ISSN: 2664-9640

Purchase and transportation planning model based on ARIMA time series

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Abstract

Based on the modeling calculation of the common purchasing and transportation model in daily life, if the production enterprise has 402 suppliers to supply, it needs A, B and C raw materials for production. According to the importance of suppliers to the production of the enterprise, we established 5 indicators for sub-factor analysis, ranked 402 suppliers according to the comprehensive factor score, and selected the top 50 suppliers. The ARIMA inter-test time prediction model was used to predict the supply of suppliers in the next 24 weeks, and the predicted data were used as samples for subsequent research. Under different problem conditions, the objective function and constraint conditions are converted, and the 24-week enterprise ordering plan and transportation plan are formulated by using 0-1 integer programming, single objective linear programming, and multi-objective linear programming based on NSGA-Ⅱ algorithm.。

Keywords

NSGA-Ⅱ algorithm ARIMA model.

1. Introduction

There are three types of raw materials used in the production of wood fiber and other duty fiber materials for construction and decoration enterprises. The company plans to produce 48 weeks in total each year. In order to ensure full application, the company needs to make a material purchase and transportation plan of 24 weeks in advance. This plan is mainly to determine suppliers according to capacity, order quantity of raw materials every week, and select third-party operators, and entrust them to transport the materials provided by suppliers every week to the warehouse of the enterprise. The production capacity of the enterprise is 28,200 cubic meters per week, and each cubic meter of finished products needs one of the materials of class A, B and C, in which each volume of finished products consumed 0.6 cubic meters of material A, 0.66 cubic meters of material B, or 0.72 cubic meters of material C. The actual purchase unit price of class A and B raw materials is 20% and 10% higher than that of Class C raw materials respectively. The unit costs for transportation and storage of the three types of raw materials are the same. The actual quantity supplied by the supplier will fluctuate on the basis of the ordered quantity. Before this week's production, the enterprise tries to stock the raw material demand for two weeks, so as to guarantee the normal production of the enterprise, the enterprise purchases all the raw material supply from suppliers. Transportation of materials Under normal circumstances, the raw materials supplied by one supplier every week should be transported by one transporter as far as possible, each of which has a transportation capacity of 6000 cubic meters per week. Due to the turnover and handling of materials in the process of transportation, there is a certain loss rate, and the material received by the enterprise warehouse is called the received amount. On this basis, we calculate the

ISSN: 2664-9640

important guarantee degree of suppliers, the minimum number of suppliers required by enterprises and the most economical purchase and operation model of enterprises.

2. Model assumes

In the process of ordering and transporting raw materials, it is stipulated that raw materials will arrive at the warehouse at the beginning of the week and reach the capacity of this week at the end of the week. The raw materials required for this week's production will not be included in the storage costs.

The company always buys all the raw materials actually provided by the suppliers.

If the weekly supply quantity is more than 6000 cubic meters occasionally, we have reason to think it is reasonable and acceptable to some extent due to the historical data of supply quantity.

3. The establishment and solution of mathematical model

3.1. The establishment and solution of evaluation model

The supply of raw materials is the main operation of production enterprises, so it is very important to ensure its normal operation. In part 1, based on the five years' order quantity of enterprises and the quantity provided by suppliers, quantitative analysis is required for the supply of 402 suppliers, and an evaluation model based on factor analysis is established. We need to analyze the factors influencing the stability of suppliers.

Will supply than to demand the frequency, the amount of material supply, supply accounts for an average of the proportion of the demand and supply of materials, the value of the difference of supply and quantity variance respectively as affordable, importance, meet, efficiency and stability of measure do factor analysis, the merchants comprehensive factor score as a sort of standard to select qualified suppliers. Finally, grey correlation analysis was used to verify the reliability of the factor analysis results

3.2. The calculation of factor analysis model

The data of the top 50 enterprises are obtained by integrating the results of grey correlation analysis in the following table.

Table 1 50 enterprise comprehensive factor score

Ranking	1	2	3	4	5	6	7	8	9	10
F_1	3.6781	4.1566	3.2496	3.8493	2.8358	2.7386	2.3953	2.4021	2.8880	2.4273
F_2	3.7726	1.8310	1.2293	1.6814	0.6071	0.6352	0.6383	0.6124	1.6230	0.4254
F_3	1.5452	-0.5843	1.4839	-0.5890	1.4457	1.4521	1.4415	1.4418	-0.6472	1.4406
F	3.1849	2.4159	2.3079	2.2220	1.9322	1.8920	1.7174	1.7143	1.7092	1.6792
vendor ID	S140	S229	S108	S361	S139	S340	S308	S330	S151	S131

Ranking	11	12	13	14	15	16	17	18	19	20
F_1	2.8267	2.6690	2.6453	1.7461	2.4583	2.4370	1.7576	2.4351	1.9178	1.7007
F_2	0.5658	0.5154	0.5042	-0.2299	0.3277	0.3277	-0.3146	0.2955	1.2358	-0.3252
F_3	0.6716	-0.6720	-0.6725	1.3962	-0.6851	-0.6839	1.3908	-0.6874	-0.6882	1.3892
F	1.4037	1.3115	1.2965	1.1590	1.1545	1.1441	1.1419	1.1341	1.1125	1.1102
vendor ID	S282	S275	S329	S31	S356	S268	S338	S306	S348	S364

Ranking	21	22	23	24	25	26	27	28	29	30

ISSN: 2664-9640

F_1	1.6426	1.6096	1.6039	1.6838	1.5233	2.2303	2.3170	2.0920	2.0153	1.2531
F_2	-0.2820	-0.3204	-0.3323	-0.5576	-0.3237	0.1356	-0.3256	0.0666	0.0482	-0.4651
F_3	1.3943	1.3926	1.3918	1.3815	1.3941	-0.6976	-0.7199	-0.6999	-0.7001	1.3697
F	1.0932	1.0664	1.0603	1.0408	1.0225	0.9879	0.9089	0.9002	0.8568	0.8446
vendor ID	S40	S367	S55	S98	S346	S194	S374	S352	S143	S175

Ranking	31	32	33	34	35	36	37	38	39	40
F_1	1.9372	1.1733	1.0706	1.9049	1.9406	0.9799	0.9838	0.9768	0.9757	0.9653
F_2	0.1636	-0.4495	-0.4228	-0.1651	-0.2635	-0.3882	-0.3930	-0.3924	-0.3919	-0.3917
F_3	-0.7112	1.3658	1.3686	-0.7173	-0.7273	1.3844	1.3795	1.3778	1.3792	1.3759
F	0.8442	0.8075	0.7633	0.7429	0.7334	0.7302	0.7298	0.7260	0.7259	0.7199
vendor ID	S307	S174	S169	S247	S284	S88	S324	S202	S172	S92

Ranking	41	42	43	44	45	46	47	48	49	50
F_1	0.9202	0.9019	0.9041	0.8846	0.8598	0.8394	1.8063	0.8322	0.8209	0.8027
F_2	-0.3775	-0.3696	-0.3744	-0.3699	-0.3497	-0.3482	-0.2695	-0.3584	-0.3493	1.6403
F_3	1.3801	1.3846	1.3791	1.3795	1.3975	1.3905	-0.7243	1.3779	1.3863	-0.7033
F	0.7019	0.6957	0.6943	0.6858	0.6827	0.6712	0.6650	0.6619	0.6606	0.6504
vendor ID	S392	S310	S141	S197	S146	S138	S365	S256	S376	S126

3.3. Establishment and solution of manufacturer's optimal purchase and operation model

In part 2.2, 50 suppliers with high security importance were selected from 402 suppliers based on factor analysis. In question 2, we need to solve how many suppliers are needed to meet the demand. In the actual production and life, enterprises often take the ordering data over the years as decision-making reference when making raw material purchasing plans, so as to decide which supplier to choose at the current time node and determine the supply quantity, so the supply quantity has time correlation. Therefore, we take a supplier as the research object and establish ARIMA(P, D, Q) model to predict its supply quantity in the next 24 weeks. Similarly, ARIMA(P, D, Q) model is used to predict the supply quantity of 50 suppliers in the next 24 weeks.

The minimum sum of suppliers was taken as the objective function to satisfy the inventory in the next two weeks to ensure the normal production of manufacturers. As the constraint function, 0-1 model was constructed and MATLAB was used to solve the program.

Establishment and solution of ARIMA model after elastic coefficient adjustment

ARIMA modle

ISSN: 2664-9640

ARIMA the model is based on autoregressive model and moving average model, combined with difference operation, based on the data of time series itself, analysis and short-term prediction, also known as autoregressive moving average model. Supplier will change over time to form the output data sequence as a random sequence, the first to do a stabilized supply data processing and inspection, through the model after testing and to estimate the parameters in the model and the applicability test, select the optimal model of ARIMA (p, d, q), using the model of the first vendors predicted 24 weeks supply in the future. The specific form is as follows:

$$\begin{cases} \phi(B)(1-B)^d Y_t = \theta(B)\alpha_1 \\ E(\alpha_t)=0, Var(\alpha_1)=\sigma^2, E(\alpha_t,\alpha_s)=0; t\neq s \\ E(Y_t,\alpha_s)=0, \forall s<t \end{cases} \tag{1}$$

$$\phi(B)=1-\varphi_1 B-\varphi_2 B_2 \cdots - \varphi_p B^p \tag{2}$$

$$\phi(B)=1-\theta_1 B-\theta_2 B_2 \cdots - \theta_p B^p \tag{3}$$

B represents the backward shift operator; $\phi(B)$ represents the polynomial of q-intercept moving average coefficient; $\{\alpha_t\}$ represents a sequence of white noise.

The establishment of the ARIMA

Stabilization of time series

In this paper, ARIMA (P, D, Q) model is established based on the 1-24 week supply data of enterprises. We use MATLAB and SPSS software to carry out stationarity test (ADF test) and white noise test respectively.

Model determination and prediction results

Through SPSS, we obtained the sequence diagrams of the top 50 suppliers. It can be seen from the diagrams that the original sequence fluctuated greatly and tended to be stable after the first difference, which also met the ADF test. The specific data of ARIMA （$p_i, d_{i,} q_i$） , the optimal model of the enterprise determined according to AIC criteria.According to the model, the supplier's supply data in the next 24 weeks are predicted.

MATLAB prediction function is used to predict, and the final calculation results

The introduction of elastic coefficients

It can be seen from background constraints that supply quantity depends to some extent on order quantity, that is, supplier supply in historical data is restricted by order quantity, but in fact supplier supply capacity may be higher. We define the elasticity coefficient of supply capacity μ_i, where F_i is the comprehensive score of the i manufacturer, and $\max F_i$、$\min F_i$ is the maximum and minimum value of all scores.

$$\mu_i = 1 + \frac{F_i - \min F_i}{\max F_i - \min F_i} \tag{4}$$

We calculate the adjustment coefficient , μ_i and apply it to improve the predicted supply quantity μ_i as the adjustment coefficient The forecast value of suppliers in the model is multiplied to obtain the adjusted forecast supply value, α_{ij}, (called forecast supply value (α_{ij})in subsequent papers), which is used as the constraint of the upper limit of enterprise order quantity.Establishment and solution of 0-1 programming model

1）Forecast capacity quantity matrix

Based on ARIMA modle, we process the predicted supply values of 50 suppliers in the next 24 weeks and obtain the unit quantity matrix of predicted capacity P, which p_{ij} represents the quantity of finished products that the i supplier can produce by ordering raw materials in the j week. a is the capacity of the enterprise every week, α_{ij} is the volume of the material predicted to be supplied by the i supplier in the j week, z_j is the order quantity of the enterprise in the week, and x_{ij} is the raw material consumption per unit product of the i supplier in the j week. The set of values is{0.6，0.66，0.72}.$i=1,2,\cdots,50, j=1,2,\cdots 24$。

$$p_{ij}=\frac{\alpha_{ij}}{x_{ij}} \tag{5}$$

The unit quantity matrix of predicted productivity is obtained P

$$P=\begin{bmatrix} p_{11} & \cdots & p_{1\,24} \\ \vdots & \ddots & \vdots \\ p_{11} & \cdots & p_{50\,24} \end{bmatrix} \tag{6}$$

2）Establishment and solution of 0-1 programming model

On the basis of ordering goods to meet the production demand, enterprises should select as few suppliers as possible, and enterprises always purchase all the raw materials actually provided by suppliers. Therefore, when solving the problem of the minimum number of suppliers, we can think that the predicted supply α_{ij} is always less than the ordered quantity of enterprises z_j

Let's introduce the 0-1 variablez_{ij}，

$$z_{ij}=\begin{cases} 1 & p_{ij}\neq 0, \\ 0 & p_{ij}=0, \end{cases} \tag{7}$$

I get the 0 minus 1 matrix$Z$

$$Z=\begin{bmatrix} z_{11} & \cdots & z_{1\,24} \\ \vdots & \ddots & \vdots \\ z_{50\,1} & \cdots & z_{50\,1} \end{bmatrix} \tag{8}$$

The total number of suppliers will be used as M an objective function to meet the production situation

$$\min M=\sum_{i=1}^{50}\left[sign\left(\sum_{i=1}^{24} z_{ij}\right)\right] \tag{9}$$

In order to meet the weekly inventory demand as the constraint condition of 0-1 planning, the purchase quantity of the enterprise in the first week should meet the production demand of the first two weeks. In the third week, after removing the consumption of the first week$a$, the inventory still needs to be greater than$2a$， Similarly, in the 24th week, the total purchase quantity of the enterprise should be enough to provide the production consumption $23a$ of the previous 23 weeks and ensure the production inventory of the 24th and 25th weeks. Then, following is obtained as the constraint condition of 0-1 planning:

$$s \cdot t \cdot \begin{cases} z_1 \geqslant 2a \\ z_1 + z_2 \geqslant 3a \\ z_1 + z_2 + z_3 \geqslant 4a \\ \vdots \\ z_1 + z_2 + z_3 + \cdots + z_{24} \geqslant 25a \end{cases} \tag{10}$$

$$z_j = p_{1j} z_{1j} + p_{2j} z_{2j} + \cdots + p_{50j} z_{50j} = \sum_{i=1}^{50} p_{ij} z_{ij} \tag{11}$$

Substituting the predicted 24-week value of 50 suppliers, namely the enterprise order quantity formula. Among them, enterprises choose at least 12 suppliers to supply raw materials to meet production needs.

The establishment and solution of linear programming model

1)The most economical ordering scheme

Based on the data of 50 suppliers obtained by question one factor analysis, the most economical raw material ordering plan for the next 24 weeks was made for the enterprise. Suppose, c_A and c_B ,c_C the total order quantity of raw materials of A 、 B 、 C different categories, c_{ij} is the quantity of goods actually purchased by the j supplier of the enterprise in the week, and x_{ij} is the corresponding raw material consumption per unit product of the i supplier in the j week. In order to save costs as the fundamental goal, companies will be based on the actual ordering plan, not always purchase the entire supply. The raw material cost consumption function is taken as the objective function C to establish the linear programming model

$$\min C = c_C + 1.1 c_B + 1.2 c_A \tag{12}$$

Let $p'_{ij} = \dfrac{1}{x_{ij}}$ be the elements of the linear programming coefficient matrix, called P'_l the linear programming coefficient matrix

$$P'_l = \begin{bmatrix} p'_{11} & \cdots & p'_{1\,24} \\ \vdots & \ddots & \vdots \\ p'_{11} & \cdots & p'_{50\,24} \end{bmatrix} \tag{13}$$

In the process of enterprise ordering and supplier supply, there are mainly three stages: planning, ordering and transportation. Planning stage: In order to ensure the smooth progress of production activities, the enterprise needs to store the goods demand in the next two weeks; Ordering stage: enterprises need to place orders within the range of suppliers' supply, so the actual purchase quantity is less than or equal to the predicted value α_{ij} in the ARIMA model. Transportation stage: Eight third-party transporters Under normal circumstances, the maximum transportation volume of each transporter is 6,000 cubic meters per week, and the total amount of the actual purchase of A, B and C raw materials by the enterprise should be less than 48,000 cubic meters. The constraint conditions of the most economical linear programming scheme are obtained by synthesizing the above three conditions

$$s \cdot t \cdot \begin{cases} \sum_{i=1}^{50} p_{ij} c_{ij} \geqslant (j+1)a & j=1,\cdots,24; \\ 0 \leqslant c_{ij} \leqslant \alpha_{ij} & i=1,\cdots,50\ ;j=1,2,\cdots,24; \\ \sum_{i=1}^{50} c_{ij} \leqslant 48000 & j=1,\cdots,24 \end{cases} \tag{14}$$

Similarly, the most economical raw material ordering plan of the enterprise in the next 24 weeks is obtained by substituting the predicted data .

4. Conclusions:

All in all,optimization of transportation plan help enterprises to quickly reduce the transportation cost in the process of logistics, transportation is an important cost to build logistics transportation cost, by reasonable management enterprise route optimization, so it can save most of the expenses, in the process of transport can save more time and energy, can reduce labor cost, shorten the transportation distance and time at the same time,It can reduce costs even more.At the same time, it can also formulate reasonable transportation plans, improve energy utilization rate and better optimize the allocation of resources, so as to achieve better transportation results under the condition of energy shortage.

References:

[1]Chuanwen Dong,Sandra Transchel. A dual sourcing inventory model for modal split transport: Structural properties and optimal solution[J]. European Journal of Operational Research, 2020,283(3):

[2]Liu Gang. Optimisation of agricultural economic structure based on factor analysis and intelligent algorithms[J]. Acta Agriculturae Scandinavica, Section B — Soil & Plant Science,2021,71(8):

[3] Centobelli Piera, Cerchione Roberto,Esposito Emilio,Passaro Renato,Shashi. Determinants of the transition towards circular economy in SMEs: A sustainable supply chain management perspective[J]. International Journal of Production Economics,2021,242:

[4]Yao Liu,Pei Lin Zhang,Hong Gang Liu. Manufacturing Enterprise Suppliers Selection Based on Improved TOPSIS Method[J]. Applied Mechanics and Materials,2014,3365:

[5]Mengru Shen,Xiaoran Pang,Tong Chen,Lei Tang,Hui Wan. Research on Power Enterprise Supplier Management System Based on Supplier Deep Portrait[J]. E3S Web of Conferences,2021,257: