

Study of ordering and transportation of raw materials for manufacturing companies based on 0-1 planning

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Abstract. The job functions of supply chain management is the planning and control of logistics related to the supply chain from the supplier to the production enterprise, specifically for the entire supply chain system of a manufacturing company, the various processes of planning, coordination, operation, control and optimization are carried out. This paper focuses on quantitative analysis of the supplier's supply characteristics and solves the optimization problem by changing different constraints to establish predictive models for future pairs of ordering and forwarding solutions, respectively. Based on a quantitative analysis of the supplier's supply characteristics, this paper optimizes the total cost of delivering the right product to the right place, at the right time, in the suitable quantity, of the right quality and in the right condition, as required by the customer.

Keywords: CRITCI weighting method, TOPSIS method, 0-1 planning, LINGO.

1. Introduction

The ordering and transportation of raw materials for manufacturing companies is crucial to the survival and growth of current businesses. In today's market environment, raw materials are as important as the lifeblood of an enterprise for a building materials manufacturer. Under the pressure of today's competitive market, enterprises pay more attention to the ordering and transportation of raw materials. Raw materials are an important element of productivity. As an object of labor, raw materials are constantly consumed in the production process and become products. The continuity of enterprise production requires constant replenishment of new raw materials, and the demand for raw materials will continue to increase as the enterprise grows. However, to choose the most suitable and least expensive raw materials, it is necessary to study and analyze a lot of data to determine the amount of raw materials needed for a certain working time to ensure that the enterprise can work in an orderly manner for a long time. It is also necessary to make a reasonable forecast for the future in order to develop a new work quarter.

In this paper, we first quantified the supply characteristics of 402 suppliers and established a mathematical model reflecting the importance of securing the production of the enterprise, based on which we identified the 50 most important suppliers and presented the results in a table in the paper.

On this basis, it is considered that the enterprise should choose at least how many suppliers to supply raw materials in order to be able to meet the demand of production. For these suppliers, develop the most economical weekly raw material ordering scheme for the enterprise for the next 24 weeks, and accordingly develop the least lossy transshipment scheme. The final analysis of the effectiveness of the implementation of the ordering and transit programs.

2. Quantitative modeling analysis of supply characteristics

We quantified the supply characteristics of 402 suppliers, evaluated them and selected the 50 most important suppliers on the basis of merit. This requires us to select appropriate indicators to study the supplier's supply characteristics, calculate the stability and robustness of the supplier's supply of raw materials, thus reflecting whether the supplier is in balance with the supply of the company, and rank the 402 suppliers in terms of importance, and then select the 50 most important suppliers.

2.1. Evaluation index screening

Based on the weekly supply quantity of 402 suppliers and the weekly order quantity of enterprises over a period of 5 years and the type of raw materials supplied, the weekly supply quantity is S and the weekly order quantity is O . After consulting the relevant literature and based on the data given in Annex I, we constructed the following four important indicators to evaluate the suppliers [1].

2.1.1 Supply continuity C

Supply continuity, reflecting whether the supplier is a continuous or intermittent supplier to the enterprise. That is, the number of weeks that the supplier supplies in the case of an order from the company. When the supplier completes such a condition, it is considered to have maintained continuity. The greater the supply continuity C , it means that the supplier is a long-term supply partner, continuous supply to the enterprise, greater reliability, the enterprise will be long-term development, will not lead to shortage of raw materials, capacity constraints, the importance of the protection of enterprise production will be correspondingly higher [2].

The specific calculation formula is.

$$C = num(O > 0, S > 0) + num(O = S = 0) \quad (1)$$

2.1.2 Total supply volume share η

The total supply share η indicates the proportion of the total supply of the supplier to the total order quantity of the enterprise for the type of raw materials. The larger the total supply share η indicates that the supplier is the main supplier of a certain type of raw materials, which means that the supplier is more reliable and is the main trading partner of the enterprise, which is in line with the supply principle of the enterprise, and the enterprise will not change the raw material supplier frequently, which affects the production capacity of the enterprise, and the more important it is to guarantee the production of the enterprise[3].

Its specific calculation formula is.

$$\eta = \frac{\sum_{i=1}^{i=240} S}{\sum_{i=1}^{i=240} O} \quad (2)$$

2.1.3 Supply capacity A

Supply capacity A indicates that the supplier meets the ordering ratio, that is, whether the supply is greater than or equal to the order quantity, less than or more than the ratio of the order. The greater the supply capacity means that when the order quantity is the same, the greater the supply quantity, the stronger the supplier, the stronger the ability to supply, the more the raw materials ordered by the enterprise can be guaranteed, the smaller the ordering risk, the higher the importance of its protection of enterprise production.

The specific calculation formula is.

$$A = \frac{S - O}{O} \quad (3)$$

2.1.4 Availability rate R

The supply rate R indicates that the supplier's supply is not less than the ratio of the order quantity ordered by the enterprise from that supplier to all ordering situations. The larger the supply rate R indicates that the supplier completes the enterprise's quantitative number of weeks, representing the higher reliability of the enterprise, can complete or exceed the enterprise's ordering needs many times, the enterprise is not prone to produce raw material shortage capacity dilemma, the higher its importance to protect enterprise production[4].

2.2. CRITIC Model

The following construction of supplier supply characteristics of the comprehensive evaluation of CRITIC weight model: selected supply continuity, total supply share, supply capacity, supply rate a total of four indicators, using the supplier supply and business order data given in Annex I within 5 years to 402 suppliers for a comprehensive evaluation.

CRITIC weighting method uses the volatility and correlation of the data, but not the larger the value of the data means that the more important the indicator, but completely use the objective properties of the data itself, scientific evaluation. Since the data of the indicator of total supply share is much smaller than other indicators, the resulting fluctuation will be large and affect the correct determination of the weight, so we need to quantize the original data in order to unify the units of the data and ensure that the standard deviation of the data will not be large. Since the normalization process makes the standard deviation all become the number 1, i.e., the standard deviation of all indicators is exactly the same, which leads to the volatility indicators being meaningless[5]. Therefore, this paper normalizes the original data. Since all the selected indicators satisfy the potential factor that the larger the data, the better the supplier supply characteristics performance, there is no need to reverse the raw data. In this study, the data related to the continuity of supply, total supply share, supply capacity, and supply rate (4 indicators in total) of 402 suppliers were calculated by using the supply volume and order quantity data of 402 suppliers in 5 years. The CRITIC weight calculation was carried out to derive the specific weight of each indicator separately. Considering that there are no obvious outliers in the data, it is not necessary to remove the abnormal invalid sample data, and the analysis first needs to be quantified and then analyzed using the processed data.

Table 1. CRITIC weighting calculation results

item	Variability of indicators	Conflicting indicators	Amount of information	Weights
MMS_ Supply continuity	0.271	1.198	0.324	24.21%
MMS_ Total supply volume share (%)	0.115	1.984	0.229	17.07%
MMS_ Supply rate (%)	0.228	1.601	0.365	27.25%
MMS_ Supply capacity (%)	0.260	1.624	0.422	31.47%

From Table 1, it can be seen that there is no significant difference between the 4 indicators in terms of the variability of the indicators, relatively speaking, the variability of the indicator of the total supply share is small, which means that its fluctuation is small and the weight will be relatively small. In terms of indicator conflict, the indicator of supply capacity has a very strong conflict, which means that the correlation between this indicator and the other 5 indicators is weak, and it can carry relatively more independent information, and the information overlap between the remaining 3 indicators is small, so the weight of the indicator of supply capacity will be higher, and the weight of the remaining 2 indicators is basically the same. The weighted histogram, as in Figure 1.

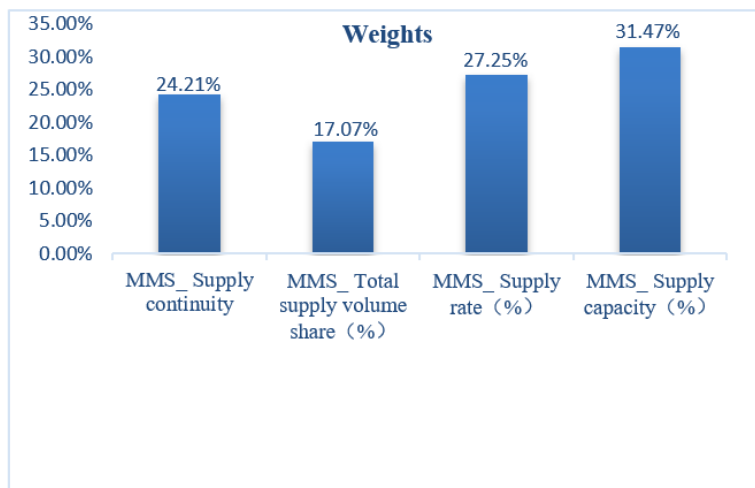


Figure 1. The weighted histogram

2.3. Determination of the evaluation system

TOPSIS method is used to study the sequential selection technique of similarity with the ideal solution, which is commonly understood that the data size has a superior and inferior relationship, the larger the data the better and the smaller the data the worse. The calculation formula is as follows.

$$D^+ = \sqrt{\sum_{j=1}^m W_j * (A_j^+ - data_{ij})^2} \tag{4}$$

The data are prepared and homotrended, i.e., let all the data be expressed as the larger the number the better (if the larger the number of an indicator item is instead the worse, and normalized to solve the gauge problem, and then find the positive and negative ideal solutions (A+ and A-) for the evaluation indicators.

Then, the distance values D+ and D- of each evaluation object from the positive and negative ideal solutions are calculated, respectively. Based on the D+ and D- values, the proximity of each evaluation object to the optimal solution (C-value) is finally calculated and can be ranked with respect to the C-value, and finally a conclusion is drawn [6].

The TOPSIS evaluation was conducted for 4 indicators (supply continuity, total supply share (%), supply capacity (%), and supply rate (%), and 402 objects were evaluated at the same time (the number of sample size is the number of objects). The results of the ranking are shown in Table 2.

Table 2. Supplier Ranking Table

Rank	1	2	3	4	5	6	7	8	9	10
SuppliersID	S229	S361	S140	S108	S151	S282	S340	S275	S329	S139
Rank	11	12	13	14	15	16	17	18	19	20
SuppliersID	S131	S330	S356	S308	S268	S306	S194	S352	S374	S143
Rank	21	22	23	24	25	26	27	28	29	30
SuppliersID	S348	S307	S247	S007	S284	S266	S365	S098	S031	S338
Rank	31	32	33	34	35	36	37	38	39	40
SuppliersID	S076	S150	S114	S080	S314	S218	S123	S364	S040	S367
Rank	41	42	43	44	45	46	47	48	49	50
SuppliersID	S055	S244	S294	S086	S346	S291	S037	S129	S213	S003

The 229th supplier ranked first The 229th supplier has been the top supplier for more than 400 suppliers in the past five years, and has been supplying to the company steadily for a long time, and has a high level of supply capacity, the calculation results are consistent with the data mentioned, and the model is reasonable.

3. Determination of ordering options

We can follow the basic solution ideas of planning class problems to start, that is, to establish the data source, set the objective function and constraints, and the objective function and constraints expressed as a function of the decision variables, if the constraints and objective function are linear, that is, the mathematical equations that represent the constraints are linear equations or linear inequalities, the objective function that represents the optimization index of the problem is linear, then the problem is linear, and vice versa belongs to the nonlinear planning problem, after establishing the mathematical planning model, and then use Lingo to solve the planning model to get the final answer[7].

3.1. Minimum Supplier Program

We will 14 suppliers of the weekly supply of the upper limit matrix is set to *UPPERA*, the weekly supply of the average matrix is set to *avg*, the weekly supply of the maximum matrix *max* matrix, then *avg* matrix, *max* matrix and *UPPERA* matrix dimensions are 14 rows and 24 columns, the row number and column number indicate the supplier ID and weekly serial number, respectively, each of the three supply matrix element values are expressed in each year at the time node of the supply of the characteristic value, that is, respectively, on behalf of the average, maximum and upper limit, and the upper limit depends on the average and maximum, then set their functional relationship as.

$$UPPERA = avgA + max A \tag{5}$$

We find the weekly supply ceiling matrix for the 14 type A suppliers set *UPPERA* as.

$$UPPERA = \begin{pmatrix} 7709 & 2138 & \dots & 2092 \\ 1812 & 909 & \dots & 780 \\ \dots & \dots & \dots & \dots \\ 715 & 436 & \dots & 290 \end{pmatrix} \tag{6}$$

Similarly, we can obtain *UPPERB*, *UPPERC*.

3.1.1 Decision Variables

In this planning model, in order to find the minimum number of suppliers to be chosen by the firm, it is necessary to know which of these suppliers will be chosen by the firm. The following 14 suppliers of supply A as an example, the selection of the 14 suppliers of 24 weeks into a 0/1 matrix *CEA* as the decision variables of this subquestion[8]. If the value of the element is 1, the supplier supplies to the enterprise, i.e., the supplier is selected, and the goods are purchased according to the maximum supply; if the value of the element is 0, the supplier does not supply to the enterprise, i.e., the supplier is not selected. Similarly, we can also derive the 0/1 matrix *CEB*, *CEC*.

3.1.2 Objective function

In this planning model, the objective function is to find the minimum number of suppliers. In this regard, we sum the elements of the decision variable matrix *CEA*, and the resulting sum is the number of weeks that the supplier will supply to the company in the next 24 weeks. If the sum is equal to 0, then the supplier has not been selected in the 24-week supply process; if the sum is greater than 0, then the supplier has been selected at least once in the 24-week supply process; the total number of non-zero columns is the number of A raw material suppliers selected by the enterprise. Similarly, we also do the same for *CEB*, *CEC*. Then the objective function *z1* expression can be.

$$\min z_1 = \sum_{j=1}^{14} \left[\sum_{i=1}^{24} (CEA)_{ij} \right] + \sum_{j=1}^{15} \left[\sum_{i=1}^{24} (CEB)_{ij} \right] + \sum_{j=1}^{31} \left[\sum_{i=1}^{24} (CEC)_{ij} \right] \tag{7}$$

3.1.3 Binding Conditions

The company has to keep as much raw material in stock as possible at the time of purchase for not less than two weeks of production demand, while the production capacity of the company is 28,200 cubic meters per week, which requires 0.6 cubic meters of raw material A, or 0.66 cubic meters of raw material B, or 0.72 cubic meters of raw material C per cubic meter of product. Therefore, we calculate the production capacity provided by raw materials A, B and C, and then add them up, requiring the final value to be greater than the required capacity of 2.82×10^4 cubic meters. The additional consideration here is that, assuming that the first week's inventory is zero, two weeks' worth of raw materials need to be purchased. So the corresponding production capacity is 5.64×10^4 m³ and for the remaining weeks, it is sufficient to purchase one week's worth of raw materials. The specific mathematical expression is [9].

$$u \times \left(\frac{CEA \cdot UPPERA}{0.6} + \frac{CEB \cdot UPPERB}{0.66} + \frac{CEC \cdot UPPERC}{0.72} \right) \geq \begin{pmatrix} 5.64 \times 10^4 & & & & & & & & & \\ & 2.82 \times 10^4 & & & & & & & & \\ & & \dots & & & & & & & \\ & & & & & & & & & 2.82 \times 10^4 \end{pmatrix} \quad (8)$$

In particular, only the diagonal part of this equation is meaningful, representing the total supply of raw materials of the corresponding week type A. The weeks selected in other positions do not correspond to the weeks corresponding to the week maximum, and the multiplication result is meaningless.

3.1.4 Model solving

According to the above planning model, the company should choose at least 43 suppliers to supply raw materials in order to meet the production needs. The selected suppliers are listed in the table 3.

Table 3. Selected supplier serial number table

Rank	1	2	3	4	5	6	7	8	9
SuppliersID	S007	S025	S30	S50	S53	S64	S66	S174	S67
Rank	10	11	12	13	14	15	16	17	18
SuppliersID	S75	S76	S86	S92	S106	S113	S175	S139	S140
Rank	19	20	21	22	23	24	25	26	27
SuppliersID	S149	S152	S157	S169	S172	S178	S197	S206	S213
Rank	28	29	30	31	32	33	34	35	36
SuppliersID	S221	S237	S239	S253	S266	S269	S307	S310	S314
Rank	37	38	39	40	41	42	43		
SuppliersID	S324	S332	S338	S342	S374	S379	S392		

3.2. Ordering options

3.2.1 Objective function

To determine the most economical raw material ordering program each week, i.e., the least costly ordering program, the objective function is the cost of the ordering program. The cost sought is the cost of ordering A, B, C raw materials for the building materials manufacturer. Due to the special nature of raw materials, suppliers can not guarantee the supply strictly according to the order quantity, the actual supply may be more or less than the order quantity, but the enterprise in order to ensure that the normal production needs, the actual supply of raw materials suppliers always buy all [10]. This means that the amount of raw materials acquired is not equal to the order quantity of the enterprise, but equal to the supplier's supply minus the amount of losses caused by the transfer to the warehouse. Since the unit cost of transporting and storing the three types of raw materials is known to be the same, let the unit cost of transporting and storing be cost . Since the unit prices of raw materials of categories A and B are 20% and 10% higher than those of category C, respectively, let

the unit price of raw materials of category C be , then the unit prices of raw materials of categories A and B are $1.2 \times a$ and $1.1 \times a$, respectively.

From this we can obtain the expression of the objective function.

$$\min z_2 = 1.2 \times a \times \sum_{i=1}^X (HA)_{ij} + 1.1 \times a \times \sum_{i=1}^X (HB)_{ij} + 1 \times a \times \sum_{i=1}^X (HC)_{ij} \quad (9)$$

3.2.2 Binding Conditions

For all suppliers in any week, the upper limit of the supply of raw materials at a supplier will not exceed the maximum supply of raw materials that the supplier can provide in that week.

Taking the first week as an example, the expression of the constraint function is obtained.

$$H_A \leq MAX_{A,1} \quad (10)$$

$$H_B \leq MAX_{B,1} \quad (11)$$

$$H_C \leq MAX_{C,1} \quad (12)$$

Secondly, in order to protect the normal production needs of enterprises, to set aside as much as possible two weeks of production needs of raw materials inventory of which each cubic meter of products need to consume A class raw materials 0.6 cubic meters, or B class raw materials 0.66 cubic meters, or C class raw materials 0.72 cubic meters, respectively, to calculate the production capacity provided by raw materials A, B, C, cumulative, and the final value required to be greater than the production capacity of building materials enterprises 28,200 cubic meters. For the first week, "in order to ensure the needs of normal production, the enterprise should, as far as possible, maintain a stock of raw materials not less than to meet the production needs of two weeks". In other words, the company needs to purchase the raw materials required in the first week and the second week, so the corresponding production capacity is 56,400 cubic meters. Each week thereafter, only the raw materials for the next week are to be purchased.

The expression of the constraint function is obtained by taking the first week as an example.

$$98\% \times \left(\frac{\sum_{i=1}^X (H_A)_{ij}}{0.6} + \frac{\sum_{i=1}^X (H_B)_{ij}}{0.66} + \frac{\sum_{i=1}^X (H_C)_{ij}}{0.72} \right) \geq 5.64 \times 10^4 \quad (13)$$

Finally, the amount of raw materials available at a supplier in that week will not exceed the maximum amount of raw materials available from the supplier in that week.

Taking the first week as an example, the expression of the constraint function is obtained.

$$HA \leq MAX_A \quad (14)$$

$$H_B \leq MAX_{B,1} \quad (15)$$

$$H_C \leq MAX_{C,1} \quad (16)$$

4. Conclusion

In this paper, a planning-type model is used to analyze the production planning scheme, and the linear planning process is computationally simple and easy to solve.

This paper uses simulation process, bringing theoretical values into the model several times for simulation, and the data results are more scientifically based.

This paper cleverly uses flowcharts to show the modeling ideas completely and clearly.

Using SPSSAU software, LINGO software and MATLAB software to normalize the data and make graphs, with textual theoretical analysis makes this paper not only clear and intuitive, but also more persuasive.

The combination of ARIMA prediction model and exponential smoothing prediction model is used to find a more realistic prediction model and give more ideal prediction results.

Ordinary mathematical planning models converge slowly and may converge to the local optimal solution, but not to the global optimal solution.

In addition to the application in production, it can be extended to the problems of selling and path planning, which have a wide range of applications.

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