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Matrix Quantization Algorithm based on Integer Programming Model

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Abstract

Raw material ordering and transportation decisions are important factors that affect the cost of enterprises. Due to the relatively large fluctuations in the supply volume of suppliers and the transportation loss of transshipped, this has become a major problem that plagues the development of enterprises. The solution to the raw material ordering and transportation problems of production enterprises can help increase the production capacity of production enterprises in reality and help producers make effective decisions. This article is aimed at such a scenario, based on the past order purchase data of the manufacturer, and under different needs, establish a raw material ordering and transshipment model to obtain the optimal solution.

Keywords

0-1 Integer Programming; Linear Programming; Matrix Quantization.

1. Introduction

The raw materials used by an enterprise that produces construction and decorative panels can generally be divided into three categories: A, B, and C. The company arranges production for 48 weeks each year and needs to formulate a 24-week raw material ordering and transshipment plan in advance, that is, determine the raw material suppliers that need to be ordered and the corresponding weekly raw material ordering quantity according to the capacity requirements, determine the third-party logistics company and entrust it to transport raw materials to the corporate warehouse.

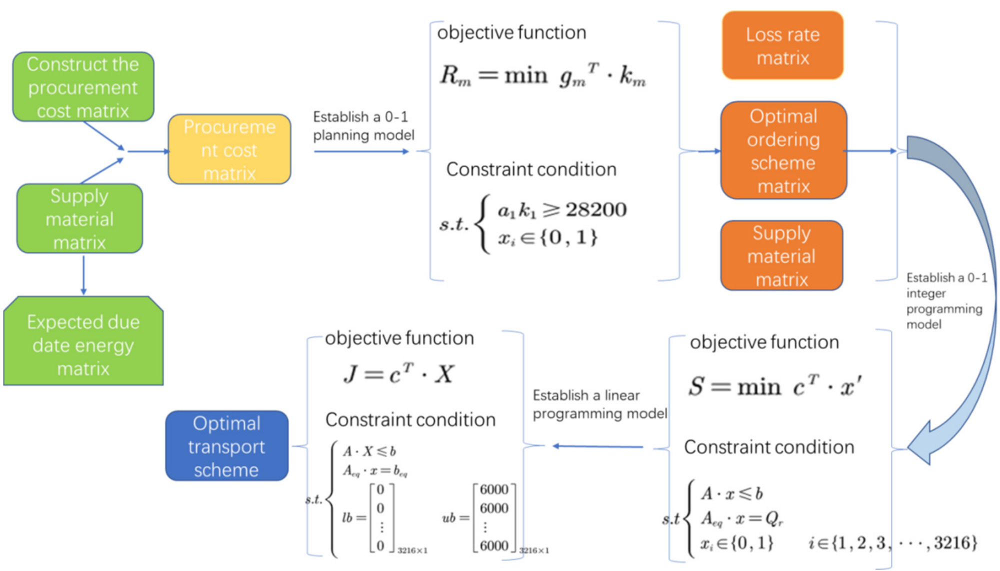

Figure 1. Main process of problem solving

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The purchase cost of raw materials directly affects the production efficiency of the enterprise. In practice, the purchase unit prices of A and B raw materials are 20% and 10% higher than those of C raw materials, respectively. The unit costs for the transportation and storage of the three types of raw materials are the same. At present, the order quantity and supply data of 402 raw material suppliers of the company in the past 5 years and the transportation loss rate data of 8 transshipment companies are available. Ordering and transshipment solutions. The main process is shown in Figure 1.

2. Organization of the Text

2.1. Matrix Normalization

First, we convert the supplier supply data for the past five years into a corresponding supply material matrix Q. $Q_{(i,j}$ indicates the number of raw materials supplied by the i-th supplier in the j-th week. Then standardize the supply material matrix to obtain the enterprise's pre-capacity matrix A, $A_{(i,j)}$ indicates the product output that the i-th supplier can convert from the raw materials supplied in the j-th week. The calculation formula for matrix normalization is as follows:

$$A_{(i,j)} = \frac{Q_{(i,j)}}{m} \quad \begin{cases} m = 0.6 & supply\ of\ materials\ A \\ m = 0.66 & supply\ of\ materials\ B \\ m = 0.72 & supply\ of\ materials\ C \end{cases} \tag{1}$$

2.2. Establish a 0-1 Integer Programming Model to Find the Minimum Number of Suppliers

For supplier i, the enterprise can only choose supplier i or not. So there is:

$$x_i = \begin{cases} 0 & do\ not\ select\ supplier\ i \\ 1 & select\ supplier\ i \end{cases} \tag{2}$$

(i=1,2,3,...402; j=1,2,3,...240)

Set the minimum number of suppliers Sm as the objective function:

$$S_m = \min \sum_{i=1}^{402} x_i \quad m \in \{1, 2, 3 \cdots, 240\} \tag{3}$$

To meet production demand as a constraint:

$$s.t. \begin{cases} a_1 \cdot k_1 \geqslant 28200 \\ x_i \in \{0, 1\} \end{cases} \tag{4}$$

Construct the row vector a1 with the first column elements of the pre-capacity matrix A, Multiply a_1 by the column vectork_1=$(x_1, x_2, x_3, \cdots, x_{402})^T$ to get the number of products that can be produced by the supplier's weekly actual supply after normalization.

After the standardization of the enterprise, the number of products that can be produced by the supplier's weekly actual supply shall not be less than the raw materials required for the actual production of the current week.

Use 0-1 integer programming to find the minimum number of suppliers S1 that satisfies the constraints. Because what is calculated here is the minimum number of suppliers in the first

week, so repeat the above steps to get the second to 240th weeks. The minimum number of suppliers is S2~S240. Statistically draw the line graph of S1~S240 as shown in Figure [2].
In summary, the minimum number of suppliers S′:

$$S' = \frac{\sum_{m=1}^{240} S_m}{240} \tag{5}$$

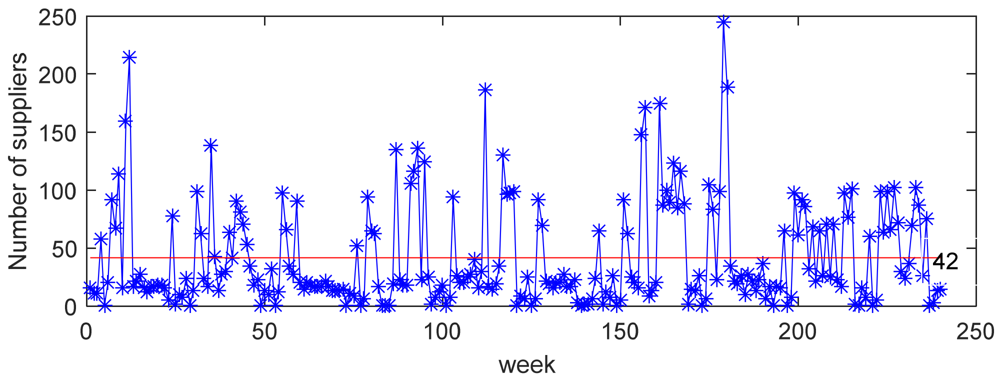

Figure 2. Week scatter diagram of the minimum number of suppliers (red line is the mean line)

2.3. Establish a 0-1 Integer Programming Model for the Most Economical Ordering Plan

Based on the purchase unit price ratio of A, B, C three types of raw materials is 1.2:1.1:1.0, construct the purchase cost ratio matrix M. Calculate Q· * M=G to get the purchase cost matrix G, $G_{(i,j)}$ indicates the cost of the company's purchase from the i-th supplier in week j, using the 0-1 integer programming model to find the optimal cost ordering plan for the next 24 weeks:

$$x_i = \begin{cases} 0 & do\ not\ select\ supplier\ i \\ 1 & select\ supplier\ i \end{cases} \tag{6}$$

(i=1, 2, 3, ...402; j=1, 2, 3, ...240)

Construct the row vector g_1^T with the elements in the first column of the purchase cost matrix G.Calculate $g_1^T \cdot k_1 = R_1$, where R_1 is the purchase cost for the first week.

In summary, the objective function is R_m:

$$R_m = \min\ g_m{}^T \cdot k_m \quad m \in \{1, 2, 3 \cdots, 240\} \tag{7}$$

The constraints are:

$$s.t. \begin{cases} a_1 k_1 \geqslant 28200 \\ x_i \in \{0, 1\} \end{cases} \tag{8}$$

In the end, we got the optimal weekly raw material ordering plan (F matrix) for the next 24 weeks and the optimal weekly ordering cost for the next 24 weeks, $R_m{}'$=15893.5.

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2.4. Establish a 0-1 Integer Programming Model and a Linear Programming Model to Find the Transfer Plan with the Least Loss

2.4.1. Data Preparation

From the previous question, we can get the optimal order plan (F matrix) of raw materials in the next 24 weeks;Predict the element composition matrix for the next 24 weeks from the supply material matrix $Q'_{(402\times24}$; For the weekly transportation loss data of the transporters in the past five years, use function fitting to get the loss rate matrix $S_{(8\times24)}$.

2.4.2. Model Establishment and Solution

Take the first week as an example for analysis, take the first column of the matrix Q' to form a column vector $Q'_{(1)}$, which represents the actual supply of each supplier in the first week; use $(G_1, G_2, G_3, \cdots G_8)$ to form The row vector G represents 8 forwarders;

Using 0-1 integer planning, for the forwarder G, the company has an only choice or no choice

$$x=\begin{cases}0 & do\ not\ choose\ a\ forwarder\\ 1 & choose\ a\ forwarder\end{cases} \tag{9}$$

★Objective function:

$$S=\min\ c^T\cdot x' \tag{10}$$

★The constraints are:

$$s.t\begin{cases}A\cdot x\leqslant b\\ A_{eq}\cdot x=Q_r\\ x_i\in\{0,1\} \qquad i\in\{1,2,3,\cdots,3216\}\end{cases} \tag{11}$$

$$b=\begin{bmatrix}6000\\6000\\ \vdots\\6000\end{bmatrix}_{8\times1},\quad Q_r(k)=\left[\frac{Q_1(k)'}{6000}\right]+1 \quad k=(1,2,3,\cdots,402)$$

Qr(k) indicates the number of forwarders required for the k-th supplier to forward materials within a week.

The calculation formula of the objective function J (minimum loss) of the linear programming model is as follows:

$$J=c^T\cdot X \tag{12}$$

★Objective function:

$$s.t.\begin{cases}A\cdot X\leqslant b \qquad (transport\ capacity\ limitation\ of\ forwarders)\\ A_{eq}\cdot x=b_{eq}\\ lb=\begin{bmatrix}0\\0\\ \vdots\\0\end{bmatrix}_{3216\times1} \quad (upper\ limit\ of\ x) \quad ub=\begin{bmatrix}6000\\6000\\ \vdots\\6000\end{bmatrix}_{3216\times1} \quad (lower\ limit\ of\ x)\end{cases} \tag{13}$$

In the end, a transshipment plan that minimizes transshipment losses was obtained.

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3. Conclusion

The ordering plan in this article optimizes the company's budget while ensuring that no less than the raw material inventory that meets the two-week production needs is always maintained so that the company can reduce the supply risk and obtain a more stable supply. The transshipment scheme in the article makes the loss rate of goods as small as possible and the number of goods received as large as possible to reduce costs and increase revenue. The ordering plan and the transshipment plan we obtained are both the optimal plan under the above constraints, which fulfills the requirements of the lowest enterprise cost, the largest enterprise profit, and the smallest operational risk under the model of different situations.

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