

Optimal Procurement Strategy of Manufacturing Enterprises Based on Integer Programming

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Keywords: Evaluation Model, TOPSIS, Integer Planning, $GM(1, 1)$

Abstract: In order to avoid the problem of production interruption and high production cost, electric power enterprises generally customize the purchase plan of raw materials such as high-voltage bus in advance. Based on TOPSIS and combining the advantages of intelligent algorithm to find the overall optimal solution, supplier evaluation model and scheduling integer programming model are constructed.

1. Introduction

In recent years, my country has put forward the strategic goal of "reaching the peak of carbon emissions by 2030 and achieving carbon neutrality by 2060", which has increased the demand for environmentally friendly materials and green energy. Therefore, power companies can only optimize internal structure and business strategies first. In order to avoid being eliminated by the market. If power companies want to enhance their competitiveness, the optimization strategy of raw material procurement is an indispensable part.

Due to the large variety of raw materials, the large quantity and the large number of suppliers, and the need to fully consider various influencing factors such as supply cycle, supplier category, inventory restriction, transportation restriction, etc., current research focuses on the evaluation of individual modules, and lacks of power companies Systematic model of raw material supplier selection and procurement ratio. Therefore, as a power company involved in the national economy and people's livelihood, it is of great practical significance to construct a scientific and reasonable raw material procurement model.

Theoretical significance: to innovate evaluation indicators, establish a supplier importance evaluation model, conduct a comprehensive evaluation of each supplier, and accurately determine the optimal supplier selection plan under different demand focus situations.

Practical significance: In view of the high inventory costs of centralized procurement of power grids, the difficulty of quantitative control of transportation losses, the dispersion of suppliers, and the difficulty of establishing long-term cooperative relations among power grids, suppliers, and transporters, establish a comprehensive decision that takes into account the interests of the three parties. Model to determine the optimal procurement plan for the power grid under a variety of changing factors.

At present, the evaluation and selection of raw material suppliers of power enterprises at home and abroad. Jade Hsu [1] put forward a formal dynamic procurement model of power materials, and considered the mutual influence between indicators, making the comprehensive evaluation of power material suppliers more objective and accurate. Zhao Huifang [2]. Established the evaluation index system of EPC. Huang Yixiang [3] selected the top several suppliers as potential suppliers to predict their delivery quality qualified rate, and divided the bidding share accordingly. Zheng Yuxia [4]. Introduced a non-parametric method like data envelope analysis to enhance the objectivity of evaluation, and used the virtual optimal decision unit to further improve the deficiencies of multiple effective decision-making units. Zhou Pengcheng, Wu Nannan and Zeng Ming [5] refined the previous

evaluation model, considering the factors and constraints affecting the supplier selection. Sun Jianxin [6]. Pointed out the importance of centralized procurement in ensuring the long-term supply and service of power plants, and gave specific and feasible procurement attention points, which can be used as the practical basis of the model.

In addition, some papers have studied the selection method of the substation high-voltage bus and the optimization method, which is of great significance to reduce the power enterprises' procurement cost. The paper [7-10] discussed the method of selecting the bus, and the application of fully insulated bus in the power system, to provide theory and certain data support for model construction. Based on this, many scholars have further studied the optimized application of buslines. The paper[11-12] introduced more practical influencing factors, proposed to reduce the demand of bus in electric power enterprises from various aspects such as type selection and performance index, optimized the allocation of resources, and provided theoretical and data support for the procurement model of this paper. Paper [13] tested the causes of the common bus faults, and gave the corresponding processing methods, which was conducive to the generalization of the model in reality.

However, the above documents are all the selection of suppliers, do not involve the formulation of subsequent ordering plans, and the multi-target and multiple impact factors of power enterprises in the procurement are not fully considered. Tao Yun [14] studied the process of using the TOPSIS method to sort and optimize the evaluation results, which can be used in the selection of suppliers in the supply chain. Xu Chang [15] applied gray prediction and 0-1 planning to the practical problems of reasonably achieving the goals under the premise of trying to save costs as far as possible. Li Junmin [16] conducted optimization research on the algorithm for solving optimization problems to improve the speed of the solution. On the basis of the traditional TOPSIS method. Zhou ya [17] promoted it separately for attribute types and attribute value types, so that it can be used to deal with more complex multi-attribute decision-making problems including various attribute types and attribute value types, and applied to the TOPSIS model. The advantages and disadvantages of different optimized models were deeply considered in the paper [18-20] to discuss effective ways to reduce the prediction error of grey prediction models.

Based on this, this paper studies the selection of suppliers of the three types of high-voltage busbars for power enterprises in the supply chain environment, establishes a comprehensive evaluation index system that affects the selection of suppliers, uses entropy weight method to determine the weight of each indicator, and uses TOPSIS method to comprehensively integrate suppliers Selection, combined with integer linear programming and other methods to establish a raw material procurement strategy model.

2. Supplier Importance Evaluation Model

In this section, the gray forecast model is used to construct the ranking percentile index for forecasting supply, and then common indexes such as order completion rate, supply accuracy rate, and out-of-stock probability are combined to construct a supplier importance evaluation model. In order to simplify the description, the rectangular, tubular, and trough-shaped high-voltage busbars are set as A, B, and C types of raw materials, respectively.

2.1 Index Construction Model for Predicting the Percentile of Supply Volume

For each supplier, take 24 weeks as a cycle, and sum up the supply in these 24 weeks as $y^{(0)}(j)$, j takes 1, 2 ... 10 to represent the first 24 weeks, the second 24 weeks ... the 10th 24 weeks, respectively. In the same way, sum up the demand for raw materials, and by electric power companies in 24 weeks as $y'^{(0)}(j)$, since the forecasting methods are exactly the same, only the forecast of supply is taken as an example, and the forecast of demand will not be repeated.

Use the $GM(1, 1)$ Use the x model to predict and establish the first-order linear differential equation about $y^{(1)}(i)$.

$$\frac{dy^{(1)}}{dt} + ay^{(1)} = u \quad (1)$$

Among them, a is called the developing coefficient, u is called the grey effect, a and u is in a finite interval. $a \in (-2, 2)$. Write the above differential equations in matrix form as follows.

$$\hat{a} = \begin{pmatrix} a \\ u \end{pmatrix} \quad (2)$$

Data matrix A and data vector X_n can be received.

Then use the least square method to solve the parameters of the differential equation

$$\hat{a} = \begin{pmatrix} a \\ u \end{pmatrix} = (A^{(T)}A)^{-1}A^T X_n \quad (3)$$

The gray prediction model of the original series is

$$\hat{y}^{(0)}(t+1) = (1 - e^a) \left(\hat{y}^{(0)}(1) - \frac{u}{a} \right) e^{-at} \quad (t=0, 1, 2, \dots) \quad (4)$$

The comparison between the gray prediction results and the true value is as follows.

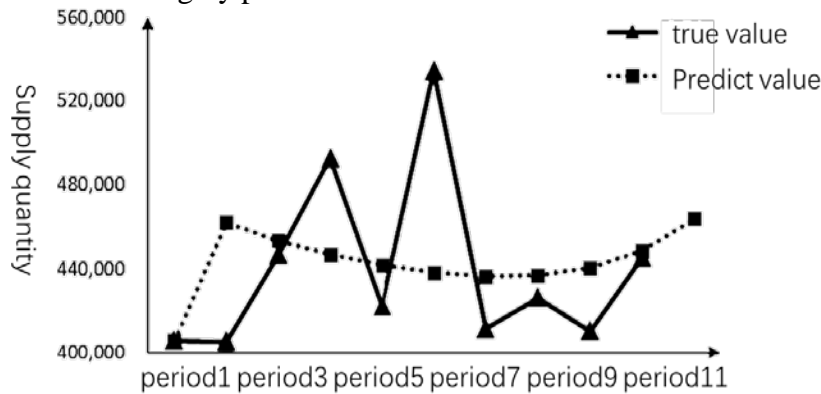


Figure 1. Grey prediction results.

Finally, define the ranking percentile index of the forecasted supply. The calculation method is to sort the 402 forecasted supplies. The first place is expressed as 100%, the second place is expressed as 401/402, and so on.

2.2 Supplier Comprehensive Evaluation Model

First, we need to extract four indicators from the collected data to characterize the importance of suppliers to the production and operation of power companies. The first indicator is order fulfillment $C(w)$, That is, the total supply volume of the w th supplier in 240 weeks is more than the total order volume; The second indicator is the accuracy of supply $D(w)$, The second indicator is the accuracy of supply, that is, the probability of the w th supplier $\frac{|supply - order|}{order} < g$ in 240 weeks, By looking up relevant literature, it can be determined that the allowable supply deviation for the normal production of the power company is $\pm 20\%$, So define the threshold here g within $\pm 20\%$; The third indicator is the probability of continuous goods $E(w)$, That is, the probability that the supply of the w -th is not 0 within 240 weeks; the fourth indicator is the ranking percentile $F(w)$ of the predicted supply constructed in the previous part.

From the above, the evaluation matrix is composed of scoring the four indicators

$$H = [C D E F] = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ \vdots & \vdots & \vdots & \vdots \\ h_{402,1} & h_{402,2} & h_{402,3} & h_{402,4} \end{bmatrix} \quad (5)$$

Standardize each score, i.e.

$$Z_{ij} = \frac{h_{ij}}{\sqrt{\sum_{i=1}^{402} h_{ij}^2}} \quad (i = 1, 2, 3, \dots, 402 \quad j = 1, 2, 3, 4) \quad (6)$$

Get the normalized matrix Z . The optimal solution matrix and the worst solution matrix at this time are as follows

$$Z^+ = [z_1^+, z_2^+, z_3^+, z_4^+] \quad z_j^+ = \max\{z_{ij}\} \quad i = 1, 2, \dots, 402 \quad (7)$$

$$Z^- = [z_1^-, z_2^-, z_3^-, z_4^-] \quad z_j^- = \min\{z_{ij}\} \quad i = 1, 2, \dots, 402 \quad (8)$$

For Z , suppose u_j as the weight of each indicator j . For i -th plan z_i , Define The distance between it and the optimal solution is $v_i^+ = \sqrt{\sum_{j=1}^4 u_j (z_j^+ - z_{ij})^2}$, The distance between it and the worst solution is

$$v_i^- = \sqrt{\sum_{j=1}^4 u_j (z_j^- - z_{ij})^2}.$$

For normalization matrix Z we build a probability matrix M

$$M = \begin{bmatrix} m_{1,1} & m_{1,2} & m_{1,3} & m_{1,4} \\ m_{2,1} & m_{2,2} & m_{2,3} & m_{2,4} \\ \vdots & \vdots & \vdots & \vdots \\ m_{402,1} & m_{402,2} & m_{402,3} & m_{402,4} \end{bmatrix} \quad (9)$$

Among that

$$m_{ij} = \frac{z_{ij}}{\sum_{i=1}^{402} z_{ij}} \quad (i = 1, 2, 3, \dots, 402 \quad j = 1, 2, 3, 4) \quad (10)$$

Therefore, the standard information entropy is.

$$l_j = -\frac{1}{\ln(402)} \sum_{i=1}^{402} [m_{ij} I(m_{ij})] \quad (j = 1, 2, 3, 4) \quad (11)$$

Under the framework of entropy method, the larger the standard information entropy, the less the amount of existing information, and the information utility value is defined as $r_j = 1 - l_j$, the greater the value of information utility, the more the amount of information available, so the entropy weight

is defined $u_j = \frac{r_j}{\sum_{j=1}^4 r_j}$ ($j = 1, 2, 3, 4$), corresponding to the weights of the four indicators, the available weights of stability, accuracy, out-of-stock probability, and future satisfaction indicators are respectively.

Table 1. Weight Table.

metric 1	metric 2	metric 3	metric 4
0.2828	0.16933	0.39874	0.14912

Finally, according to the analysis of the comprehensive distance in TOPSIS, the smaller the distance from the optimal solution, the higher the overall score, so the score of the definition scheme is

$$S_i = \frac{v_i^-}{v_i^+ + v_i^-} \quad (12)$$

From the above, the scores of each evaluation object for the four indicators are:

$$G(i) = (S_{i1}, S_{i2}, S_{i3}, S_{i4}), \quad (i = 1, 2, 3, \dots, 402) \quad (13)$$

3. Optimal ordering plan model

In actual production, in addition to the selection of suppliers, the number and batch of orders from each supplier, and the selection of the corresponding transshipment provider are all critical to reducing the operating costs of the enterprise. In this section, based on the optimal ratio of A, B, and C raw material supply that meets the power company's 24-week production plan in the previous section, the power company's 24-week ordering plan and transportation plan are formulated.

3.1 Order plan

According to the forecast value of supply in the next 24 weeks, define the "supply capacity" of each supplier. According to the required 24-week total output of A, B, C materials, select from the highest "supply capacity" sequentially downward, until the supply of raw materials meets the needs of 24-week production. By calculation, at least 27 suppliers are needed.

From the above, suppose the auxiliary matrix. $E_A = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}_{1 \times 13}$. $E_B = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}_{1 \times 7}$. $E_C = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}_{1 \times 7}$ With 24

weeks as a cycle, each week as a time node, for each supplier, whether to order from that supplier, establish an "order matrix". Since the same product is produced, if raw materials A are used, which tends to use more, if C, which tends to use less. Therefore, for 13 production suppliers of A, 7 production suppliers of B, and 7 production suppliers of C, an "order matrix" should be constructed respectively.

$$T_A = \begin{bmatrix} t_{A1,1} & t_{A1,2} & \cdots & t_{A1,24} \\ t_{A2,1} & t_{A2,2} & \cdots & t_{A2,24} \\ \vdots & \vdots & & \vdots \\ t_{A13,1} & t_{A13,2} & \cdots & t_{A13,24} \end{bmatrix} \quad (t_{Aij} = 0, 1) \quad (14)$$

For T_B, T_C the process is similar. The values of the variables of the matrix are all between (0, 1). A value of 0 means no order from this supplier in this week, and a value of 1 means order from this supplier in this week. This problem is transformed into an integer programming problem. Thus, the objective function and conditional matrix of the variable matrix can be constructed.

The definition of "supplier's comprehensive supply" is used to characterize the number of suppliers that can meet the production, and the supply forecast value is used as the embodiment of each supplier's supply capacity. Constructing a "supplier comprehensive supply" matrix, then for the three types of merchants producing A, B, C there are supply capacity of each supplier, the same as the previous screening of the minimum nu

$$S_A = \begin{bmatrix} S_{A,1} \\ S_{A,2} \\ \vdots \\ S_{A,13} \end{bmatrix} S_B = \begin{bmatrix} S_{B,1} \\ S_{B,2} \\ \vdots \\ S_{B,7} \end{bmatrix} S_C = \begin{bmatrix} S_{C,1} \\ S_{C,2} \\ \vdots \\ S_{C,7} \end{bmatrix} \quad (15)$$

Therefore, it is possible to obtain a fixed weekly output, that is, a constant income, and the "most economical" is the ordering plan with the least cost. And because the order quantity of A 、 B 、 C is uncertain, assuming that there is an inventory that can meet the production of two weeks at the beginning, the consumption amount every week afterwards is equal to the purchase amount, that is, the inventory cost is a certain value. Therefore, only considering the minimum total purchase price including the three raw materials, the cost objective function is obtained as follows

$$\begin{aligned} \min COST = & (\alpha + \eta)S_A^T \cdot T_A \cdot E_A + (\beta + \eta)S_B^T \cdot T_B \cdot E_B \\ & + (\gamma + \eta)S_C^T \cdot T_C \cdot E_C + 24S_{keep} \end{aligned} \quad (16)$$

α 、 β 、 γ Represent respectively the unit price A 、 B 、 C , among that $\begin{cases} \alpha = 1.2\gamma \\ \beta = 1.1\gamma \end{cases}$ represents the

proportional relationship between unit price and freight, by searching for information, get $\eta = 0.25\gamma$; S_{keep} refers to the storage cost of the raw material inventory that meets the production demand for two weeks.

Construct a conditional matrix about the variable matrix, since the total amount of products produced by raw materials A , raw materials B , and raw materials C is equal to the weekly output, so

$$\frac{1}{0.6}S_A^T T_A + \frac{1}{0.66}S_B^T T_B + \frac{1}{0.72}S_C^T T_C = NUM \quad (17)$$

NUM is a row vector, and meets condition that $num_j \geq 2.82 \times 10^4 (j = 1, 2, \dots, 24)$. The above solution obtains whether to supply to a certain supplier at the time node of each week, so it is also necessary to construct the "actual order quantity matrix", expressed as T' , each value in the matrix should be the amount of raw materials that each supplier can actually provide at the time of each week, recorded as the "actual supply capacity", and the calculation method is the order completion calculated by the first question multiplied by the first The "comprehensive supply capacity" in the second question.

First construct the reciprocal matrix TR_A 、 TR_B 、 TR_C corresponding to the order completion degree, take TR_A as an example, that is

$$TR_A = \begin{bmatrix} tr_{A,1} \\ tr_{A,2} \\ \vdots \\ tr_{A,n} \end{bmatrix} \quad (18)$$

Among that $tr_{A,i}$ represents the reciprocal of the order completion rate of the i -th vendor among the suppliers that produce A material within five years.

$$tr_{A,i} \cdot row(T)_i = row(T')_i \quad (i = 1, 2, \dots, 24) \quad (19)$$

In the same way, express B 、 C so that the "actual order quantity matrix" can be solved, and then combined with the "order matrix", the final optimal order plan can be determined.

3.2 Transit plan

On the basis of solving the optimal ordering plan, formulating the transfer plan with the least loss in the next 24 weeks, mainly using the idea of dynamic programming, taking the case of A as the raw material as an example:

First find out the expectation of the loss rate of 8 forwarders, and construct the expectation matrix $E(DEL)$ Reorder them (from top to bottom from small to large), get $E'(DEL)$

$$E(DEL) = \begin{bmatrix} DEL(1) \\ DEL(2) \\ \vdots \\ DEL(8) \end{bmatrix} \quad E'(DEL) = \begin{bmatrix} DEL'(1) \\ DEL'(2) \\ \vdots \\ DEL'(8) \end{bmatrix} \quad (20)$$

Reorder them (from top to bottom from small to large), get

Reorder them (from small to large from top to bottom), extract each column vector of T_A to get $T_{A_j} (j = 1, 2, \dots, 24)$ and build a new matrix $S_{A_j} (j = 1, 2, \dots, 24)$

S_{A_j} is a dynamically changing matrix. S_A Changes from the value of each element of T_{A_j} , that is, when the corresponding element in T_{A_j} is 1, the element in S_{A_j} remains unchanged, and when the element in T_{A_j} is 0, the element in S_A becomes 0. S_{B_j} , S_{C_j} Can be obtained by taking this as an example.

Construct the most economical supply data matrix

$$S_{ABC_j} = [S_{A_j}^T \quad S_{B_j}^T \quad S_{C_j}^T] \quad (j = 1, 2, \dots, 24) \quad (21)$$

The elements in S_{ABC} can be combined freely, but the following restrictions must be met.

Define $sum_{k,j}$ as the sum of the k -th free combination on the j -th day, and construct a "sum order" matrix

$$BS = \begin{bmatrix} BS_1 \\ BS_2 \\ \vdots \\ BS_8 \end{bmatrix} \quad (22)$$

The BS matrix can be entered when the following constraints are met in $sum_{k,j}$. The consideration process of the constraints is shown in the figure below

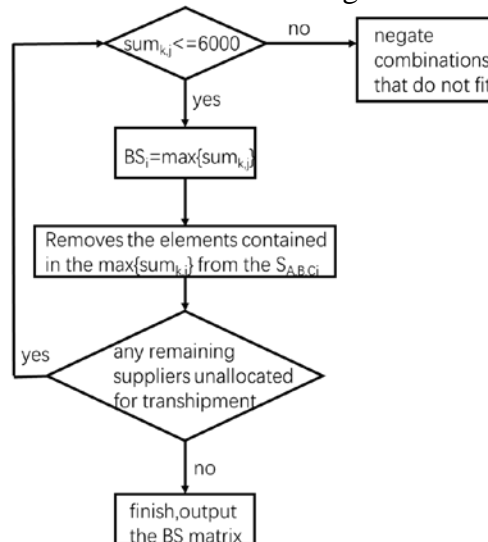


Figure 2. Condition flow chart.

Sort the combined sum from largest to smallest, and assign it to the corresponding transshipment company in $E'(DEL)$, which is the optimal transshipment plan for Class A raw materials in week j .

Under the condition that the minimum number of suppliers that can meet the production has been selected, the following initial constraints are considered: the supply can meet the weekly production; the unit material cost is the lowest; the maximum transportation capacity of each forwarder is 6000 cubic meters $M/week$, that is, the weekly supply of each supplier is not more than 6000 cubic meters/week.

3.3 Model solving

To solve the "order matrix", the progressive algorithm is mainly used. The algorithm as a whole uses the idea of decision tree optimization. The root node is the most initial constraint. Then, the order plan for each week is based on the least cost and meets the production requirements. An optimal target attribute judgment label. The label value is only 0, 1. When the label value is 0, it means that the path is blocked, and the path is excluded. When it is 1, it means that the path can continue to be optimized, but the decision should be considered for the next week the influence of the attribute judgment of the ordering plan. That is, the optimal "order matrix" T_1 for the first week is solved under the given conditions, so that the $COST(week_1)$ is minimized, and the production demand is satisfied, and then it is used as the known condition for solving the next local optimum, and then proceed until the calculation The last local optimal solution, because T_1, T_2, \dots, T_{n-1} are optimal, this local optimal solution can be approximated as a global optimal solution.

4. Case analysis

4.1 Example structure

The calculation example in this paper adopts a power company's order plan and transportation plan for the next 24 weeks based on its phased production goals. The phased goal of the power company is to purchase as many Class A high-voltage wires as possible and as little as possible to purchase Class C high-voltage wires to reduce the cost of transshipment and storage. At the same time, it is hoped that the transshipment company's transshipment loss rate will be as small as possible. According to this, the optimal ordering plan and the optimal transshipment plan of the electric power enterprise are obtained.

4.2 Calculation example results

Through calculation, it can be known that the purchase price of A, C , that is, the unit price multiplied by the consumption, is 0.72γ to produce the same amount of electricity. Therefore, the difference in the ratio of ordering A, C will only affect the transportation cost and storage cost. Obviously, the transportation cost and storage cost of choosing A to produce are lower, so it is necessary to determine how to choose how much A is the best, establish a pairwise comparison evaluation model, and compare the cost of the order plan solved under the new restriction conditions. Cyclic comparison, and finally get the optimal ratio of ordering A, B, C under the condition of as many A as possible.

First, a feasible solution to the ordering plan needs to be required. In this section, it is necessary to determine the scoring value of each supplier based on the supplier importance evaluation model, cut out 108 more important suppliers that can meet production, and update the "supplier comprehensive supply" matrix.

$$S'_A = \begin{bmatrix} S'_{A,1} \\ S'_{A,2} \\ \vdots \\ S'_{A,\pi_A} \end{bmatrix} \quad (23)$$

For S'_{A,π_A} , S'_{B,π_B} , S'_{C,π_C} we need to determine the amount of A and C under the condition that A is as much as possible and C is as little as possible.

The auxiliary matrix E'_A , E'_B , E'_C is also updated, taking A as an example

$$E'_A = [1 \ 1 \ 1 \ , \ \dots \ 1]_{1 \times \pi_B} \quad (24)$$

Update the "Order Matrix" accordingly

$$T'_A = \begin{bmatrix} t'_{A1,1} & t'_{A1,2} & \dots & t'_{A1,24} \\ t'_{A2,1} & t'_{A2,2} & \dots & t'_{A2,24} \\ \vdots & \vdots & & \vdots \\ t'_{A\pi_A,1} & t'_{A\pi_A,2} & \dots & t'_{A\pi_A,24} \end{bmatrix} \quad (25)$$

T'_B , T'_C Update at the same time.

Similarly update the objective function

$$\begin{aligned} \min COST' &= (\alpha + 2\eta) S'^{T'}_A \cdot T'_A \cdot E'_A + (\beta + 2\eta) S'^{T'}_B \cdot T'_B \cdot E'_B \\ &+ (\gamma + 2\eta) S'^{T'}_C \cdot T'_C \cdot E'_C + 24S_{keep} \end{aligned} \quad (26)$$

Use progressive algorithm to solve the appropriate ratio of A , B , C . Set the minimum cost goal $COST$, update the priority of the restriction conditions in the optimal ordering plan model, give priority to incorporating more A suppliers into the ordering strategy, and then use B , C to supplement A 's unsatisfied raw material demand for the corresponding capacity. The "more" is defined by a pairwise evaluation model, that is, a cyclic comparison algorithm is set up to compare each feasible solution, and finally a unique optimal solution is obtained.

We can finally choose 24 suppliers of type A , 31 suppliers of type B , and 38 suppliers of type C , order 133908.1 meters of raw materials from type A suppliers, and 150306.2 meters of raw materials from type B suppliers. 162635.2 meters of raw materials were ordered from C suppliers.

5. Conclusions

This paper establishes an optimal procurement model for power companies that comprehensively considers supplier selection and ordering plans, and introduces the impact of transportation losses on company costs, and establishes an optimal transshipment model. According to the simulation results of the numerical example, the conclusion can be drawn: The progressive algorithm can find the overall optimal solution on the basis of the local optimal. Through iterating layer by layer, it is beneficial to "select the best among the best" and reduce the procurement cost of power enterprises.

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