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Raw Material Procurement and Transportation Model of Construction Enterprises

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Abstract: *In the operation of production-oriented enterprises, in order to meet the objectives of enterprise production planning and cost control, the procurement, transportation, storage and supplier selection of raw materials are all factors that need to be considered. In this paper, through the establishment of evaluation model and 0-1 programming algorithm, formulate relevant procurement plans and transshipment plans for enterprises to choose stability.*

Keywords: *Scoring Model, Time Series, 0-1 Model, Linear Programming*

1. Introduction

In the production and operation of an enterprise, it is necessary to formulate relevant procurement schemes and transshipment schemes, which requires comprehensive consideration of many factors, such as the production plan of the enterprise, the supply situation of suppliers, transshipment consumption, and the freight restrictions of transshipers. According to the order and supply information of 402 suppliers and the weekly loss rate of 8 transshipers in the past five years, this paper propose relevant evaluation models and the solution of a large number of planning problems through mathematical modeling.

2. Establishment and Solution of Model

2.1 Supplier Evaluation System Model

2.1.1 Index Selection

(1) Completion rate of supply and demand

The overall index refers to the judgment of the supply-demand relationship of the enterprise within five years. If the supply exceeds the demand is recorded as 1, and the supply is less than the demand, we set the following function first.

$$f_i = \begin{cases} 1 & \mathrm{S_{ij}} > \mathrm{D_{ij}} \\ 0 & \mathrm{S_{ij}} < \mathrm{D_{ij}} \end{cases} \tag{1}$$

$\mathrm{f_i}$ represents the average weekly supply and demand index of the ith supplier. $\mathrm{S_{ij}}$ represents the supply volume of the ith supplier in week j. $\mathrm{D_{ij}}$ represents the order quantity required by the enterprise from the supplier in the i th week to the supplier in the j th week. P_i represents the completion rate of supply and demand of the ith enterprise within five years.

$$P_i = \sum_{j=1}^{402} f_i. \tag{2}$$

(2) Enterprise selection coefficient

The popularity of each enterprise is classified according to the suppliers selected by the enterprise in the past five years and the corresponding order quantity. Therefore, we define the enterprise selection coefficient.

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$$O_i = \frac{\sum_{j=1}^{240} D_{ij}}{\sum_{i=1}^{402}\sum_{j=1}^{240} D_{ij}} \tag{3}$$

D_{ij} represents the supply volume of the ith supplier in week j.

(3) Stability coefficient

The selection of this index mainly takes into account whether the supplier has stable supply capacity. We give a certain weight to the stability coefficient every year.

$$G_i = \frac{1 \cdot G_{i1} + 2 \cdot G_{i2} + 3 \cdot G_{i3} + 4 \cdot G_{i4} + 5 \cdot G_{i5}}{15} \tag{4}$$

At the beginning, we used the variance of the supply quantity as the stability coefficient, but the variance was too large due to too much difference in the supply quantity. After correction, we first processed the data and compared the weekly supply and demand relationship in week j to set x_{ij}, when the supply is greater than the demand, take 1, and when the supply is less than the demand, take 0. To sum up, the stability coefficient of each year is calculated as follows (take the variance of the first year of the i house as an example).

$$G_{i1} = \frac{\sum_{j=1}^{48}(x_{i1} - \bar{X}_{i1})^2}{48} \tag{5}$$

2.1.2 Establishment and Solution of Model

The relevant evaluation system is established by giving corresponding weights to various indicators selected by entropy weight method, critical objective weight method and information weight, which is reflected by the comprehensive evaluation index production guarantee coefficient R.

$$R_i = f_i.\mathrm{W_f} + B_i.\mathrm{W_B} + G_i.\mathrm{W_G} \tag{6}$$

(1) Entropy weight method

For each index, the entropy value can be used to judge the dispersion degree of the index. This method can be used to calculate the weight of each index and provide a basis for the comprehensive evaluation of the index.

(2) Critical objective weighting method

It considers the weight of indicators based on the contrast strength of indicators and the conflict between indicators, which is more objective.

(3) Information weight

Its core is to use the discrete coefficient of each index for weight assignment. If the discrete coefficient is larger, it means that the index carries more information and the weight will be larger. The calculation formula is as follows:

$$CV = \frac{\delta}{\mu} \tag{7}$$

CV is discrete coefficient, δ is standard deviation of index, μ is the mean value of the index.

Table 1: Weight results of three methods

Indicator type	Entropy weight method	Critical objective weighting method	Information weight
Completion rate of supply and demand	2.83%	48.32%	5.39%
Enterprise selection coefficient	52.00%	23.26%	53.63%
Stability coefficient	45.17%	28.42%	40.98%

(4) Combining the three methods

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Table 2: Index mean

Indicator type	Weight coefficient of each index
Completion rate of supply and demand	18.85%
Enterprise selection coefficient	42.96%
Stability coefficient	38.19%

Finally, we determine the production guarantee coefficient model. We substitute the relevant indicators of each supplier to obtain their own production guarantee coefficient, and finally select the top 50 suppliers by ranking.

2.2 Formulation of the most economical procurement scheme

2.2.1 Selection of minimum suppliers

Firstly, we preprocessed the weekly supply of the 50 suppliers just selected and found that the number of weeks met the production needs. Therefore, we made iterative judgment and processing on this basis.

$$n_j = \begin{cases} n_j - 1 & \sum x_{ij}/0.6 + \sum x_{mn}/0.66 + \sum x_{pq}/0.72 \geq 28200 \\ n_j & \sum x_{ij}/0.6 + \sum x_{mn}/0.66 + \sum x_{pq}/0.72 < 28200 \end{cases} \quad (8)$$

$$\text{s.t.}\begin{cases} \sum x_{ij} + \sum x_{mn} + \sum x_{pq} = \sum S_{ij} \\ x_{ij}, x_{mn}, x_{pq} \geq 0 \end{cases}$$

$\sum x_{ij}$ is the total amount of raw material a provided by 15 companies, $\sum x_{mn}$ is the total amount of B raw materials provided by 15 companies, $\sum x_{pq}$ is the total amount of raw material C. n_j represents the minimum number of suppliers meeting the production demand in week j, and N is the minimum supplier to be selected when the enterprise meets the production demand. Final solution N = 15

Among the 15 suppliers, S140 and S150 were selected because they have a large supply volume and meet the oversupply, which may cause errors to the results. 6 suppliers provide material a, 6 suppliers provide material B and 3 suppliers provide material C.

2.2.2 Formulation of ordering scheme and procurement scheme

(1) Time series prediction

The formulation of enterprise ordering scheme and transshipment scheme in the later stage requires us to predict the supply volume of each supplier and the loss rate of each transshiper every week. Therefore, we use AR model in time series prediction to predict its weekly situation. The model is represented as follows:

$$x_t = \sum_{k=1}^{p} \propto_k x_{t-p} + u_t \quad (9)$$

(2) Determination of ordering scheme

Here, the objective function is mainly established based on the principle of economy, specifically considering the cost of raw materials and their related transportation and storage costs. Because the price is not clearly given, C is expressed by two constantsC_0, C_1 represents the unit price of raw material and the unit transportation and storage cost, so the unit prices of A and B are $1.2C_0, 1.1C_0$. Therefore, the corresponding objective function can be established:

$$C = min(\sum(C_0 + C_1) \cdot x_{ij} + \sum(1.2C_0 + C_1) \cdot x_{nj} + \sum(1.1C_0 + C_1) \cdot x_{pj}) \quad (10)$$

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$$\text{s.t.}\begin{cases}\sum x_{ij}/0.6+\sum x_{mj}/0.66+\sum x_{pj}/0.72\geq 2\times 28200\\ \sum x_{ij}+\sum x_{mj}+\sum x_{pj}=\sum S_{ij}\\ x_{ij},x_{mj},x_{pj}\geq 0\end{cases}$$

$\sum x_{ij}$ is total amount of A raw material provided by 15 households, $\sum x_{mj}$ is total amount of B raw materials provided in 15 households, $\sum x_{pj}$ is total amount of C raw materials. At the same time, due to certain errors in the predicted value, we expanded the scope of weekly supply $S_{ij}{}'$ of each company during data processing, $S_{ij}\in(0.95S_{ij}{}', 1.05\cdot S_{ij}{}')$. The upper limit of upward expansion is 5% of the maximum loss rate within 5 years. At the same time, in order to meet the most economic conditions, the order quantity may be reduced compared with the predicted value, so the same quota is expanded downward.

(3) Determination of transshipment scheme

The loss rate of transshipment among the eight transshipers in five years is given in the data. First, we will calculate the loss rate l_{kj} of the next 24 transshipers per week. (loss rate of the k-th forwarder in week j). Refer to 0-1 planning to optimize the model. m represents the total number of forwarders, n represents the number of suppliers, and 0-1 variable P_k refers to whether the kth forwarder chooses to be selected, $P_k=0$ means that the k-th forwarder is not selected, $P_k=1$ means selected. Establish the following mathematical model:

$$\text{Min } l_j=\frac{\sum_{i=1}^{402}\sum_{k=1}^{8}P_k(Y_{kij}\cdot l_{kj})}{\sum_{i=1}^{402}S_{ij}} \tag{11}$$

$$\text{s.t.}\begin{cases}\sum_{k=1}^{8}Y_{kij}=S_{ij}\\ \sum_{i=1}^{402}Y_{kij}\leq 6000\\ 1\leq k\\ k\leq 8\\ Y_{kij}\geq 0\end{cases}$$

Where, S_{ij} represents the supply volume of the ith supplier in week j, l_j represents the loss rate in week j, Y_{kij} refers to the transportation volume of the k-th forwarder to the i-th supplier in week j, l_{kj} refers to the loss rate of the k-th forwarder in week j. We select the supplier selection matrix for week 16 as follows:

Table 3: Week 16 supplier selection matrix

	T001	T002	T003	T004	T005	T006	T007	T008
S140	0	0	1	0	0	0	0	0
S229	0	0	1	0	0	0	0	0
S201	1	0	0	0	0	0	0	0
S361	0	0	1	0	0	0	0	0
S108	0	0	0	1	0	0	0	0
S151	0	0	0	0	0	1	0	0
S139	0	0	0	1	0	0	0	0
S282	0	0	0	1	0	0	0	0
S308	0	0	0	1	0	0	0	0
S340	0	0	0	1	0	0	0	0
S348	0	0	0	0	0	1	0	0
S330	0	0	1	0	0	0	0	0
S275	0	0	0	0	0	1	0	0
S329	0	0	0	0	0	1	0	0
S356	0	0	0	1	0	0	0	0

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Where, 1 indicates that the transporter is selected.otherwise, the transporter is not selected.In this week, each supplier can only be supplied by one forwarder, and the forwarder with low loss rate is preferred, which is in line with the actual conditions. Through the residual analysis of the order quantity results, the residual values are in an acceptable range, so the prediction results are more accurate.

3. Model Evaluation

The establishment of the model in this paper is based on rational analysis and a large number of data support, which has high rationality. The indicators established by the model evaluation are reasonable, the evaluation is fair and objective, the solution of the model and the overall performance evaluation of the queuing system are accurate, and can give a more practical and accurate scheme. However, the selection of indicators is not comprehensive, and there is a lack of analysis on the implementation effect of the scheme.

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