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Ordering of Raw Materials in Manufacturing Enterprises Based on Objective Programming Model

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Abstract: According to the order quantity and supply quantity data of 402 enterprises for 240 weeks in 5 years, this paper first makes a quantitative analysis of the given data, observes the surface characteristics of the data, and further looks for relevant indicators. The improved AHP model is combined with TOPSIS method to modify and obtain the index weight. Based on this, 50 most important suppliers are selected. Then on this basis, we can solve the two problems: how many suppliers to choose and how to establish the most cost-effective ordering scheme. By establishing the 0-1 programming model, with the help of lingo, Python and other modeling tools, it is calculated that at least 24 suppliers should be selected to supply raw materials to meet the production demand under given objective functions and constraints. Finally, with the help of dynamic programming model and intelligent algorithm, the most economical weekly production and supply plan is given.

1. Introduction

This paper mainly studies the ordering and transportation of raw materials in the production process. In practical problems, for the purpose of saving cost, the method of minimum batch and multiple orders is often adopted to reduce inventory. The production raw materials of the enterprise are generally divided into three types: A, B and C. The production is carried out according to 48 weeks every year. It is necessary to formulate the weekly production raw material ordering plan and procurement plan of suppliers and ordering quantity half a year in advance. The cost of raw materials consists of the conversion of raw materials corresponding to the production of finished products, raw material pricing, raw material volume and raw material loss. Based on the known information, this paper selects the optimal supply scheme for the given order quantity and supply quantity data of 402 companies in 5 years and 240 weeks.

2. Model Establishment and Solution

2.1 Supplier screening

2.1.1 Data preprocessing

Observing the given data, we will find many abnormal and repeated data, and there are also noisy data in some data segments. Therefore, the data preprocessing stage will filter and eliminate these abnormal data, and cluster the data.

2.1.2 Establishment of model

Firstly, according to the given data, the five indicators of supply standard deviation, supply mean, order times, effective mean of supply and satisfaction rate are determined. Through the visualization of data, the importance of these indicators is studied to reduce the subjectivity of AHP model. Through MATLAB, we use analytic hierarchy process to score the indicators, and use three methods to calculate the weight.

In order to reduce the impact of multicollinearity on the accuracy of the evaluation model and avoid the complexity of the model, this paper uses factor analysis to screen the above five indicators to simplify the model. Kmo (Kaiser Meyer Olkin) and Bartlett sphericity test are used to test the correlation between the above five indexes, and the results are shown in Table 1. It shows that the index data selected by factor analysis has high convergence and correlation, so factor analysis can be carried out.

Table 1: Results of factor analysis

Kaiser-Meyer-Olkin		0.491
Bartlett Sphericity test	Approximate chi square	1043.541
	df	85
	Sig	0.000

Through the analysis of 240 weeks' historical data of 402 suppliers, the quantitative results of indicators are obtained, and the visual results are shown as follows:

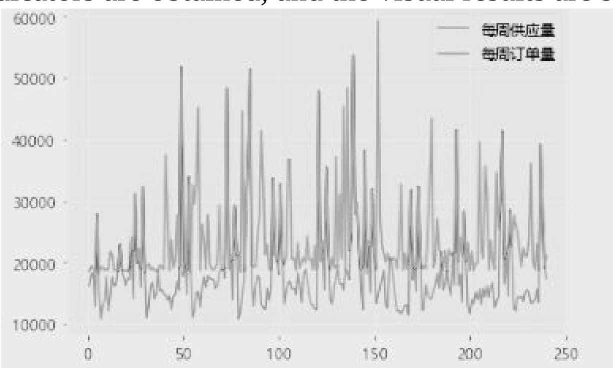

Figure 1: Weekly supply quantity

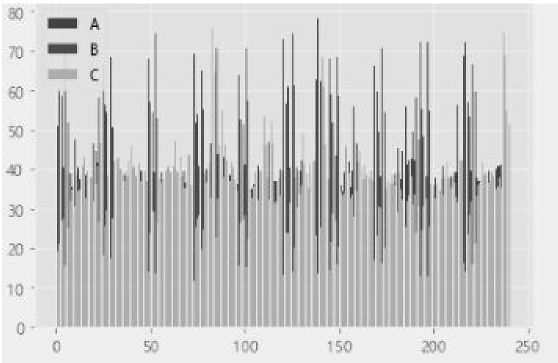

Figure 2: Weekly supply proportion of three raw materials

Due to analytic hierarchy process ω_a is still subjective, so we consider using entropy weight method to obtain a completely objective weight ω_b and combine them in proportion as our weight in TOPSIS scoring.

Formula for calculating the weight of each index by entropy weight method:

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}, \quad j = 1, \cdots, m \tag{1.}$$

Correct the weight ω_b according to the calculated value and obtain the combined weight in the proportion of 0.7:0.3:

$$\omega = 0.7\omega_a + 0.3\omega_b \tag{2.}$$

Then, according to the weight determined by the combination index, 50 most important suppliers are selected.

2.2 Determine the minimum number of suppliers

Since the economic benefits of class A and C raw materials are the highest, we find that the transportation and storage costs of class C raw materials are higher than those of class A and B, because more supply is required to replace the production capacity, and the suppliers supplying class C materials are the least. Since it is necessary to consider the minimum number of suppliers, 0-1 programming is selected for model establishment. The target supply quantity adopts the random distribution method of maximum supply quantity and effective mean value of supply quantity. We have made several simulation attempts in the process, and finally come to the conclusion that the planning result obtained by the method of maximum supply quantity: effective mean value of supply quantity = 1:299 is the most ideal.

0-1 planning model establishment process:

Objective function:

$$min = x_1 + x_2 + x_3 + ... + x_{50}; \tag{3.}$$

Constraints:

$$A / 0.6 + B / 0.66 + C / 0.72 >= 2.82 * 10000; \tag{4.}$$

$$\begin{aligned} A = {} & 1478.14163208852 * x_1 + 706.060082987552 * x_2 + 658.923278008299 * x_3 + 650.524107883817 * x_4 \\ & + 370.521825726141 * x_5 + 350.772807745505 * x_6 + 583.80465 * x_7 + 481.776666666667 * x_8 \\ & + 914.833019607843 * x_9 + 1737.57073333333 * x_{10} + 49.362658045977 * x_{11} + 29.2504426002766 * x_{12} \\ & + 27.0896265560166 * x_{13} + 27.0501383125864 * x_{14} + 37.9700149476831 * x_{15} + 9.35879668049793 * x_{16}; \end{aligned} \tag{5.}$$

$$\begin{aligned} B = {} & 1433.14941176471 * x_{17} + 1022.74322268326 * x_{18} + 712.87683264177 * x_{19} + 706.715748148148 * x_{20} \\ & + 572.06724757953 * x_{21} + 593.831576763485 * x_{22} + 597.690677731674 * x_{23} + 171.250124481328 * x_{24} \\ & + 133.384605809129 * x_{25} + 121.010719225449 * x_{26} + 110.899612724758 * x_{27} + 103.476002766252 * x_{28} \\ & + 96.6500968188105 * x_{29} + 153.320260162602 * x_{30}; \end{aligned} \tag{6.}$$

$$\begin{aligned} C = {} & 1366.17670816044 * x_{31} + 875.245491009682 * x_{32} + 544.850636237898 * x_{33} + 539.189349930844 * x_{34} \\ & + 524.54918395574 * x_{35} + 421.182987551867 * x_{36} + 235.617206085754 * x_{37} + 282.551466113416 * x_{38} \\ & + 199.387385892116 * x_{39} + 173.436929460581 * x_{40} + 329.82695473251 * x_{41} + 80.2721715076072 * x_{42} \\ & + 78.2986307053942 * x_{43} + 68.4477731673582 * x_{44} + 64.6306639004149 * x_{45} + 519.504092409241 * x_{46} \\ & + 89.4031904761905 * x_{47} + 66.7610333333333 * x_{48} + 7.18601694915254 * x_{49} + 74.1695833333333 * x_{50}; \end{aligned} \tag{7.}$$

It can be obtained by using LINGO program: at least 24 suppliers should be selected to supply raw materials in order to meet the production demand.

2.3 Determine the most economical ordering scheme

The most economical scheme needs to be given, so only the objective function in 2.2 needs to be replaced with the influencing factor of unit price, and the 0-1 programming model is established as follows:

Objective function:

$$\min = 1.2*A + 1.1*B + C \quad (8.)$$

The constraints are the same as 2.1

By solving the model, we can get the supplier's type scheme, and then apply the dynamic programming method to allocate the 0-1 planning result to the 24-week supply scheme with Python program.

Establishment of dynamic programming model:

Divide the problem into 21 stages according to the production cycle: $k = 1, 2, 3, ..., 21$

S_k: Number of raw materials owned when allocating to phase K:

$$S_0 = 2.82*10^4*2 \quad (9)$$

Uk: Number of raw materials allocated to stage K:

$$S_{20} = S_{19} - U_{19}, S_{21} = S_{20} - U_{20} \quad (10)$$

Stage index:

$$f_{21}^{*}(s_{21}) = 2.82*10^4*2 - f_{20}(s_{20}) \quad (11)$$

2.4 Scheme implementation effect analysis

Select the three-week suppliers of the ordering scheme and the random scheme respectively to supply raw materials, and ensure that the random scheme and the ordering scheme use the same transshipment scheme. Calculate the average unit price (total cost / total capacity) of the week by calculating the capacity of the week and the total cost of the week. The results are shown in the table below:

Table 2: Implementation effect of ordering scheme

Average unit price	First week	Second week	Third week
Ordering scheme	1.877	1.877	1.877
Random scheme 1	1.953	1.951	1.98

According to the analysis in the above table, the average unit price of the ordering scheme is smaller than that of the random scheme 1, indicating that the obtained ordering scheme is the most economical raw material ordering scheme, and the actual effect of the ordering scheme is good.

3. Conclusion

This paper observes the 240 week data characteristics of 402 suppliers through the method of data visualization, which is more intuitive and paves the way for the next work. The dynamic programming model is used to formulate the weekly production plan, and the conditions of meeting the production capacity and reserving two-week inventory are fully considered. Before the model is established, the data is preprocessed and denoised, which greatly reduces the time waste caused by the large amount of data, and is more intuitive and convenient. However, due to the limitation of data volume and time, the results obtained by objective programming and dynamic programming are local optimization rather than global optimization. However, it is undeniable that 0-1 programming model and dynamic programming problem are very important to solve common problems in supply chain and have extensive extension value.

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