ISSN 2616-5805 Vol. 3, Issue 2: 48-56, DOI: 10.25236/AJMS.2022.030208

Mathematical Model for Ordering and Transporting Raw Materials for Production Companies

Liang Gao[1], Lili Cheng[2,*], Yanxiang Wang[3], Zhenwei Ma[4]

[1]*College of Mathematics and Computer Science, Yan'an University, Yan'an, China*
[2]*School of Economics and Management, Yan'an University, Yan'an, China*
[3]*Medical School of Yan'an University, Yan'an University, Yan'an, China*
[4]*School of Marxism, Yan'an University, Yan'an, China*
[*]*Corresponding author: 2531014128@qq.com*

Abstract: *This paper analyzes the problem of ordering and transporting raw materials for production in an enterprise, and uses a linear programming model to solve the following problems: (1) The problem that suppliers cannot supply goods according to demand is solved. We use the TOPSIS evaluation model to weight each supplier according to different indicators to derive the importance value of suppliers and select 50 suppliers that meet the requirements. We analyze the data and calculate the minimum number of suppliers to supply raw materials to meet the demand of production, and construct a linear programming model to calculate the number of suppliers with the lowest cost under the condition of guaranteed capacity. (2) To solve the problem of certain loss of raw materials during transportation, we first consider the ordering quantity, price, transportation loss in transit, and storage price of raw materials; then we analyze the data and construct a multi-objective planning model, and find the final ordering plan and transit plan through a large amount of data analysis; finally, we analyze the feasibility of the plan. (3) In order to maximize the production capacity of the enterprise, the maximum supply quantity of the supplier is obtained through analysis, and the ordering scheme is determined by combining the supplier's past performance; the transshipment scheme is determined according to the ordering scheme and the transshipment loss rate.*

Keywords: *Ordering Scheme, Transit Scheme, Planning Model, TOPSIS Method*

1. Introduction

For the ordering and transportation of raw materials in manufacturing enterprises, on the one hand, enterprises have a fixed weekly production capacity, but the consumption of raw materials per unit of product A, B and C is different; on the other hand, due to the material itself, the supply side is unable to provide products that can meet the needs of the enterprise itself and various unavoidable losses occur in the distribution process, so it is necessary to take scientific ordering measures according to the actual situation [1-3]. For the company, the directness of the product determines the interests of the company. Therefore, it is very important for companies to choose the right company in order to reduce losses to a minimum and gain maximum profit [4-5].

A manufacturer of architectural and decorative panels produces in 48 weeks per year and needs to plan in advance the ordering and forwarding of raw materials for the next 24 weeks of production. Due to the special nature of the production raw materials, the supplier cannot guarantee that the supply will be strictly in accordance with the company's order quantity, and the actual supply quantity will fluctuate around the company's order quantity.

This paper combines the above restricted information and possible contingencies to make an ordering and forwarding plan for the next 24 weeks for this business that satisfies the topic, as follows.

(1) Quantitative analysis of the supply characteristics, the establishment of a mathematical model reflecting the importance of ensuring the production of the enterprise, on the basis of which the 50 most important suppliers are identified.

(2) Consider the minimum number of suppliers that an enterprise should choose to provide raw materials for the enterprise to meet its own production capacity needs, determine the most economical raw material ordering scheme based on the enterprise's economic consumption as the ordering target, and develop a transfer scheme with the least loss in the transfer process based on the ordering scheme.

ISSN 2616-5805 Vol. 3, Issue 2: 48-56, DOI: 10.25236/AJMS.2022.030208

(3) Among the 402 companies, we redesigned their ordering and transfer programs for the next 24 weeks with the goal of minimizing total ordering costs and total transfer consumption [6].

(4) According to the existing actual situation, the enterprise gradually develops and grows over time, and it is necessary to predict whether and how much the weekly capacity can be increased in the future, and to give the relevant specific transfer and ordering scheme.

2. Supplier selection

2.1 Supplier Ranking

2.1.1 Modeling

In this section, we construct a mathematical model of "evaluation + decision making", based on the TOPSIS method for comprehensive evaluation analysis, and rank the scores of suppliers to make a choice.

The TOPSIS method is often used to conduct comprehensive evaluation by using raw data, and its basic principle is to rank the evaluation objects by detecting the distance between them and the optimal and inferior solutions. The value of each index of the optimal solution reaches the optimal value of each evaluation index, and the value of each index of the worst solution reaches the worst value of each evaluation index. The solution steps are.

(1) The original data matrix is orthogonalized to obtain the orthogonalized matrix.

Depending on the type of indicator, different formulas need to be followed for forwarding, i.e., converting all indicators to very large. The conversion to very small is easy, as the data in this topic are all non-negative, so it is straightforward to use the inverse of the data.

(2) The normalization of the normalized matrix can then eliminate the influence of the magnitude of each indicator.

$X=\begin{bmatrix} X11 & \cdots & X1m \\ \vdots & \ddots & \vdots \\ Xn1 & \cdots & Xnm \end{bmatrix}$, the first question has 402 objects to be evaluated (suppliers) have 4 evaluation indicators (supply quantity, order quantity, supply stability, and order ratio), so the matrix is a 402*4 matrix.

Noting the normalized matrix as Z, each element in it is equal to the value taken by the element in the corresponding matrix X divided by the square of the element in its column and the open root sign, i.e.

$$Zij = \frac{Xij}{\sqrt{\sum_{i=1}^{n} Xij^2}} \tag{1}$$

Define the maximum value as the set of the maximum values of the elements in each column, as follows:

$$\mathrm{z}^{+} = (\max(z_{11}, z_{12}, ..., z_{n1}), \max(z_{12}, z_{22}, ..., z_{n2}), ..., \max(z_{1m}, z_{2m}, ..., z_{nm})) \tag{2}$$

(This expression means that taking the maximum value of each row in the matrix separately constitutes an n-dimensional vector of max)

Define minimum as the set of minimum values for each column element, as follows:

$$\mathrm{z}^{-} = (\min(z_{11}, z_{12}, ..., z_{n1}), \min(z_{12}, z_{22}, ..., z_{n2}), ..., \min(z_{1m}, z_{2m}, ..., z_{nm})) \tag{3}$$

(This expression means that the maximum value of each row in the matrix is taken separately to form a min n-dimensional vector)

Then the distance of the i-th evaluation object from the maximum value is the summation of the j indicators after calculating the distance from the maximum value respectively:

$$D_i^{+} = \sqrt{\sum_{j=1}^{m} (z_j^{+} - zij)^2} \tag{4}$$

ISSN 2616-5805 Vol. 3, Issue 2: 48-56, DOI: 10.25236/AJMS.2022.030208

Similarly, the i-th evaluation object and the minimum value distance is the summation formula after calculating the distance between the j-th indicator and the minimum value, respectively.

$$D_i^- = \sqrt{\sum_{j=1}^{m} (z_j^- - zij)^2} \quad (5)$$

Then, the unnormalized score of the i-th evaluation object is $S_i = \frac{D_i^-}{D_i^+ + D_i^-}$. Obviously, Si takes values between 0 and 1, and the larger D_i^+ is, the larger Si is, the closer it is to the optimal solution. After normalization, the score is:

$$S\tilde{i} = \frac{Si}{\sqrt{\sum_{i=1}^{n} Si^2}} \quad (6)$$

(3) Find the optimal solution based on the ranking, i.e., select the 50 most important suppliers.

After getting the scores of all solutions, the sorted supplier ranking can be displayed visually, and a line graph and final ranking can be drawn using Excel.

2.1.2 Solution of the model

(1) Sum of supply quantities by line graph analysis as shown in figure 1.

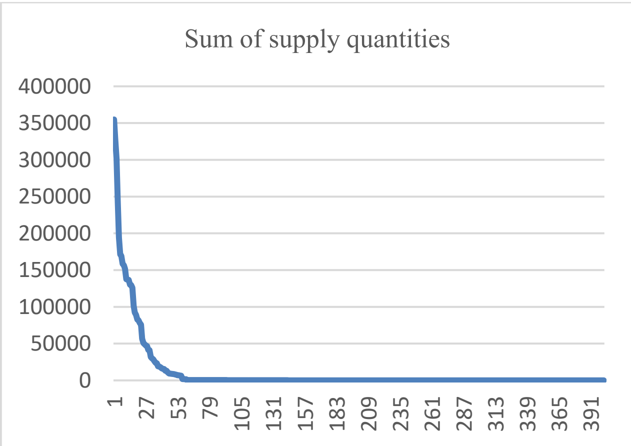

Figure 1: Sum of supply quantities

(2) Analysis of the sum of order quantities by line graph as shown in figure 2.

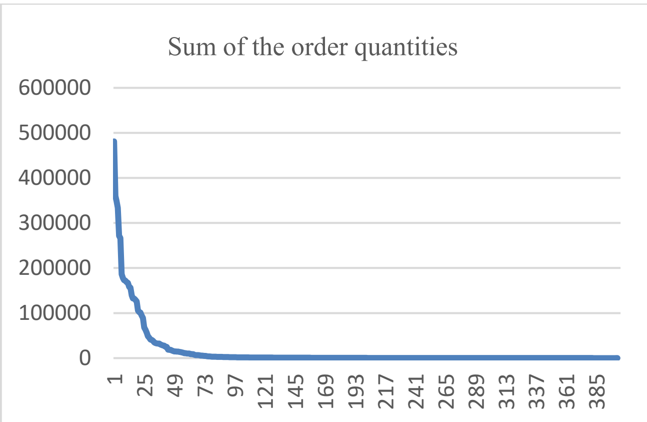

Figure 2: The sum of the order quantities

(3)Use Matlab to analyze the data and do normalization of the data. Use D_P=sum([(Z-repmat(max(Z),n,1)).^2],2).^0.5, find the distance vector between D+ and the maximum value; apply D_N=sum([(Z-repmat(min(Z),n,1)).^2],2).^0.5, find the distance vector between D- and the minimum. The result as shown in Table1.

(4)Use stand_S = S / sum(S)% normalized formula to get the score.

ISSN 2616-5805 Vol. 3, Issue 2: 48-56, DOI: 10.25236/AJMS.2022.030208

Table 1: Surface 2 Supplier Comprehensive Evaluation Ranking

supplier	Score	D_P	D_N	total supply	total order quantity	Delivery rate	Reciprocal stability rate	Supply stability rate
S140	0.017472464	0.126670666	0.573810632	302047	481103	0.627821901	0.000433268	2308.041215
S229	0.0166450036	0.1516362072	0.538792375	354887	359885	0.98611223	0.002795414	357.7288194
S361	0.0158215055	0.1738061089	0.49925142	328080	333452	0.983889735	0.003215606	310.9833333
S108	0.0127559062	0.2584319036	0.384499505	240950	271445	0.8876568	0.002066168	483.9878472
S151	0.0114463067	0.2948278024	0.341458909	194498	266510	0.729796255	0.00257785	387.9202083
S201	0.0102997024	0.3647080039	0.340566147	81989	348699	0.235128291	0.001651417	605.5404861
S340	0.0088846009	0.3737347001	0.266813733	171426	172000	0.996662791	0.00780267	128.16125

2.2 Supplier Selection

2.2.1 Modeling

(1) Basic model:

Establish a linear programming model for supplier selection.

(2) Model Principle:

Linear programming model is used to deal with the problems in people's daily production life

(3) Data pre-processing:

The suppliers are classified and ranked according to the supply materials of each supplier, and after the model is established, the suppliers are selected by analysis in the order of the previous one.

(4) Modeling:

The initial optimization problem for the number of suppliers selected to meet the capacity of the enterprise as little as possible, but also the most said: the important optimization is to ensure the selection of the least number of suppliers, the goal of optimization is to select the number of suppliers, the analysis can be obtained, A, B, C three suppliers have to meet the score is very high, the supply is very large and high supply stability, the supplier is reliable, should be preferred.

Raw materials can be composed of A or B or C. Let the enterprise have weekly production of x1 is done by A, x2 is the production is done by B, x3 is the production is done by C. And x3 needs to meet the production needs of the enterprise as well as the supply ceiling of each supplier. First, the optimal value of each raw material selection is initially derived by solving the planning problem through LINGO.

Objective function:

$$\min = 1.2 * x_1 + 1.1 * x_2 + x_3$$

Constraints:

$$\frac{x_1}{0.6} + \frac{x_2}{0.66} + \frac{x_3}{0.720} \geq 28200$$

$$x_1 \leq 11178.46$$

$$x_2 \leq 6909.978$$

$$x_3 \leq 514.798$$

The second optimization is to meet the enterprise's own production conditions to develop 24 weeks of the lowest economic cost of raw materials ordering program, to meet the initial optimization after the completion of the selection of the supplier conditions, according to the goal of the lowest cost, in these

ISSN 2616-5805 Vol. 3, Issue 2: 48-56, DOI: 10.25236/AJMS.2022.030208

suppliers to take the amount of optimization, in order to minimize the economic goal.

The last step of optimization requires the lowest rate of loss in the transfer of raw materials for the enterprise, not only to meet the needs of the enterprise's own production volume, but also to meet the transfer volume of each forwarder not more than 6000. on the basis of the previous optimization step, using EXCEL analysis to obtain the weekly loss rate of each forwarder and the amount of raw materials transferred, that is, 24 weeks of the enterprise transfer program.

Construct the matrix T=[T1,T2,T3,T4,T5,T6,T7,T8], let each element of the matrix be tij, the transshipment merchant loss be sj, and the number of raw materials to be shipped be Gi, so a new objective function of planning can be obtained.

Objective function:

$$\min = \sum_{i=1,j=1}^{j=8} G(i) \times t_{ij} \times s_j$$

2.2.2 Solution of the model

Data processing

(1) First express the effective number of supplies for each supplier.

(2) Then calculate the supply and for each enterprise.

(3) Calculate the effective average supply of the supplier.

(4) Calculate the average capacity of suppliers, and rank them from largest to smallest according to the resulting capacity.

Select out the suppliers to meet the production demand - the company should maintain as much as possible not less than the supply of raw materials to meet the production demand for two weeks, that is, to be greater than or equal to 28,200 cubic meters. 21 suppliers were selected using EXCEL as shown in the table.2 below.

Table 2: Suppliers Selected

Supplier ID	Effective delivery week	supply and	average supply	average capacity
S201	28	81989	2928.178571	4880.297619
S229	240	354887	1478.695833	2464.493056
S140	219	302047	1379.210046	2089.71219
S361	240	328080	1367	1898.611111
S395	74	75843	1024.905405	1708.175676
S108	240	240950	1003.958333	1521.14899
S282	240	169340	705.5833333	1175.972222
S151	240	194498	810.4083333	1125.56713
S275	240	158553	660.6375	1101.0625
S329	240	156518	652.1583333	1086.930556
S340	240	171426	714.275	1082.234848
S139	222	151862	684.0630631	1036.459186
S131	240	137512	572.9666667	868.1313131
S308	240	136998	570.825	864.8863636
S330	240	136652	569.3833333	862.7020202
S348	194	92421	476.3969072	793.9948454
S307	171	78196	457.2865497	762.1442495
S356	240	130307	542.9458333	754.0914352
S268	240	129786	540.775	751.0763889
S306	240	126096	525.4	729.7222222

3. Order program and transit program

3.1 Ordering options

Objective function:

ISSN 2616-5805 Vol. 3, Issue 2: 48-56, DOI: 10.25236/AJMS.2022.030208

$$\min = 1.2*x_1 + 1.1*x_2 + x_3$$

Constraints:

$$\frac{x_1}{0.6} + \frac{x_2}{0.66} + \frac{x_3}{0.720} \geq 28200$$

$$x_1 \leq 11178.46$$

$$x_2 \leq 6909.978$$

$$x_3 \leq 514.798$$

(1) The supply of each supplier is calculated and evaluated each week, the supply products of different suppliers are classified, and the total output of the enterprise is calculated every week.

(2) Weekly capacity analysis.

Firstly, by analyzing the data of weekly supplier's supply in Annex 1, we get the weekly supply and; Secondly, according to the question, we know that for every 1 cubic meter of product, we need to consume 0.6, 0.66 and 0.72 cubic meters of raw material A, B and C. Let the quantities of A, B and C products ordered are x1, x2, x3, and by the relationship between raw material consumption and production capacity (production capacity = x1/0.6+ x2/ 0.66+ x3/0.72) to obtain the total weekly production capacity. The total weekly capacity is sorted and filtered to determine the ordering data that meet the enterprise's capacity requirements. The graph of partial ordering options that meet the enterprise capacity requirements is shown in the following table 3.

Table 3: Partial ordering options

S174	B	0	1	2	2	5
S024	B	0	3	0	0	0
S276	B	0	0	0	0	0
S079	B	0	0	0	0	0
S175	B	3	2	3	4	5
S272	B	0	0	0	0	0
S050	B	0	0	0	0	0
S259	B	0	0	0	0	0
S319	B	0	0	0	0	0
S311	B	0	0	0	0	0
S146	B	1	1	0	1	1
S230	B	0	0	0	0	0
S098	B	1	2	2	1	3
S166	B	0	0	0	0	0
S333	B	0	0	0	0	0
S224	B	0	0	0	0	1
B Sum	B	19482	3675	20584	22004	25304
B capacity Sum	B	29518.18182	5568.181818	31187.87879	33339.39394	38339.39394
A+B capacity Sum	A + B	36319.84848	28704.84848	39311.21212	40907.72727	44976.06061

In order to save costs, only suppliers A and B are selected to supply, and weekly weekly production capacity is calculated based on the availability of raw materials from each supplier, and the data that cannot reach the weekly production capacity of the enterprise is eliminated to get the 24-week data that can reach the production capacity requirement by supplying only A and B, i.e., the 24-week ordering plan of the enterprise. The weekly production distribution is shown in the figure 3 below.

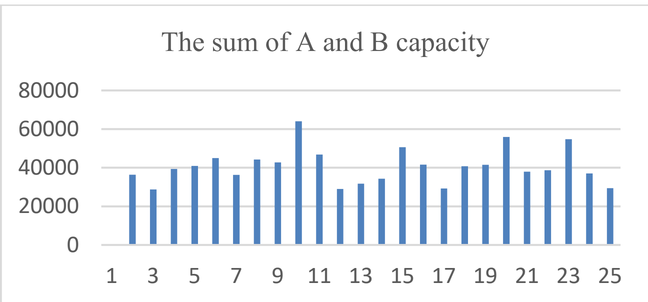

Figure 3: The sum of A and B capacity

3.2 Transit program

According to the transport capacity of each forwarder is 6000 cubic meters per week, the average effective loss rate of 8 forwarders is found out, and the average effective loss rate of these 8 forwarders is ranked from largest to smallest, the smaller the loss rate, the higher the priority, and the priority of these 8 forwarders is T3>T6>T2>T8>T4>T1> T7>T5, as shown in the following table 4.

Table 4: Average carrier loss rate and ranking of each transshipment

forwarder	Average attrition rate	sort
T3	0.186055556	1
T6	0.543761111	2
T2	0.921370417	3
T8	1.010282759	4
T4	1.570482353	5
T1	1.904769167	6
T7	2.078833333	7
T5	2.889825301	8

In order to minimize the amount of loss in transit, for the weekly subscription program, since the maximum capacity of each forwarder is fixed at 6,000 cubic meters, the forwarding program is determined by selecting the forwarder with the lowest loss rate as much as possible within the scope of the forwarding capacity according to the loss rate ranking.

4. Order and transit program for the next 24 hours

4.1 Modeling

In real life, things evolve, and since the company has the potential to upgrade and continue to grow, the product order and supply data cannot be used from the previous five years. Therefore, we build a gray prediction model to predict the supply quantity for the next 24 weeks. We can take 24 as a cycle and use the first 10 cycles to predict the total supply quantity for the next one cycle, and we can use the first 24 weeks of the previous five years to predict the 24 weeks of the sixth year, and combine it with the top 50 ranking of problem 1 to reset the number of enterprises.

(1) The gray system theory is based on the gray derivative and gray differential equation, and further uses the discrete data column to establish a dynamic model in the form of differential equation, that is, the gray model is to do correlation analysis of the data, the use of discrete random number generation changes to the original data gray generation and according to which the generation of a significantly weaker and more regular number of sequences, the establishment of differential equation Such a model is useful for predicting and describing the future trend of the data.

(2) Steps of GM(1,1) gray prediction.

1) Perform data testing and processing.

In order to guarantee the feasibility of the model, modeling with GM(1,1) first requires the necessary tests on the data, first calculating the rank ratios of the series $\lambda(k)=\frac{x^0(k-1)}{x^0(k)}$, where k=2,3,...,n If all the rank ratios of the series fall within the tolerable coverage interval $X=(e^{\frac{-2}{n+1}},e^{\frac{2}{n+1}})$, then the series x0 can be built into the GM(1,1) gray model to predict the data.

2) Construction of gray model.

Define the gray derivative of x(1) as $d(k)=x^0(k)=x^1(k)-x^1(k-1)$, and let $z^1(k)$ be the sequence of neighboring values generated by the series x1 , i.e., $z^1(k)=ax^1(k)+(1-a)x^1(k-1)$, so that the gray differential equation model of GM(1,1) is defined as $d(k)+ax^1(k)=b$, where a is the development factor and b is called the gray action quantity.

ISSN 2616-5805 Vol. 3, Issue 2: 48-56, DOI: 10.25236/AJMS.2022.030208

$$x^0(2)+az^1(2)=b \tag{7}$$

$$x^0(3)+az^1(3)=b \tag{8}$$

$$x^0(n)+az^1(n)=b \tag{9}$$

Then listed according to the matrix method.

$$u=\begin{bmatrix} a \\ b \end{bmatrix}, Y=\begin{bmatrix} x^0(2) \\ x^0(3) \\ \cdots \\ x^0(n) \end{bmatrix}, B=\begin{bmatrix} -z^1(2) & 1 \\ -z^1(3) & 1 \\ \cdots & \\ -z^1(n) & 1 \end{bmatrix}$$

3) Data prediction.

The corresponding whitening model is:

$$\frac{dx^1(t)}{dt}+ax^1(t)=b \tag{10}$$

This yields the following solution for $x^1(t)$.

$$x^1(t)=(x^0(1)-\frac{b}{a})e^{-a(t-1)}+\frac{b}{a} \tag{11}$$

Let t+1=t to obtain:

$$x^1(t+1)=\left(x^0(1)-\frac{b}{a}\right)e^{-a}+\frac{b}{a} \quad (t=1,2,3,\ldots,n-1)$$

4) Results testing.

Calculation of residuals:

$$e(k)=x^0(k)-\hat{x}^0(k) \tag{12}$$

4.2 Solution of the model

Since the company already has the capacity to increase its production capacity through technical modifications, we can determine how much the company can increase its production capacity per week and can give an order and transfer plan for the next 24 hours, based on the specifics of the raw materials available, such as the suppliers and forwarders of the existing raw materials.

5. Conclusions

This paper analyzes the problem of ordering and transportation of raw materials for production in an enterprise, establishes the model of procurement and transportation of raw materials for the enterprise, gives the ranking of suppliers, and combines with the real conditions, reasonably selects the ordering scheme and transfer scheme, which has certain reference value.

References

[1] Qiyuan Jiang, Jinxing Xie, Jun Ye, Fundamentals of Mathematical Modeling. 2005.

[2] Jinqian Xiang, Jie Li, Huang Peiqing, Raw material purchasing and inventory strategy of industrial enterprises, Shanghai Management Science, 2004.

[3] Xiang Jinqian, Li Jie, Huang Peiqing, Corporate raw material procurement strategy and inventory control, Journal of Shanghai Jiaotong University, School of Management, 2008 (04).

[4] Cui Bin, How to control raw material procurement planning cost and inventory in enterprises, China Foreign Trade, 2010 (16).

[5] Zhou Tao, Cheng Junzhu, Third party logistics procurement model in supply chain environment, East

ISSN 2616-5805 Vol. 3, Issue 2: 48-56, DOI: 10.25236/AJMS.2022.030208

China Economic Management 2002.
[6] Zhu Daoli, Gong Guohua. Roach Logistics and Supply Chain Management [M]. Shanghai,Fudan University Press, 2001.