

An integer planning-based model for ordering and transporting raw materials for manufacturing companies

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Abstract. With the development of building materials manufacturing enterprises, the ordering, transportation and storage of raw materials have become important factors affecting the production of manufacturing enterprises. In order to ensure the normal production and operation activities and reduce the production cost as much as possible, enterprises need to reasonably adjust the relevant raw material ordering scheme and transportation scheme to ensure both the considerable production efficiency and the healthy and sustainable production. In this paper, a mathematical model based on sequential heuristic algorithm and integer programming is established to develop the most economical ordering scheme and the least lossy transportation scheme for raw materials in the process of production operation.

Keywords: Normal distribution test method; sequential heuristic algorithm; integer programming; iterative equations.

1. Introduction

In this paper, we first use the normal distribution test method^[1,2] combined with the sequential heuristic algorithm^[3,4] to refer to the 50 important suppliers that have been selected, and finally arrive at the result that the enterprise can satisfy the production requirements by selecting the top 22 suppliers among them. The integer programming method^[5~7] is used to develop the most economical ordering scheme for raw materials. According to the ordering scheme and the loss rate of forwarders using 0-1 planning to develop the least amount of loss forwarding scheme.

2. Model assumptions and notation

2.1 Basic assumptions

(1) Assume that in the first week of the first year, the firm has just enough raw materials in stock to meet two weeks of production.

(2) Assume that the statement in the title that "the enterprise shall maintain, as far as possible, a stock of raw materials that is not less than sufficient to meet its two-week production requirements" means that this week's stock meets this week's and next week's production capacity.

(3) Assume that there are no production accidents in the production process of the enterprise.

2.2 Variable Description

The symbols appearing in this paper are specified in Table 1.

Table 1. Symbol Description

Symbols	Description
W_{ij}	Supplier i's out-of-stock week
A_{ij}	Supplier i's supply in week j
B_{ij}	The order quantity placed by the firm to supplier i in week j
X_i	Number of weeks out of stock by supplier
M_{ij}	Supplier i's out-of-stock rate in week j
Y_i	Total out-of-stock rate by supplier

Q_i	Parent sequence
m	The maximum value in the bipolar difference table
n	The minimum value in the bipolar difference table
T_{QX}	The gray correlation of Q_i and X_i
d	Weights
G_i	Evaluation score of the i th supplier
L	Unit capacity
$G(A)$	Amount of materials A purchased
D_j	Order volume in week j
K_i	Inventory in week i
ρ_j	Average arrival rate in week j
a_{ij}	Supplier Supply Capability Matrix
β_{ij}	The wastage rate of j forwarders transferring the supply of the i -th supplier
C_j	Capacity in week j

3. Model construction and solving

First we identified the 50 most important suppliers and the results are shown in Table 2.

Table 2. 50 suppliers

Number	Suppliers	Score	Number	Suppliers	Score
1	S229	0.02080	26	S395	0.01699
2	S282	0.02026	27	S352	0.01696
3	S151	0.01960	28	S031	0.01687
4	S108	0.01949	29	S218	0.01657
5	S284	0.01935	30	S037	0.01654
6	S374	0.01919	31	S126	0.01652
7	S139	0.01917	32	S005	0.01639
8	S140	0.01906	33	S201	0.01600
9	S275	0.01889	34	S064	0.01590
10	S340	0.01881	35	S040	0.01583
11	S306	0.01876	36	S273	0.01543
12	S329	0.01868	37	S367	0.01543
13	S307	0.01865	38	S143	0.01540
14	S361	0.01863	39	S294	0.01510
15	S356	0.01849	40	S055	0.01504
16	S268	0.01832	41	S080	0.01467
17	S194	0.01815	42	S346	0.01452
18	S247	0.01776	43	S078	0.01451
19	S365	0.01769	44	S189	0.01428
20	S330	0.01739	45	S244	0.01426
21	S308	0.01731	46	S266	0.01421
22	S131	0.01726	47	S157	0.01385
23	S364	0.01711	48	S003	0.01357
24	S338	0.01710	49	S007	0.01338
25	S348	0.01700	50	S086	0.01311

The supply volume basically tends to be stable, except for some large fluctuations. Analyzing the reasons for individual fluctuations, we found that, considering the actual situation, there may be a

situation where the higher the order quantity, the higher the supply quantity, i.e., the supply quantity and the order quantity are changing in an approximate trend^[8]. Therefore, the ranking is not only related to the supply quantity, that is, the order quantity, but also affected by the out-of-stock rate and the number of weeks out of stock, so there are individual fluctuations.

3.1 3.1 Selection of suppliers

The conversion rate of converting A, B and C raw materials to capacity is.

$$A=\frac{L}{0.6}, B=\frac{L}{0.66}, C=\frac{L}{0.72} \quad (1)$$

where L is the unit capacity. First we use the above conversion formula to convert the order quantity and supply quantity for each week in Annex 1 to capacity respectively, and draw two line statistical graphs, as in Figure 1 and Figure 2.

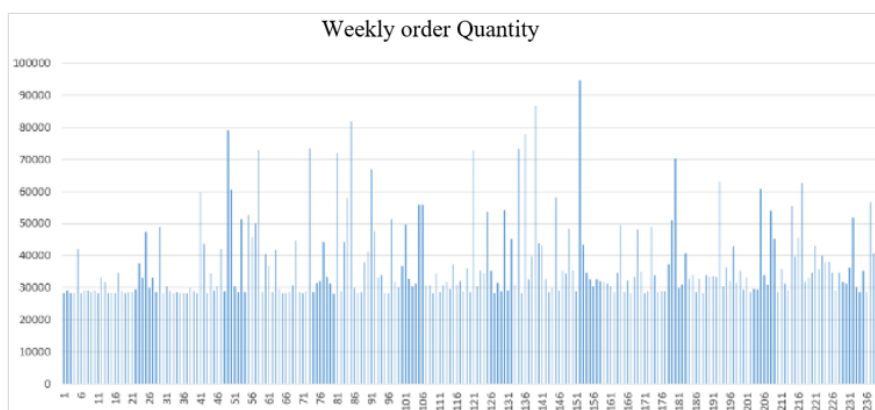


Fig. 1 Order volume statistics chart

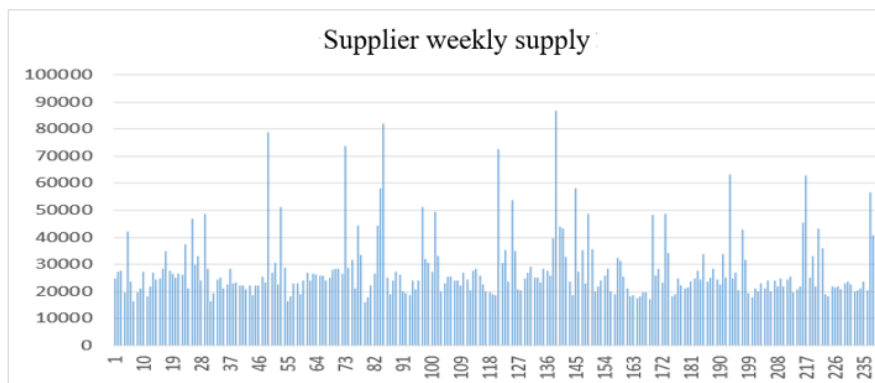


Fig. 2 Supply statistics chart

From the above chart, we can see that the capacity of each week's order quantity is above 28.2 thousand cubic meters, and most of them are less than 30.0 thousand cubic meters, and a few data of order quantity are on the large side. Comparing the capacity of each week's supply quantity, we find that the capacity of supply quantity most of the time does not meet the capacity of 28.2 thousand cubic meters, which may make the inventory decrease after accumulating for many weeks, so we think the data of large order quantity is to make the supply quantity increase in order to increase the inventory, and do not treat it as abnormal data. At the same time, according to the order quantity of each week from the first week is slightly more than 28,200 cubic meters can be inferred, the data of the last five years is only the data of the enterprise for a certain period of time, so we assume that the first week has inventory to meet the capacity of 56,400 cubic meters for two weeks, after each week only to meet the order quantity greater than 28,200 cubic meters can be. According to the supplier

ranking, firstly, the supplier's weekly supply is converted to capacity, and then the total weekly supply of all suppliers for 240 weeks is tested for normal distribution, and the histogram and normal distribution curve are drawn as in Figure 3.

From Figure 3, we can see that the total weekly supply of all suppliers is normally distributed, and we take the confidence interval as 0.95. The weekly supply outside the confidence interval is not considered, and then the capacity of each week is accumulated from the first ranked supplier using the sequential heuristic algorithm for the remaining weeks until there is one week in 240 weeks with a capacity greater than or equal to 28,200,000 m³. The number of suppliers that appear at this moment as the selected suppliers is the minimum number of suppliers. Finally, the minimum number of suppliers is 22, which are the top 22 suppliers in question 1, as shown in Table 3.

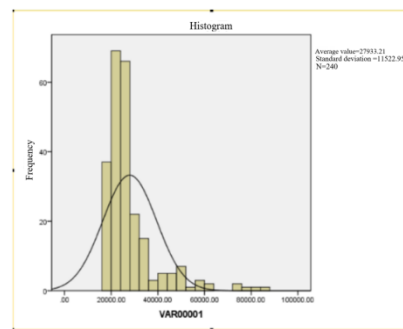


Fig. 3 Normal Distribution Chart

Table 3. Select Supplier

Ranking	1	2	3	4	5	6	7	8	9	10	11
Suppliers	29	282	151	108	284	374	139	140	275	340	306
Ranking	12	13	14	15	16	7	18	9	20	21	22
Suppliers	329	307	361	356	268	194	247	365	330	308	131

3.2 Ordering program development

Assuming that the unit price of raw materials of category C is a, the raw materials of category A and B are 1.1a and 1.2a, respectively, and considering that the capacity generated by units of raw materials of category A, B and C is different, the consumption of each unit of raw materials of A, B and C are.

$$F(A) = 0.72a, F(B) = 0.726a, F(C) = 0.72a \quad (2)$$

Considering that in addition to raw material purchase costs, there are raw material transportation and storage costs, and the unit costs of these two costs are the same. The size of these two costs is mainly reflected in the amount of raw materials required per unit of product, the more raw materials of a certain type required per unit of product, it means that the more transportation and storage costs per unit of this type of raw materials required. The question gives a unit of product consumption A material 0.6m³, consumption B material 0.66m³, consumption C material 0.72m³, therefore, the unit A, B, C material required for the transport costs in the order of A < B < C.

From the actual situation, the cost of purchasing materials must be much larger than the material transportation cost and storage cost, so first consider the material cost: A = C < B, it can be concluded that A and B materials are superior to C materials. Then consider the transportation and savings fees: A < B < C, you can conclude that A material is better than B material is better than C material. Considering the three costs together, the order of priority for ordering raw materials A, B and C is.

$$A > C > B \quad (3)$$

Therefore, when developing the ordering scheme, the priority should be given to purchasing material A, then material C, and finally material B. The objective function of the most economical ordering scheme is given according to the order of purchase priority.

$$f = \frac{G(B)+G(C)}{G(A)} + \frac{G(C)}{G(A)+G(B)} \quad (4)$$

Where $G(A)$ represents the purchase of material A, and $G(B)$ and $G(C)$ are the same.

The total weekly supply of 22 suppliers is plotted in Figure 4.

Different color dots in the graph indicate the supply quantity corresponding to the same week in each of the 5 years, and the graph is randomly selected to mark the 5 weeks of each year. From the figure can be seen in the same week of each year has a certain periodicity of supply, therefore, for each supplier in the next 24 weeks of weekly supply capacity, we take the maximum value of the previous 5 years of the week's orders for its supply ceiling, for each supplier in the next 24 weeks of arrival rate, take the average of the previous 5 years of the week's arrival rate as the supply rate of this week in the program.

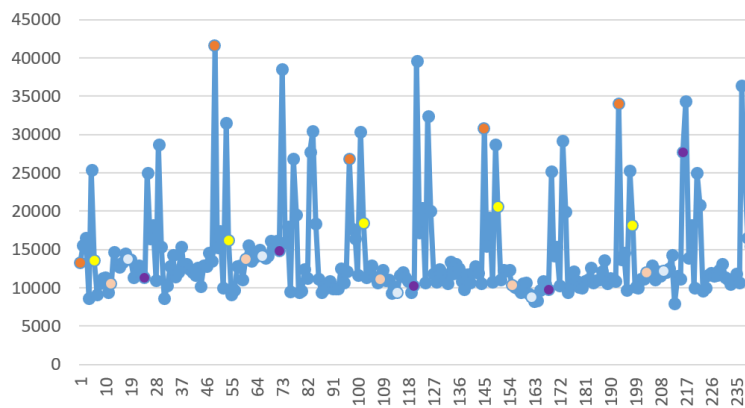


Fig. 4 Line graph of total supply from selected suppliers

According to the arrival and capacity of the first 240 weeks to calculate the last week of inventory is 0.94 million cubic meters, that is, the future before the first week of inventory is 0.94 million cubic meters, according to the title conditions of the first week of orders should meet.

$$D_1 = 5.64 - K_0 \quad (5)$$

Where D_1 denotes the order quantity in the first week and K_0 denotes the inventory quantity before the first week, which is 0.94 million cubic meters. Then the inventory for any week should satisfy.

$$K_i = \frac{D_j}{\rho_j} + k_{i-1} - 2.82 \quad (6)$$

According to each supplier's weekly supply ceiling for the next 24 weeks can generate a matrix of suppliers' weekly supply capacity, where each element is each supplier's weekly supply ceiling, set to a_{ij} (i is the supplier ranked 1-22, j is the number of weeks), then.

$$\begin{cases} G(A) = \sum_i \sum_{j=1}^{24} a_{ij} x_{ij}, i = 1,2,9,12,13,18 \\ G(B) = \sum_i \sum_{j=1}^{24} a_{ij} x_{ij}, i = 4,7,8,10,20,21,22 \\ G(C) = \sum_i \sum_{j=1}^{24} a_{ij} x_{ij}, i = 3,5,6,11,14,15,16,17,19 \end{cases} \quad (7)$$

Processing the matrix yields the constraint as^[9].

$$\frac{x_j}{\rho_j} \geq Y_i \quad (8)$$

Therefore, building a planning model.

$$\min f = \frac{G(B)+G(C)}{G(A)} + \frac{G(C)}{G(A)+G(B)} \quad (9)$$

$$\text{s.t. } \frac{x_j}{\rho_j} \geq Y_i \quad (10)$$

3.3 Transit program development

At this point we already know the ordering scheme for the next 24 weeks and how much raw material to order from which suppliers for each week is known, so we develop a specific transit scheme for each week. As with solving for the future weekly supply ceiling, we take the average of the loss rates for the same week each year as the loss rate for this week in the next 24 weeks for each future supplier's weekly supply^[10].

Establish the objective function.

$$\min \beta_{ij}x_{ij}a_{ik} \quad (11)$$

Binding Conditions.

$$\text{s.t. } \begin{cases} x_{ij} = \begin{cases} 1, & \text{The total supply of the } j\text{th forwarder forwarding the } i\text{th supplier} \\ 0, & \text{The } j\text{th forwarder does not forward the entire supply of the } i\text{th supplier} \end{cases} \\ \sum_{i=1}^{22} x_{ij}a_{ik} \leq 6000, j = 1,2,\dots,8; k = 1,2,\dots,24 \end{cases} \quad (12)$$

Using the above model to find the transit solution for each future week.

Finally, the matrix of the resulting ordering scheme is column summed to obtain the order quantity for each week, which is compared with the order quantity for the first 24 weeks of each of the previous 5 years to obtain Figure 5.

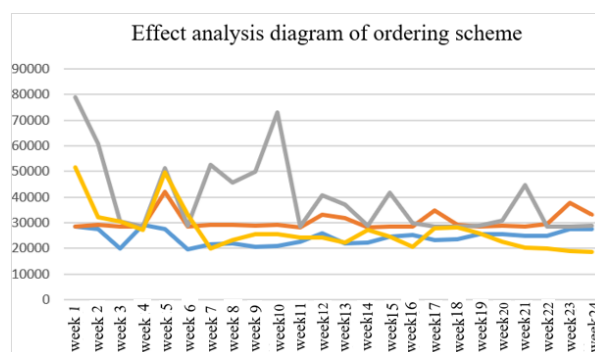


Fig. 5 Order solution rendering

The graph above shows that the next 24 weeks have roughly the same ebb and flow trend as the first 24 weeks of ordering in each of the previous five years, so the ordering program is working relatively well.

4. Conclusion

The main raw materials required for the production of a building materials manufacturer are wood fibers and other fiber materials, etc. The types available are A, B, and C. The enterprise schedules

production on a 48-week basis in a year and needs to determine suppliers, order quantities, forwarders, and supply quantities 24 weeks in advance based on capacity requirements.

This paper solves the problem of choosing at least a few suppliers to meet the production needs of this enterprise. The paper also develops the most economical weekly ordering plan for raw materials and the least costly transportation plan for the next 24 weeks for these suppliers. Finally, we analyze the effectiveness of the implementation of the ordering and transfer schemes. In this paper, a combination of sequential heuristic algorithm and normal distribution rejection data is flexibly used for least supplier selection; integer programming and iteration are combined to find the most economical ordering scheme. However, uncertainties such as backlog of goods are not considered when building the model.

References

- [1] Cheng Yan. Application of normal distribution [J]. Inner Mongolia Coal Economy, 2021, (11): 229-230.
- [2] Yu Jian, Zhou Yangyang, Wang Xincheng. Optimization method of layout congestion based on normal distribution evaluation method [J]. Electronics and packaging, 2021, 21(07): 46-50.
- [3] Deng Guobin, Shen Ping, Pan Liwu. Two-dimensional cutting algorithm of coiled material based on multi-stage layout [J]. Forging technology, 2019, 44(09): 46-50.
- [4] Chen Yan, Xie Qiqi, Liu Yong, Cui Yaodong. Design and implementation of heuristic algorithm for cutting sequence grouping of circular parts [J]. Journal of graphics, 2017, 38(01): 5-9.
- [5] Zhang Wenzhe. An integer programming algorithm based on signed Groebner basis [J]. Practice and understanding of Mathematics, 2020, 50(16): 271-277.
- [6] Wu Yuting, Zhang Yu. Research on wood planking optimization based on integer programming [J]. Scientific and technological style, 2020, (17): 111.
- [7] Liu Fei, Zhen Can, Liu Zheng, Zhang Litao. Research on production line balancing based on IE and integer programming theory [J]. Modern manufacturing engineering, 2021, (06): 101-115.
- [8] Zhang Liangliang, Jia Yuanhua, Niu Zhonghai, Liao Cheng. Trend change detection of traffic flow sequence based on approximate entropy [J]. Journal of Beijing Jiaotong University, 2014, 38(06): 7-11.
- [9] Lian Hongbo, Chen Yang, Li Jiarui. Data modeling method based on random matrix theory [J]. Electrotechnics, 2021(13): 69-73.
- [10] Xiao Shuting. MResearch on demand forecasting and ordering strategy of garment enterprises [D]. Beijing Jiaotong University, 2021.