Planning Model Based on the Raw Material Ordering and Transportation Problems of the Production Enterprises

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Abstract: This paper mainly studies the building materials enterprise raw materials ordering and transportation, building materials market procurement efficiency, unstable supply relationship, transportation loss, established the evaluation supplier for the importance of enterprise production model, select 50 suppliers with high score, to ensure the stable supply of raw materials. At the same time, this paper also puts forward a numerical method to simulate the law of things, used to solve the ordering scheme and transportation scheme in the enterprise movement and state change, after the evaluation index test, the model effect is good.

Keywords: planning model; transportation problem; simulate the law of things method by numbers

1. Introduction

As one of the traditional pillar industries in China, the building materials industry is an important industry to drive the development of the national economy, and makes great contributions to the rapid development of China's national economy. [1-5] On the ordering and transportation of materials, domestic and foreign scholars have done a lot of research, Lee and others [6-7] have studied the existence of production/ordering start-up fees, but not allowed out of stock situation. Chand et al [8] studied situations where production startup costs exist but learning from the startup process. Bitran et al [9] studied a bulk ordering problem that allows out of stock and proposed an algorithm based on dynamic programming. [10] Li et al. studied a very general bulk ordering model, which allows out of stock, unlimited orders, and unit production costs, unit inventory costs, and shortage costs to vary over time. They proposed a very effective dynamic programming algorithm. Li et al [11] further studied a dynamic batch ordering model with a price discount and product resale, and gave an effective algorithm. So let's take the MCM2021 competition as an example to study and solve a series of problems faced by building materials manufacturers.

The raw materials used by a building materials manufacturer are mainly wood fiber and other vegetable fiber materials, which can be roughly divided into three types: A, B and C. The enterprise production by 48 weeks a year, need to make 24 weeks of raw material ordering and transfer plan, namely, according to the capacity requirements to order raw material supplier (called "supplier") and the corresponding weekly raw material order quantity (called "quantity"), determine the third party logistics company (called "transshipment") and entrust the supplier weekly raw material quantity (called "quantity") to the enterprise warehouse.

The company's weekly production capacity is 28200 cubic meters, and each cubic meter consumes 0.6 cubic meters of class A raw materials, or 0.66 cubic meters of class B raw materials, or 0.72 cubic meters of Class C raw materials. Because the raw materials are relatively special, the supplier cannot strictly follow the order quantity. In order to ensure normal production needs, the company should store as much as possible as raw materials to meet the two weeks of production demand. Therefore, the enterprise always buys all the raw materials actually supplied by the supplier (the detail are shown in Table1)

Table 1 Types of raw materials and their specific conditions

Types of raw materials	Production unit product consumption (cubic meters)	Purchase unit price ratio
A	0.6	1.2
B	0.66	1.1
C	0.72	one

Actually, in the process of transshipment, there will be a certain loss of raw materials (the percentage of loss to supply is called "loss rate"), and the quantity of raw materials actually transported to the enterprise warehouse by the forwarder is called "receiving quantity". The maximum transportation volume of each forwarder is 6000 cubic meters/week. Usually, the raw materials supplied by a supplier every week are transported by a forwarder as much as possible.

The purchase cost of raw materials directly affects the production efficiency of enterprises. In practice, the purchase unit price of Class A and Class B raw materials is 20% and 10% higher than that of Class C raw materials, respectively. The unit cost of transportation and storage of

the three types of raw materials is the same. Annex 1 gives the order quantity and supply quantity data of 402 raw material suppliers of the enterprise in the past five years. Annex 2 presents the transport loss rate data for the eight transporters. It is necessary to analyze the relevant data in depth according to the actual situation, and study the following problems:

According to the data in Annex 1, the supply characteristics of 402 suppliers are quantitatively analyzed, and to reflect the mathematical model of the importance of enterprise production, and determine the 50 most important suppliers according to the model.

The enterprise has the potential to increase production capacity through technical transformation. According to the actual situation of suppliers and forwarders of existing raw materials, determine how much the production capacity of this enterprise can be increased.

2. The Problem Analysis

The first problem is how to quantitatively evaluate the importance of suppliers to ensure the production of enterprises. We first understand the background of the problem, process and analyze the whole data, then determine the evaluation indexes by referring to the known evaluation indexes and extracting the data. Finally, we select the supplier scale and delivery capacity as the evaluation indexes, and establish a supplier evaluation model. The supplier evaluation model consists of supplier scale coefficient and delivery capacity evaluation function. Through the supplier evaluation model, we can select the top 50 suppliers, which are considered to be important for ensuring the production of enterprises.

The second problem is a traditional sensitivity analysis problem, the purpose of which is to consider the actual situation of suppliers and forwarders of existing raw materials, increase the output of enterprises as much as possible, and formulate the ordering and transshipment plan for the next 24 weeks. Therefore, we should consider the efficiency of the forwarding company (which can be expressed as the amount of forwarding/supply), the type of supplier company, and whether a supplier's raw materials are transported by a forwarder as much as possible. We propose a novel numerical simulation method to simulate the dynamic change process of enterprises and solve the changes of ordering scheme and transportation scheme when the production capacity is increased.

3. Model Assumptions

1. Assume that the same materials provided by different suppliers have the same unit price.
2. The distance from each supplier to the warehouse and the unit freight are the same.
3. Assume that the inventory in the first week of each cycle has met the capacity of the previous two weeks.

4. Symbol Description

In this paper, we will represent the valuable content by some math formula. So we are going to introduce the symbol meaning in this section.

O_{ij} means that the quantity of raw materials ordered by the enterprise from the ith supplier in week j, i=1,2,...,402, j=1,2,...,240, S_{ij} means that quantity of raw materials supplied by i supplier in week j. The more symbol description are in Table 2.

Table 2. Symbol description

symbol	meaning	unit
O_{ij}	The quantity of raw materials ordered by the enterprise from the ith supplier in week j, i=1, 2,..., 402, j=1,2,...,240.	m^3
S_{ij}	Quantity of raw materials supplied by i supplier in week j	m^3
S_i	Total quantity supplied by the i supplier within five years	m^3
t	Type of raw material, t={A,B,C}	\
S_t	Total quantity of t-type raw materials supplied by all suppliers within five years	m^3
N	Number of all suppliers	\
N_t	Number of suppliers supplying all t-type raw materials	\
θ_t	Production and consumption rate of class T raw materials, θ_A= 0.6, θ_B=0.66, θ_C= 0.72	\
β_t	T raw materials production cost ratio,β_A = 1.2,β_B =1.1, β_C= 1	\
α_{ij}	The stable supply quantity of the i th supplier in week j.	m^3

5. Modeling and Solution of Problem 1

5.1 Thinking Analysis

The main problem of this problem is how to quantify the importance of supplier guarantee enterprise production, problem solving idea is mainly: first understand the background, for the overall data analysis, then consider a variety of aspects to determine the evaluation index, finally selected the supplier scale, delivery capacity as an evaluation index, established the supplier evaluation model, the solution of problem 1 is shown in Figure 1.

5.2 Supplier Evaluation Model Building

The supplier assessment model consists of the supplier scale coefficient and the delivery capacity assessment function. Considering the importance of ensuring normal production, enterprises should focus on establishing

cooperation relationship with large scale suppliers, thus proposing the concept of supplier scale coefficient, secondly, considering the delivery capacity of suppliers

$$F(S_i) = \sum_{j=1}^{240} w_i g(S_{ij})$$

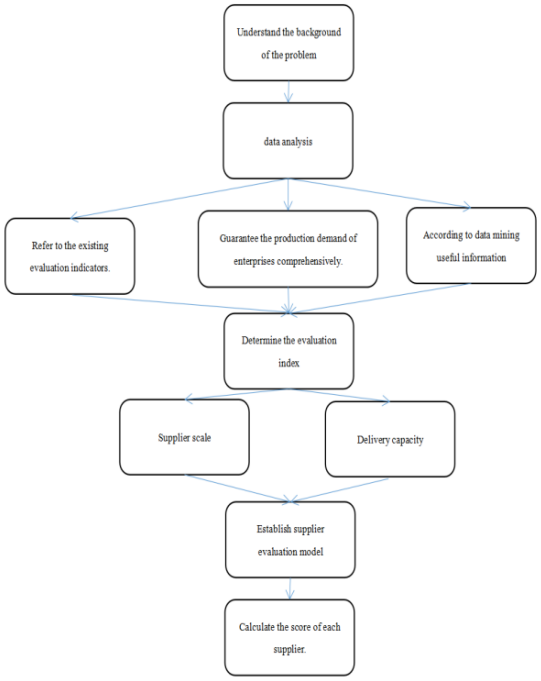

Figure 1. Solution of problem 1

5.2.1 Supplier scale factor

In this paper, the evaluation of suppliers is related to the supplier size, and the size of a supplier is an important consideration when a company chooses them. The larger the supplier is, the easier it is to establish a stable cooperative relationship with it and provide products with large quantity, good quality and low unit price. In order to better measure the enterprise size, this paper introduces the concept of enterprise scale coefficient according to the data, and the calculation formula is:

$$W_i = \frac{S_i}{S_t}$$

As we can see in Figure 2, among them, it is the total quantity supplied by the first supplier within five years, and t is the type of raw materials, divided into three raw materials: A, B and C, and it is the total quantity of t-class raw materials supplied by all suppliers within five years. Here, we use the ratio of the first supplier in the five years to the total supply of all raw materials in class t to describe the supplier size coefficient. The larger the ratio, the larger the size of the supplier S_iS_t

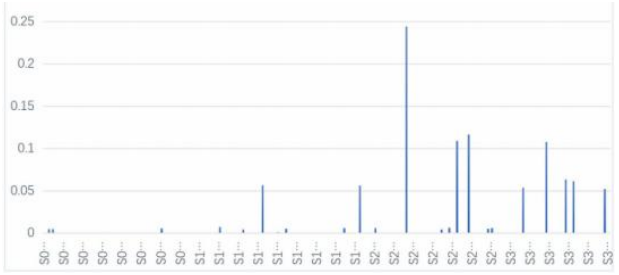

Figure 2. Scale coefficient of suppliers of class a products

As can be seen from the above table, there is a large gap in the scale coefficient of suppliers of various products, indicating that although there are hundreds of suppliers of various products, they are mainly supplied by some suppliers, and the scale gap between suppliers is large. The side reflects that when establishing a mathematical model reflecting the production of enterprises, priority should be given to the suppliers with large supplier scale coefficient.

5.2.2 Delivery capacity assessment function

According to the data given in the title, the relationship between the order quantity and the supplier's supply quantity becomes an important basis to measure the supplier's delivery capacity. In order to quantify the delivery capacity of the enterprise, we divide the delivery situation into the following four kinds: (1) when the order quantity is zero. (2) when the supply quantity is less than the order quantity. (3) when the supply quantity is greater than and less than the sum of order quantity and storage expectation. (4) when the supply quantity is greater than the sum of order quantity and storage expectation.

$$g(S_{ij}) = \begin{cases} \frac{\sum_{j=1}^{240} S_{ij}}{\sum_{j=1}^{240} O_{ij}}, O_{ij} = 0 \\ \frac{S_{ij}}{O_{ij}}, S_{ij} \le O_{ij} \\ 1, S_{ij} \le O_{ij} \le O_{ij} + q_t \\ 1 - \ln(\frac{S_{ij} - O_{ij}}{O_{ij}} + 1), S_{ij} \ge O_{ij} + q_t \end{cases}$$

5.3 Problem Solving

In the actual process of solving the problem, we first analyze the data by Excel and MATLAB, then establish the supplier evaluation model by python, and use the data given in Annex 1 to solve the problem. The top 50 suppliers are listed in Table 3.

Table 3. Top 50 suppliers with model score

ranking	supplier	**score**	ranking	supplier	**score**
1	S229	177.11	26	S374	24.65
2	S361	164.27	27	S126	23.80
3	S140	146.16	28	S284	23.33
4	S108	116.59	29	S365	20.85
5	S151	97.39	30	S031	19.94
6	S282	84.51	31	S040	15.44
7	S340	82.95	32	S338	14.57
8	S275	79.13	33	S364	13.92
9	S329	78.11	34	S367	12.74

10	S139	73.48	35	S055	11.63
11	S131	66.54	36	S346	11.25
12	S308	66.29	37	S080	9.63
13	S330	66.12	38	S294	9.43
14	S356	65.25	39	S086	8.99
15	S268	64.99	40	S244	8.21
16	S306	63.14	41	S210	7.86
17	S194	50.75	42	S218	7.75
18	S348	46.12	43	S003	6.58
19	S352	44.43	44	S074	6.53
20	S143	41.32	45	S114	5.46
21	S201	40.92	46	S273	4.73
23	S395	37.85	48	S189	4.44
24	S247	28.39	49	S208	4.37
25	S037	25.38	50	S078	4.27

6. Modeling and Solution of Problem 2

6.1 Thinking Analysis

With the development of science and technology, enterprises have the potential to increase production capacity through technological transformation, but the production capacity is often limited by the supply of raw materials and the actual situation of forwarders.

This topic is a sensitivity analysis problem, the purpose of which is to consider the actual situation of suppliers and forwarders of existing raw materials, increase the output of enterprises as much as possible, and formulate the ordering and transshipment plan for the next 24 weeks. Therefore, we should consider the efficiency of the forwarding company (which can be expressed as the forwarding quantity/supply quantity), the type of supplier company, and whether the raw materials of a supplier are transported by a forwarding company as much as possible. The process of actual digital change of this modeling method can be visually understood as "numerical flow", and this model is named as numerical simulation method.

6.2 Planning Model Based on Numerical Simulation Method

Generally speaking, the decisions made by enterprises are profit-seeking. Therefore, from the local point of view, that is, from the supplier's point of view, we hope that every supplier can be transported, and all of them are transported through the forwarder with the lowest transport loss rate in this week (initial state). However, due to the constraints of actual resources, the best forwarder can't transfer all the raw materials supplied by suppliers. Therefore, the forwarder with the second lowest transportation loss rate should be selected for transshipment (process 1). If the transshipment volume of the forwarder with the second lowest transportation loss rate has reached the limit, the forwarder with the third lowest transportation loss rate should continue to settle for the next best for this reason by analogy. Secondly, because the production and consumption rates of different raw materials are different, A<B<C, so when several forwarders simultaneously select a certain forwarder for raw material transshipment, it will exceed its own carrying capacity(6000 cubic meters), then at this time, when selecting suppliers, priority should be given to Class A, then Class B and finally Class C.

In addition, from the overall point of view, we also need to consider another key factor of the model the transportation capacity of the forwarding company. When the raw materials supplied by each supplier are transported by the most appropriate forwarding company, it shall also consider that a supplier's raw materials are transported by a forwarder as much as possible, so the data value of each supplier's corresponding forwarder will "flow" on the "supplier-forwarder" diagram. In this paper, the method of deducing the actual scene by the process of digital constant change is called "numerical simulation method". In this question, we will use numerical simulation to solve the problem.

6.3 Model Solving

6.3.1 Main steps of numerical simulation method

This topic uses numerical simulation method to solve the maximum production capacity, and the main steps are:

Step1 The weekly supply quantity j of each supplier is in Part I;

Step2 according to the priority of A>B>C, determine the j that needs to enter Part II;

Step3 J leaving part I is the same as j entering part II;

Step4 Repeat the process of step1-3 in Part II until there is no overflow in the part where j is located;

Step5 The transportation volume of each part (I, II ...) must not exceed 6000.

6.3.2 Calculation result

The numerical simulation method is programmed by Python, and the weekly numerical relationship between suppliers and forwarders is obtained, and the new ordering scheme and transshipment scheme are obtained. Please refer to Appendix A and Appendix B for details. The adjustable capacity changing in the next several weeks are shown in Table 4.

Table 4. Table of productivity change

week	**1**	**2**	**3**	**4**	**5**	**6**
Productivity change (cubic meters)	-13009	1555	-3548	10276	-7382	-5212
week	seven	eight	nine	10	11	12
Productivity change (cubic meters)	668	1771	771	2266	-1142	8484
week	13	14	15	16	17	18
Productivity change (cubic meters)	-8198	-157	-411	1129	-1064	1436
week	19	20	21	22	23	24
Productivity change (cubic meters)	-1679	2910	-908	2785	-3553	0

6.3.3 Result analysis and test

In view of the novelty of numerical simulation method, we selected several indexes to realize the comprehensive evaluation of the model, for example, Such as "freight efficiency: freight volume /6000", "traffic volume/ supply" and "24-week capacity change". The experimental results show that the effect of the model is excellent. The following table shows the experimental values of freight efficiency indicators. In addition, by comparing with the decision scheme given by the decision model given in the second question, it is concluded that the performance of this model is better than that of the second question, and its comprehensive performance is excellent (the detail are shown in Table 5).

Table 5. Experimental values of freight efficiency indicators

	T1	T2	T3	T4	T5	T6	T7	T8
w1	0%	0%	28%	100%	0%	97%	0%	91%
w2	0%	47%	20%	0%	100%	92%	95%	0%
w3	0%	73%	99%	0%	0%	95%	0%	0%
w4	100%	61%	95%	100%	0%	73%	97%	0%
w5	96%	97%	10%	47%	0%	0%	0%	100%
w6	0%	20%	100%	0%	0%	0%	0%	88%
w7	0%	0%	94%	0%	0%	94%	0%	37%
w8	0%	25%	88%	0%	85%	73%	0%	0%
w9	0%	73%	100%	0%	0%	88%	0%	0%
w10	0%	0%	91%	61%	0%	96%	0%	98%
w11	0%	24%	100%	0%	0%	95%	0%	98%
w12	97%	92%	100%	94%	0%	14%	58%	100%
w13	0%	45%	92%	0%	0%	93%	0%	99%
w14	0%	91%	0%	0%	0%	88%	48%	94%
w15	0%	34%	93%	0%	0%	90%	0%	94%
w16	0%	55%	95%	94%	0%	99%	0%	0%
w17	0%	91%	89%	43%	0%	92%	0%	0%
w18	0%	90%	84%	43%	0%	48%	0%	0%
w19	0%	27%	96%	0%	0%	95%	0%	91%
w20	0%	89%	100%	0%	19%	85%	0%	82%
w21	0%	0%	100%	0%	58%	95%	0%	99%
w22	23%	100%	99%	0%	100%	23%	0%	91%
w23	0%	0%	95%	0%	92%	90%	0%	65%
w24	0%	65%	95%	0%	0%	90%	0%	0%

7. Advantages, Disadvantages and Improvement of the Model

7.1 Advantages of Model

1. This paper analyzes the rationality of assumptions before modeling, which makes the assumptions more reasonable and appropriate.

2. This paper puts forward a set of relatively complete supplier evaluation indexes, comprehensively considers the relationship between the order quantity and the supply quantity, and applies it to the enterprise order analysis, which has a good effect.

3. This paper provides a new method to solve the enterprise dynamic planning problem, which is an important innovation in this model.

4. When solving the problem, the established model is simple, low in complexity and easy to understand.

7.2 Model Defect

1. Due to the limitation of the subject data, the supplier evaluation index mainly considers the relationship between the order quantity and the supply quantity. Although the information given in this subject achieves good results, there are still many other influencing factors between enterprises and suppliers in practical problems.

2. Because of the small amount of data, the performance of the model with large amount of data cannot be verified.

7.3 Model Improvement Direction

1. Improve the multi-objective programming algorithm. As a widely used multi-objective solution algorithm, NSGA-Ⅱ algorithm can be applied to multi-objective programming.

2. Whether the numerical simulation method can be more widely used in other fields.

8. Conclusions

As one of the traditional pillar industries in China, the building materials industry is an important industry to promote the development of the national economy, and has made great contributions to the rapid development of the national economy in China.

This paper mainly studies the ordering and transportation of raw materials in building materials enterprises. Aiming at the problems of low purchasing efficiency, unstable supply relation -ship and large transportation loss in the building materials market, a model is established to evaluate the importance of suppliers to ensure the production of enterprises, and various planning models are used to formulate the optimal raw materials ordering scheme and transportation scheme for this enterprise. It is worth mentioning that this paper innovatively puts forward a numerical simulation method, which is used to solve the ordering scheme and transportation scheme in the dynamic changes of enterprises. After the evaluation index test, the model has a good effect.

For the first question, firstly, the whole data is processed and analyzed, from which the indexes for quantitatively evaluating the importance of suppliers to ensure the production of enterprises are extracted. Finally, the scale and delivery capacity of suppliers are selected as the evaluation indexes, the supplier evaluation model is established, and the 50 most important suppliers are established.

In view of the second question, instead of using the traditional sensitivity analysis method, this paper proposes a novel numerical simulation method to solve the changes of ordering scheme and transportation scheme under the condition of increasing production capacity. Through the evaluation index and the comparison with the original model, it can be proved that the model is effective.

Of course, in the process of establishing the model, we still have many shortcomings. For example, due to the limitation of the subject data, the supplier evaluation index mainly considers the relationship between the order quantity and the supply quantity. Although it achieves good results under the information given in this subject, there are many other influencing factors between enterprises and suppliers in practical problems. In the future study process, we will gradually improve and strive to achieve better results.

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