary with high input and output efficiency based on the input and output efficiency evaluation model, or trend to input based on the decision vector model.

4 CALCULATION EXAMPLES

This paper adopts simulated calculation examples to research a certain Power Grid Enterprise Group, to represent the feasibility of related methods.

(1) A comprehensive evaluation is given to the infrastructure input and output efficiency of 27 subsidiaries from 2011 to 2013 by the use of Analytical Hierarchy Process (AHP), shown in Figure 3. Wherein, due to large development input and low output efficiency, six subsidiaries located in the fourth quadrant should become units controlled over by the Group construction project input and arrangement. Due to small development input and high output efficiency, seven subsidiaries located in the second quadrant should become units with increasing construction project input.

The input and output efficiency analysis of construction project and rank is given to 27 subsidiaries by the further use of envelopment analysis model. The result shows that the difference of input and output efficiency of 27 subsidiaries is relatively large. The former three companies with a maximum input and output efficiency are I, J and K, which are basically consistent with the conclusions of the Analytic Hierarchy Process (AHP).

(2) For the subsidiaries with special situations in indexes, the optimization strategies shall be further analyzed by the use of arrangement and optimization decision vector model of a single subsidiary's engi-
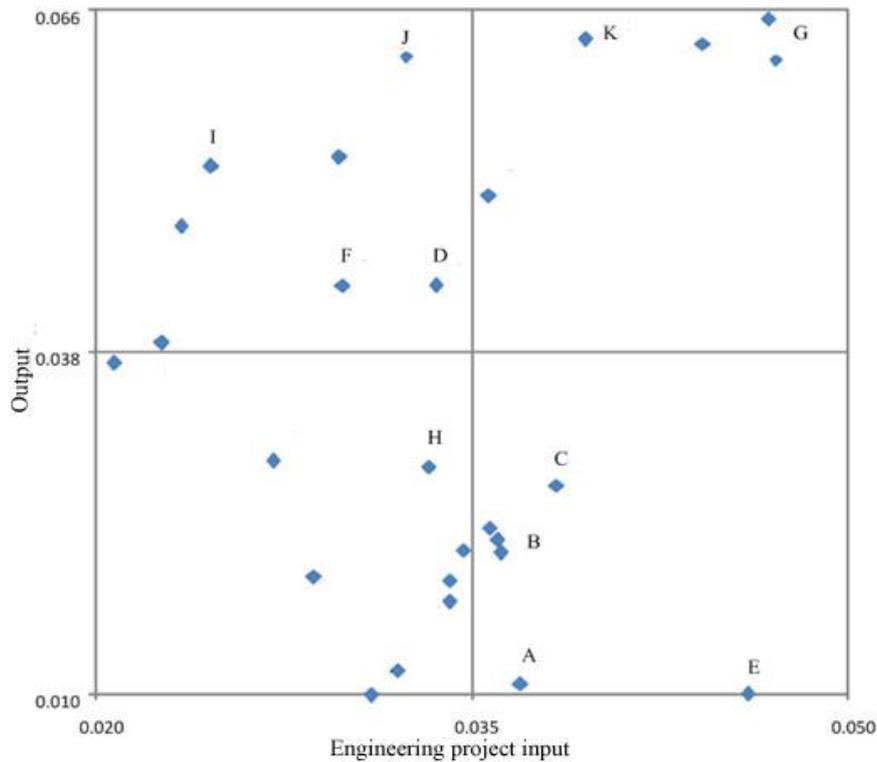
Figure 3. Classified evaluation of input and output efficiency of subsidiary's engineering project

neering project input.

First, for continual declining in the profit, asset-liability ratio, depreciation rate, electricity sales amount and other indexes of A company, there is a need to strictly control over the investment scale of the engineering construction.

Second, the assets-liability ratio of B and C companies is relatively high, the scale of losses is relatively large, and the electricity sales amount fails to cover costs, and the increment investment is relatively low for the border effect of electricity increase, so there is a need to strictly control over the scale of debt.

Third, D, E, F and G companies are provincial companies expected to eliminate the accumulated losses, and have been inclined to the development input in recent two years, to ensure the achievement of target to reverse losses.

Fourth, the profit level of H Company is general, increase in asset-liability ratio is relatively rapid, purchase and sales price difference is relatively low, and there is a space of investment increased electricity sales amount of unit, so it is proposed to control appropriate debt scale, and focus on guiding input and market development.

5 CONCLUSION

In summary, this paper gives a general analytical framework and establishes a series of quantitative analysis models for the research of decision optimization model of engineering project of the Power Grid Enterprise Group. During specific application, the adaptive adjustment shall be given to this set of methods by complete integration of input and output characteristics of the engineering project of the industry. In view of the complexity of the actual project arrangement, there is a need of overall plan, qualitative determination and quantitative analysis. Next, there is a need to fully consider relevant impact of the public welfare project input in the input and output efficiency evaluation model and other models, which is also a direction of further research.

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