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An Optimization Model for Ordering and Transporting Raw Materials by Manufacturers Based on Linear Programming

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Abstract

This study applies analytic hierarchy process (AHP), 0-1 integer programming and other systematic programming models, combined with the needs of manufacturers to build a set of mathematical models to help manufacturers select suppliers, control raw material ordering costs, and transporting costs. As the production costs of products is linked to the ordering and transporting of raw materials, manufacturers need to choose suitable raw material suppliers and develop the most economical ordering and transporting schemes with the most negligible loss so as to improve profits and enhance the market competitiveness. Taking a building and decorative plate enterprise as a case, this model shows that AHP can effectively quantify the supplying characteristics of suppliers and obtain a list of high-quality suppliers. LINGO software combined with linear programming can be used to obtain the optimal weekly ordering and transporting schemes, thus reducing the raw material ordering costs and transporting losses. It is shown from the results that the production costs of enterprises from the source can be reduced so as to improve their cost control system. The present study seeks to fill the gap in ordering and transporting raw materials for manufacturers to control production costs. At the same time, this model provides references for producers who have the demand for processing raw materials and play a significant role in controlling production costs.

Keywords: manufacturers, mathematical modeling, linear programming, hierarchy analysis, ordering and transporting costs

1. Introduction

Raw materials serve as the foundation to promote the quality of production and control the cost. With the development of global economic integration, competition among manufacturers is becoming increasingly fierce. Production costs affect manufacturer's production efficiency and product quality (Li et al., 2020). To survive, develop, and establish advantages in the current market environment, manufacturers are faced with how to choose appropriate suppliers (Hosseini et al., 2022) and control production costs (Chang et al., 2022).

Supplier selection scheme and ordering and transporting raw materials directly affect the production costs of enterprises (cf. Zhu, 2005; Li, 2012; Chen, 2013). The ordering costs directly affects the profit margin of the enterprise (Guo, 2022), whereas the transporting costs directly affects the production cost control of the enterprises (Cui et al., 2016). The choice of raw material suppliers directly affects the production efficiency and survival of the enterprises (Kannan & Tan, 2022), which means that the enterprises' ordering costs and transporting costs are related to the enterprises' production costs. If enterprises can accurately select high-quality suppliers and make reasonable ordering and transporting plans in advance (Wang et al., 2003), they can significantly reduce production costs, avoid market risks, and improve their core competitiveness. Due to a large number of suppliers, there are many choices of suppliers and transporters in the original ordering and transporting schemes. This study aims to explore how to accurately help enterprises select high-quality suppliers, formulate and optimize the ordering and transporting schemes of raw materials, and help enterprises reduce production costs.

The present study uses two mathematical methods, namely the analytic hierarchy process (AHP) and linear programming, to establish mathematical models combined with manufacturers' requirements. For supplier selection, this study adopts AHP (cf. Acquaye et al., 2014) to conduct data analysis and visualization of the data provided by a particular survey institution. Supply quantity, order rate, occupancy ratio (Weber et al., 1991), and supply stability ratio (Zimmer et al., 2015) are investigated as the four indicators in this study to establish the decision-making layer and help to obtain the supplier quality ranking.

In order to determine the number of suppliers, this study establishes the 0-1 integer programming model (cf. Li et al., 2006) and obtains the results with LINGO software. For the formulation of the ordering schemes and transporting schemes, this study establishes reasonable constraints and objective functions through the supply quantity of suppliers, establishes a new 0-1 integer programming model, and formulates the most economical ordering schemes in the future. This study also takes into account that the losses should be as minimal as possible in the transporting process, so as to modify the model and formulate the transporting schemes.

In order to better solve the problems facing enterprises in controlling production costs, this study first reviews the current situation of manufacturers, then analyzes the problems in enterprise production cost control, and proposes methods and models to solve each problem. Based on the analysis, this study combines the data of suppliers and transporters to conduct data analysis and establish a mathematical model. After analyzing and discussing results of the model, this paper draws a conclusion about enterprise production cost control.

2. Literature Review

2.1 Ordering and Transporting Raw Materials

In recent years, the research object of the manufacturing-type enterprise product cost control is still relatively single. For product cost control of manufacturing-oriented enterprises, Yang (2016) proposes a method of controlling production control for manufacturers based on constrained optimization theory, while Fan & Wei (2016) studies enterprise cost management from suppliers, enterprises, and customers. Du et al. (2020) constructs a cost control model which the financial cloud for enterprises centering on corporate financial management. It can be seen that the current research on product cost control of manufacturers mainly focuses on the overall improvement of the cost system but pays less attention to the impact of different links. In other words, ordering and transporting raw materials, product production and transporting sales, inventory, and other aspects are also worth a further study.

Existing research pays little attention to the different links of product cost systems in order to effectively reduce production costs. In the 1980s, the supply chain was proposed as a production network composed of raw material suppliers, suppliers, manufacturers, and retailers. Suppliers are indispensable in processing raw materials into products and selling them to customers (Liu, 2003). Jing & Li (2008) believes that ordering is indispensable in realizing business goals and coping with final market competition. The manufacturing industry has a strong linear correlation between transporting costs, production costs, and inventory overstocking (Gao & Zhang, 2003). In the production cost system of the whole product, the diversity of raw materials and the randomness of the ratio will affect the fluctuation of the ordering cost (Zhang, 2014), and the loss of the original product in the transporting process will affect the change of the transporting cost (Xu & Suo, 2012). In short, the cost of a manufacturer' product is closely related to the ordering and transporting raw materials. Therefore, this study focuses on the control of production cost in two aspects: ordering and transporting raw materials.

2.2 Application of Linear Programming Methods

Currently, enterprises' control measures for the costs of ordering and transporting raw materials, labor cost control, supplier selection, and improvement of raw materials transporting schemes are still mainstream research (Rong, 2022). The ordering and transporting schemes differ for different manufacturers, and most are analyzed at the scheme and process level (Yu, 2016; Teng, 2017). Previously, scholars have proposed to use activity-based costing, operations research, and other methods to analyze and make decisions on manufacturer costs (cf. Zhang et al., 2006; Arikan, 2013). After decades of development, the discipline system of "Operations Research" has been relatively perfect and involves many mathematical knowledge points, such as AHP (Rawal & Nekram, 2021), 0-1 integer programming (Russell Impagliazzo et al., 2014), multi-objective programming (Taghavi et al., 2021). Among them, different methods have different characteristics in their applications. AHP can help to get the optimal weight ordering based on fundamental indicators. The 0-1 integer programming can help to provide the optimal solution of objective function based on constraints (Ding et al., 2009). Also, Xie et al. (2019) and Cui et al. (2022) have combined ideas of operation research with other research fields, achieving new developments and breakthroughs.

At the same time, the research and development of LINGO (Linear Interactive and General Optimizer) software effectively improve the calculation and analysis of Linear programming methods. LINGO is a software package specially used for solving optimization problems. It has a fast execution speed and convenient input and can be used to solve and analyze mathematical planning problems. So it has been widely used in mathematics, scientific research, and industry (Xu, 2014). LINGO is a convenient tool for solving linear and nonlinear optimization problems. It has a built-in language for solving optimization models, which can solve mathematical models easily and quickly to analyze the results (Wan & You, 2007). In addition, Ding et al. (2009) have proved through experiments that LINGO software could support the decision variables in the optimization model to be integers. So this software supports integer programming, which could contribute to the present study. Therefore, this study combines Lingo software to translate the optimization model established by mathematical modeling into computer language for solving practical problems.

Thus, global experts and scholars have carried out in-depth research on linear programming methods. This paper summarizes the previous experiences and puts forward a mathematical model to optimize the ordering and transporting cost of raw materials. In this study, various linear programming methods and the LINGO software are used to calculate examples to verify the validity of the mathematical model.

2.3 Research Questions

Most of the existing research investigates the overall system and process of cost control and seldom breaks down the whole to explore manufacturers' raw material ordering and transporting costs. At the same time, the current research status is not based on operations research to explore such problems, so this study aims to focus on the point-to-point, systematic and reasonable analysis and interpretation of raw material costs. In order to better explore the optimal solution under different circumstances, this study, based on the method of case analysis, takes a building and decorative plate manufacturer as a case to explore the relationship between the manufacturer, supplier, and transporter and proposes the following three questions:

a) How can the best suppliers be selected?

b) How many suppliers should the enterprise choose to meet the production needs at least, in the best supplier selection scheme?

c) How can the most suitable weekly raw material ordering schemes and transporting schemes be made for the next 24 weeks for the best quality suppliers?

Given the first research question, this study combines AHP, hoping to build an evaluation model based on existing data and set up the evaluation mechanism according to the indicator system of suppliers. Based on this, this paper analyzes the other two research questions with 0-1 integer programming and linear programming.

3. Research Methods and Models

3.1 Research Method

3.1.1 Research design

The first research points to establishing a hierarchical programming model to screen out high-quality suppliers based on a quantitative analysis of existing suppliers. This study first evaluates the importance of suppliers by establishing a transparent indicator system, then weighs the importance of existing suppliers after constructing a hierarchical model. In this study, high-quality suppliers are taken as the optimal target layer, and decision-makers select four indicators through data visualization analysis: supply quantity, order rate, occupancy ratio, and supply stability ratio (Chai & Ngai, 2019). Then, this study sets up a judgment matrix for the index system and carries out a consistency test. The consistency of the model is measured by calculating the consistency ratio CR by MATLAB. Finally, the study determines the corresponding weight of each indicator, carries out the weighted score to find the importance ranking of suppliers, and screens out 50 high-quality suppliers.

Based on the second research question, this study calculates the minimum supplier value to meet the production demand by establishing a 0-1 integer programming model. First, the material inventory after production meets at least two weeks of supply as a constraint condition and the minimum number of suppliers as an objective function. Secondly, the 0-1 integer programming model is established. 0 indicates that the supplier does not provide raw materials, and 1 indicates that the supplier does. Last but not least, this study takes 50 suppliers as decision variables and obtains the number of suppliers through LINGO software.

In terms of the third research question, this study aims to by establish a 0-1 integer programming model to meet the two requirements of the most economical and the minor loss. The present study first selects three materials ordering the minimum total cost as the objective function of the "most economical" suppliers as decision variables. The supply number in the data of a survey agency is averaged every 10 weeks as the coefficient of the decision variable. Then, the number of goods supplied by the supplier and the weekly production demand are considered constraints, and a linear programming solution obtains the ordering schemes. Then the ordering schemes is obtained as a linear programming solution. For the formulation of the transporting schemes, this study takes the most negligible transporting loss as the objective function, sets the decision variable as the i-th supplier choosing the j-th transporter, and the constraint condition is the maximum transport capacity of each transporter. Finally, the optimal transporting scheme is obtained through 0-1 integer programming.

3.1.2 Research data

This study selects the data of different production enterprises of a survey institution and finally selects the data of building and decorative plate enterprises in recent five years to make it universal. The selection of suppliers and the selection of ordering and transporting schemes will directly affect the production cost control of enterprises. Accurate and actual supplier data and ordering and transporting data can help this study more accurately select high-quality suppliers and formulate ordering and transporting plans. This study uses the data set of the enterprise for empirical analysis, and the enterprise's products involve three raw materials. In this study, A, B, and C refer to the three raw materials, and their unit prices were 1.2 yuan, 1.1 yuan, and 1 yuan, respectively. The company's weekly capacity is 28, 200 cubic meters, consuming 0.6 cubic meters, 0.66 cubic meters, and 0.72 cubic meters, respectively.

This study selects the most representative enterprise data from the statistical data of a survey organization to make it authentic and feasible. In order to effectively improve the accuracy of the model, this study ensures the accuracy of data sources through comparative analysis of various manufacturing enterprises in different institutions. By comparison, it is found that the data provided by the building and decorative plate enterprises are representative of raw material ordering and transporting costs and can genuinely reflect the market, suppliers, and transporters' dynamics. Secondly, there is a total of 240 weeks' data of suppliers and transporters in 5 years, among which 402 suppliers provide different types of raw materials, including the name of the enterprise, order quantity, and supply. An additional eight carriers are responsible for transporting raw materials, including the name of the carrier, whether it is transported, and the rate of transporting attrition. The data of the enterprise is objective and accurate, so this data of the enterprise is selected as the research data of this study.

3.2 Research Model

The data of ordering and transporting in the past five years are analyzed in the model calculation, which serves as the basis for establishing the model. In the construction of the model, this study also needs to ensure that the supply situation of ordering and transporting situation of transporters are similar to that of the past five years, and the enterprise needs a certain amount of inventory before production, which will not affect the production in the first week. Therefore, in order to facilitate model calculation and prediction, the following three hypotheses are made for the research data:

(1) the supplier's supply situation remains the same as in the previous five years;

(2) the transporting performance of the forwarders remains the same as in the previous five years;

(3) the enterprise has material reserves before construction.

Table 1. Parameter definition table

Parameter	Definition	Parameter	Definition
A	Total amount of A material	RI	Mean Random Consistency Index
B	Total amount of B material	ω_i	Weight vector
C	Total amount of C material	X_i	Supplier
n	Order of the matrix	K_i	The weekly average quantity of supplier I
λ	Matrix-eigenvalue	H	Attrition rate
CI	Consistency index	K_j	The attrition rate of the j-th transporter in the same week
CR	Consistent ratio	X_{ij}	Indicates that the i-th supplier chooses the j-th transporter

3.2.1 Optimal supplier screening

Based on the first research question, this study makes a quantitative analysis of the supply characteristics of 402 suppliers and establishes a mathematical model reflecting the importance of the production of the guarantee enterprise. This study makes assumptions by reviewing several factors and indicators mentioned above. Importance can be expressed in supply quantity, order rate, occupancy ratio, and supply stability ratio (cf. Weber et al., 1991; Zimmer et al., 2015).

- Supply quantity

According to the number of materials produced by a specific supplier after receiving the order demand from the enterprise in a single week in the research data, it is concluded that some suppliers have obvious over-quantity or under-quantity of the order quantity of the enterprise, and the supplier cannot guarantee the supply strictly following the order quantity. At the same time, enterprises need to ensure the stability of production (Li & Tang, 2015). Even if the order quantity is already over, they will generally purchase all the supplies from suppliers (Chen & Yang, 2009) to ensure the material inventory needed for two weeks' production. The supply quantity information is shown in Figure 1.

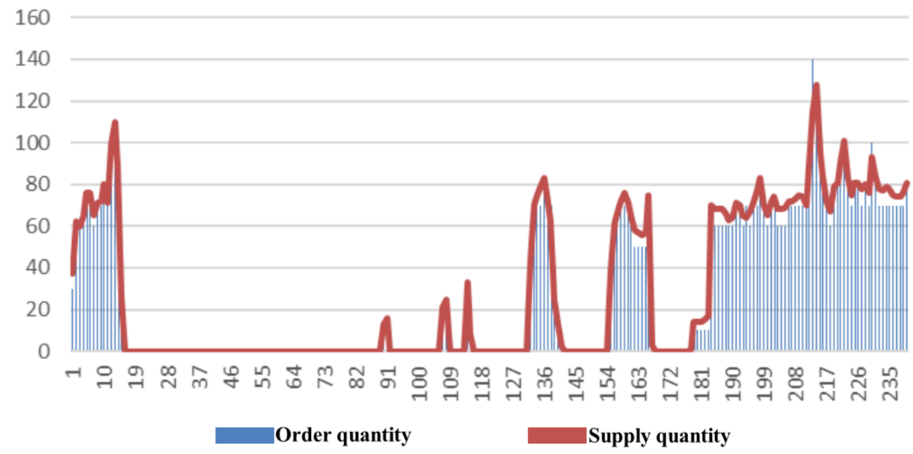

Figure 1. Supply quantity

- Order rate

According to the above description, the order quantity of the enterprise to all suppliers in a week is obtained in this study, which is the sum of three different materials, A, B, and C. The supplier can only supply a single material, so a ratio can be obtained by comparing the order quantity of the enterprise to the supplier in a week with the order quantity of the enterprise corresponding to a single material, which is called the order rate in this study. Since the order rate can, to some extent, reflect the enterprise's value on a single supplier (Narasimhan et al., 2001), the order rate is also regarded as a secondary factor in the importance assessment in this study. The proportion of supplier order quantity to total order quantity is shown in Figure 2.

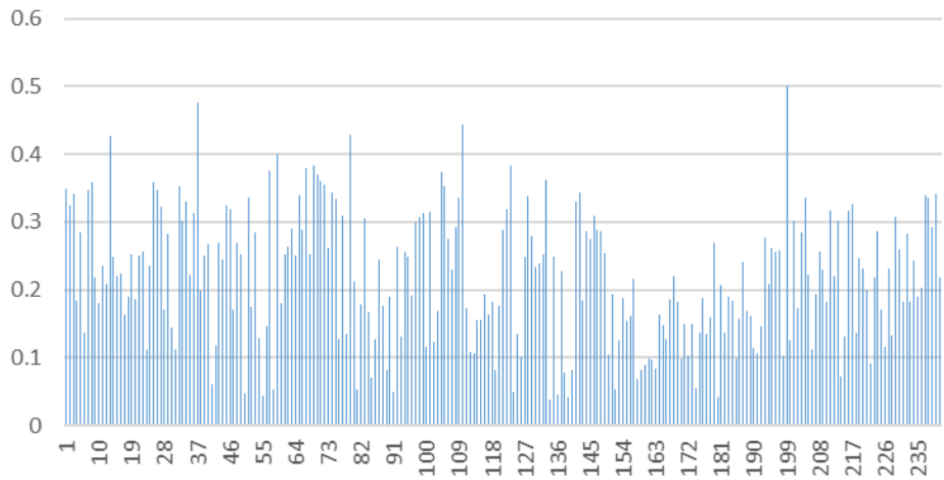

Figure 2. Order rate

- Occupancy ratio

In this study, the sum of the orders of all suppliers to the enterprise for three different materials in a week is obtained, and the occupancy ratio is obtained by comparing the supplier's weekly supply to the manufacturer with its output of single materials. Teng et al. (2006) found that the yield ratio can effectively reflect the elasticity of supply and demand between suppliers and manufacturers, so this index is a critical evaluation factor in this study. Figure 3 gives relevant yield information.

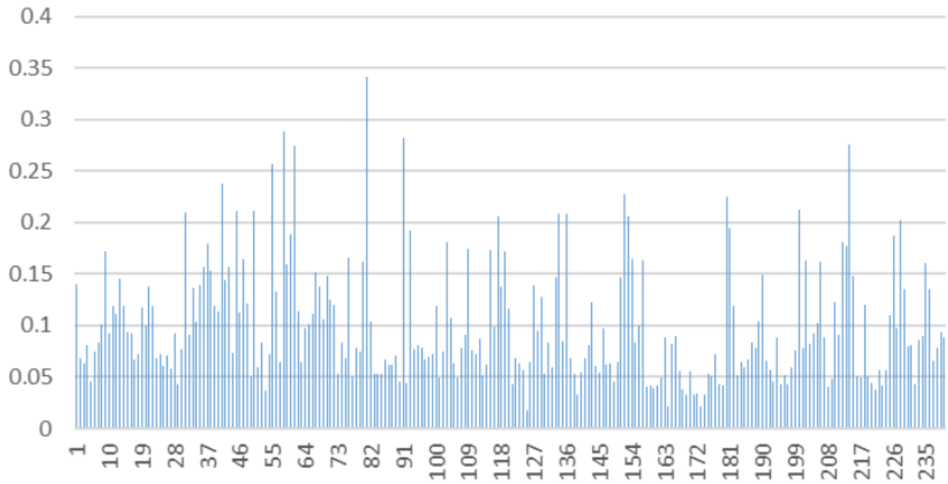

Figure 3. Occupancy ratio

- Supply stability ratio

In this study, the completion rate is calculated according to the ratio of weekly order quantity and supply quantity of the supplier. The average deviation of the completion rate reflects the supplier's stability rate and obtains the supply stability rate. To a certain extent, the supply stability ratio can reveal the dynamic stability of suppliers, that is, the supply quantity stability of suppliers in a period. If its stability is good, the supplier can provide the raw materials required by the manufacturer within a certain period (Yao, 2017). Figure 4 points to the supply stability information of suppliers.

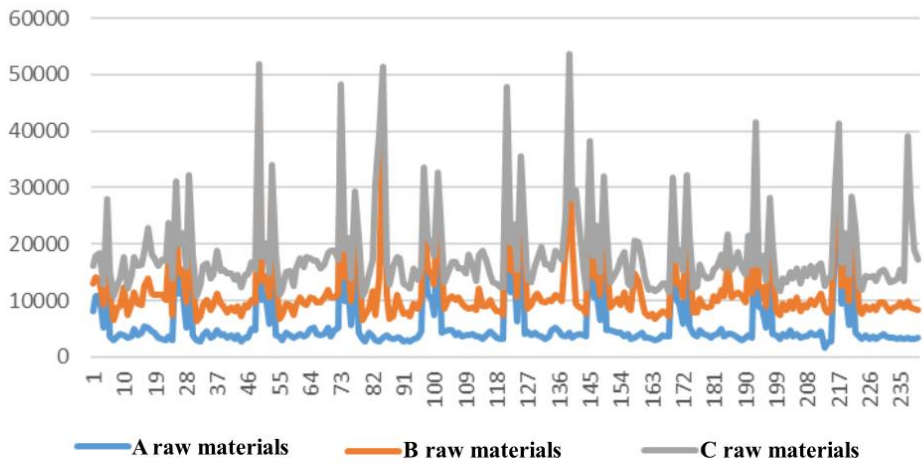

Figure 4. Supply stability ratio

According to the principle of AHP, this study establishes a hierarchical structure model and divides the decision-making objectives, factors to be considered (decision-making criteria), and decision-making objects into the highest, middle, and lowest levels according to their mutual relationship, and draws the hierarchical structure diagram as shown in Figure 5.

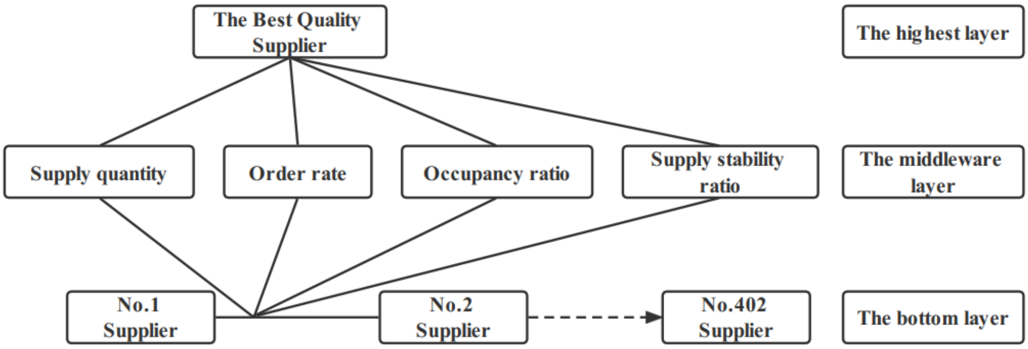

Figure 5. Hierarchy diagram of analytic hierarchy process (AHP)

In the hierarchical structure diagram, the highest level is the optimal merchant, the lowest level is 402 suppliers, and the middle level is four indicators: supply quantity, order rate, occupancy ratio, and supply stability ratio. Suppliers at the bottom get the best merchants at the top through index construction and screening at the middle layer. Then the judgment matrix is constructed:

$$\begin{bmatrix} 1 & 2 & \frac{1}{9} & \frac{1}{8} \\ \frac{1}{2} & 1 & \frac{1}{9} & \frac{1}{9} \\ 9 & 9 & 1 & 2 \\ 8 & 9 & \frac{1}{2} & 1 \end{bmatrix} \quad (1)$$

The corresponding element is denoted as a_{ij} and ω after normalization (making the sum of all elements in the vector equal to 1). The element of ω is the ordering weight of elements at the same level for the relative importance of a factor at the next level. This process is called single hierarchical ordering. Furthermore, ω is the square matrix of order n. Then the consistency test is carried out, which is divided into the following steps:

Step 1 Calculate consistency index

$$CI = \frac{\lambda - n}{n-1} \quad (2)$$

As CI=0, there is complete consistency. CI is close to 0, and there is satisfactory consistency. The greater the CI, the less satisfactory the consistency.

Step 2 Find the average random consistency indicator RI. The n is the order of the matrix

Table 2. Consistency index RI table

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Step 3 Calculate the consistent ratio CR

$$CR = \frac{CI}{RI} \quad (3)$$

This study calculates the weight of the four indicators by the weighted score method and obtains the importance ranking of all suppliers. Since the consistency test of the weighted score of the suppliers below the top 50 is not within a reasonable range, the top 50 suppliers are extracted as reference data. The hierarchical method generally believes that when the consistency ratio CR is less than 0.1, A's degree of inconsistency is within the allowable range, with satisfactory consistency and passing the consistency test. The normalized eigenvector can be used as the weight vector; otherwise, the pairwise comparison matrix A should be reconstructed and adjusted. Then, the calculation result of weight by MATLAB in this study is CR=0.0383, which is acceptable. Then the weight vector [0.0608 0.0419 0.5329 0.3643] is calculated in this study by means of arithmetic average. Supplier No.229 ranks first with a score of 0.192828403.

3.2.2 The minimum number of suppliers

Based on solving 50 high-quality suppliers, this study establishes the 0-1 integer programming model based on supplier data to solve the minimum number of suppliers to meet the production needs of enterprises. In this study, $(X_1, X_2, \ldots\ldots, X_{50})$ represent 50 suppliers, and 50 suppliers are decision variables. Since the minimum number of suppliers is required, the objective function of this study is set as $Min(Z = X_1 + X_2 + \ldots\ldots + X_{50})$. According to the data of the investigation agency, the production capacity of the enterprise is 28200m³ / week. Each cubic meter of product produced by the enterprise consumes 0.6m³ of raw material A, 0.66m of raw material B, and 0.72m³ of raw material C. Meanwhile, W_A represents the quantity of material A ordered by the enterprise every week; W_B represents the quantity of material B ordered by the enterprise every week; W_C represents the quantity of material C ordered by the enterprise every week. As a result, on this basis, the weekly production capacity of raw material A is $\frac{W_A}{0.6}$m³ / week, that of raw material B is $\frac{W_B}{0.66}$m³ / week and that of raw material C is $\frac{W_C}{0.72}$m³ / week.

Based on the above data, the 0-1 integer programming model is established in this study:

Decision variable: $X_i(i = 1,2,\ldots,50)$

Objective function: $Min(Z = X_1 + X_2 + \ldots\ldots + X_{50})$

Constraint condition:

1) The sum of the weekly production capacity of A, B, and C's three raw materials should be greater than or equal to the normal weekly production capacity of the enterprise 28200m³ . That is:

$$\underbrace{1/0.6 \times W_A}_{\text{Weekly production quantity of material A}} + \underbrace{+1/0.66 \times W_B}_{\text{Weekly production quantity of material B}} + \underbrace{1/0.72 \times W_C}_{\text{Weekly production quantity of material C}} \geq 28200 \quad (4)$$

2) X_i indicates whether the supplier is needed. There are only 0 and 1 results (0 is not selected and 1 is selected).

In this study, the 0-1 integer programming model is input into LINGO software for solving, and the minimum value of *Z* can be calculated as 38, so at least 38 suppliers are needed to meet the weekly production needs.

3.2.3 Optimal ordering and transporting solutions

3.2.3.1 Ordering scheme model

Decision variables: *(i=1, 2. . . .50)*represents 50 suppliers.

Objective function: Assuming that material A is used as A, material B is used as B, and material C is used as C, and the unit price of material C is set as unit 1, then material A is 1.2A, material B is 1.1B, and the ordering cost is $Z = 1.2A + 1.1B + C$. In order to obtain the most economical ordering scheme, the ordering cost must be minimal, namely: $Min(Z = 1.2A + 1.1B + C)$.

Constraints:

1) The sum of the weekly order quantity of the three raw materials should be greater than or equal to the enterprise's weekly capacity. The constraint condition can be expressed as:

$$\underbrace{1/0.6 \times (\mathrm{K}_1 \times \mathrm{X}_1 + \ldots + \mathrm{K}_{50} \times \mathrm{X}_{50})}_{\text{16 suppliers of raw material A}} + \underbrace{1/0.66 \times (\mathrm{K}_3 \times \mathrm{X}_3 + \ldots + \mathrm{K}_{45} \times \mathrm{X}_{45})}_{\text{16 suppliers of raw material B}} +$$

$$\underbrace{1/0.72 \times (\mathrm{K}_2 \times \mathrm{X}_2 + \ldots + \mathrm{K}_{49} \times \mathrm{X}_{49})}_{\text{16 suppliers of raw material C}} \geq 28200 \quad (5)$$

2) This study assumes in production that manufacturer uses material A. In order to ensure normal production, the number of raw materials ordered by the supplier should be greater than or equal to A. The constraint condition can be expressed as:

$$\mathrm{K}_1 \times \mathrm{X}_1 + \ldots + \mathrm{K}_{50} \times \mathrm{X}_{50} \geq \mathrm{A} \quad (6)$$

3) Similarly, the constraint conditions of materials B and C can be expressed as:

$$\mathrm{K}_3 \times \mathrm{X}_3 + \ldots + \mathrm{K}_{45} \times \mathrm{X}_{45} \geq \mathrm{B} \quad (7)$$

$$\mathrm{K}_2 \times \mathrm{X}_2 + \ldots + \mathrm{K}_{49} \times \mathrm{X}_{49} \geq \mathrm{C} \quad (8)$$

Therefore, the constraint conditions of the linear programming model can be expressed as:

$$\begin{cases} \underbrace{1/0.6 \times (K_1 \times X_1 + \ldots + K_{50} \times X_{50})}_{\text{16 suppliers of raw material A}} + \underbrace{1/0.66 \times (K_3 \times X_3 + \ldots + K_{45} \times X_{45})}_{\text{16 suppliers of raw material B}} \\ + \underbrace{1/0.72 \times (K_2 \times X_2 + \ldots + K_{49} \times X_{49})}_{\text{16 suppliers of raw material C}} \geq 28200 \\ K_1 \times X_1 + \ldots + K_{50} \times X_{50} \geq A \\ K_3 \times X_3 + \ldots + K_{45} \times X_{45} \geq B \\ K_2 \times X_2 + \ldots + K_{49} \times X_{49} \geq C \\ K_1 = The\ average\ of\ the\ supplier's\ supply \end{cases} \quad (9)$$

In this study, the linear programming model is input into LINGO software to solve the research questions, and the ordering scheme can be obtained. If the result is 0, the supplier is not needed.

3.2.3.2 Transporting scheme model

Given the weekly attrition rate of the transporter, this study solves the transport scheme through 0-1 integer programming, where the value is set to represent the selection of the *j*-th transporter by the supplier, and the value of 1 represents the selection of the transporter. The $n \times m$ decision matrix is established in this study. *N* indicates *n* suppliers. The ordering scheme determines the value of *n* per week, with *m* = 8 representing eight transporters.

In this study, the attrition rate is set as H, and the objective function is $H = \sum_{i=1}^{n} \sum_{j=1}^{m} X_{ij} C_i K_j$. Here, K_i represents the weekly supply quantity of supplier i. The C_j represents the attrition rate of the transporter j.

Decision variable: X_{ij}

Objective function: To minimize the attrition rate, the objective function is $MinH = \sum_{i=1}^{n} \sum_{j=1}^{m} X_{ij} C_i K_j$.

Constraint condition:

Since each supplier can only select one transporter, the decision matrix is made per row $\sum_{j=1}^{m} X_{ij} = 1$. That is, $\{\sum_{j=1}^{m} X_{ij} = 1$.

Based on the principle of assignment problem (Sun & Lin, 2012), one supplier can only choose one transporter, but multiple suppliers can select different transporters. In this study, the 0-1 integer model is established to solve the traversal cycle for each supplier, and the transport scheme is obtained.

4. Interpretation of Results

4.1 The Best Quality Supplier

This study uses the actual order quantity and supply quantity data to extract the supply characteristics of corresponding suppliers and gives the corresponding quantitative indicators and standardized processing results (see Figure 6 for the results). The horizontal coordinate is the supplier ranked from 1 to 50, the blue bar line represents the weighted total score of the corresponding supplier, and the red curve represents the weekly supply output of the corresponding supplier. As can be seen from Figure 6, the top suppliers produce more weekly supplies, indicating that such suppliers generally have higher supplies. The above conclusions help calculate the minimum number of suppliers to meet the production needs and formulate the most economical ordering scheme.

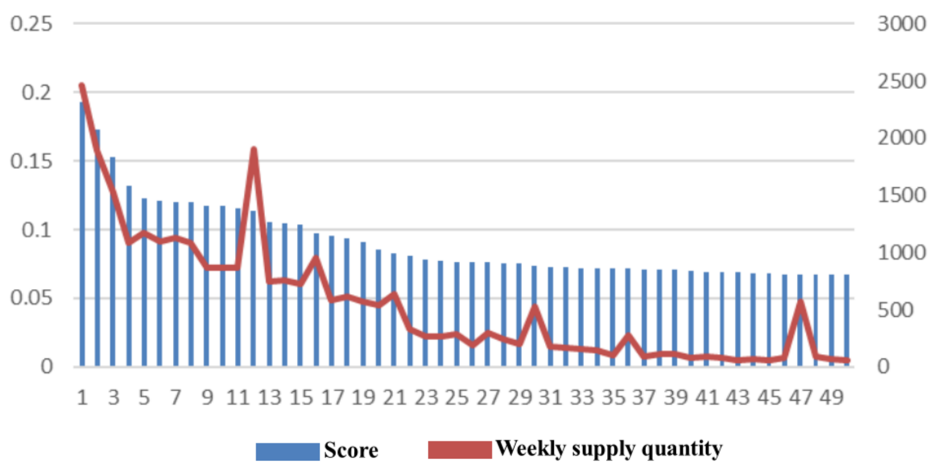

Figure 6. Supplier Ranking chart

On this basis, this study uses the 0-1 integer programming method to solve questions. The result is that the manufacturer needs at least 38 suppliers to meet its production needs. When the number of suppliers is less than 38, the constraint condition of the solution model for the minimum number of suppliers cannot be satisfied (see Formula (4)), which means that the constraint condition of the manufacturer's minimum capacity cannot be met.

Table 3. The weighted total ranking chart of 38 suppliers

Supplier	Total weighted score	Supplier	Total weighted score
No.229	0.192828	No.307	0.085625
No.361	0.172481	No.348	0.082484
No.108	0.152491	No.247	0.080510
No.340	0.131620	No.031	0.077872
No.282	0.122962	No.284	0.077393
No.275	0.120776	No.374	0.076266
No.151	0.120175	No.338	0.076250
No.329	0.119941	No.037	0.076096
No.308	0.117727	No.365	0.075765
No.131	0.117075	No.040	0.075720
No.330	0.115720	No.395	0.073978
No.140	0.113780	No.364	0.072338
No.268	0.105822	No.367	0.072296
No.356	0.104140	No.055	0.072117
No.306	0.103495	No.346	0.072081
No.139	0.097367	No.086	0.071830
No.194	0.095538	No.126	0.071553
No.352	0.093429	No.218	0.071150
No.143	0.090553	No.294	0.070462

4.2 The Optimal Ordering and Transporting Schemes

This study establishes a linear programming model to predict future ordering and transporting schemes based on the data of enterprise suppliers and transporters in a survey institution. The results are interpreted as follows.

This paper studies the ordering scheme by establishing a linear programming model. First of all, the objective function is set up in this study. According to the constraint conditions that meet the supply of inventory for at least two weeks, the suppliers that do not meet the constraint conditions are eliminated, and the optimal future ordering scheme is obtained. Secondly, through a comparative analysis of the final scheme and the original data, this study concludes that enterprises should increase and decrease the use of A/B raw materials respectively in production activities to reduce the cost of raw materials and improve product profits. Most of the manufacturers' choices are on the list of best quality suppliers, and the new scheme effectively improves the stability of raw materials, which is conducive to meeting weekly production needs while reducing costs.

As for the transporting scheme, this study establishes the 0-1 integer programming model, takes the minimum loss rate as the objective function, and eliminates the transporters that do not meet the constraint conditions to obtain the best future transporting scheme. In this study, the analysis of the resulting scheme shows that the best quality supplier in the transporting process can reduce the material loss to the greatest extent and effectively help enterprises save costs. Therefore, both outcome schemes can effectively improve enterprise capacity and reduce production costs.

The model established in this study can effectively predict the ordering and transporting scheme and effectively help enterprises control production costs and improve production income. The above methods and research results can be used to evaluate high-quality suppliers in the market, develop the most economical ordering scheme and transporting scheme, and help enterprises control production costs and improve production efficiency. Therefore, this model has particular practical significance.

4.3 Feasibility Analysis

Early work are based on the traditional theory and method for the production enterprise product cost control. For example, some scholars have analyzed the enterprise cost control model through constraint optimization theory (e.g., Fan et al., 2016; Yang, 2016). Zhang et al. (2006) use activity-based costing to calculate the production costs of enterprises. Based on previous studies, this paper investigates the raw materials in production. In this study, an overall simplified optimization model is constructed to predict future ordering and transporting schemes by combining linear programming theory and AHP. Previous studies on the overall improvement of the production cost system have relatively broad content and a simple theoretical basis.

The feasibility of this study mainly includes the following three aspects. First of all, in terms of selecting high-quality suppliers, this study adopts AHP based on comparing other scholars' different choices on index construction and exploration. AHP greatly simplifies the difficulty of data processing and considers the supply characteristics of suppliers, such as supply stability rate, to establish a hierarchical structure model for selecting high-quality suppliers. Second, this study is based on the 0-1 integer programming, solving several suppliers to satisfy the minimum production needs. Finally, this study proposes using operations research methods to improve the cost control framework. Since the dynamic change of weekly raw material inventory will affect the ordering plan, and the actual supply quantity and transporting plan will affect the actual order quantity and inventory, this study determines the future weekly ordering plan and transporting plan through 0-1 integer programming. According to the production cost selected by enterprises, this study compares the calculation results with the actual ordering scheme and obtains high accuracy and credibility.

5. Conclusion

This study seeks the optimal solution of suppliers that meet the minimum inventory and combines AHP and linear programming to work out the optimal ordering and transporting schemes under the background of raw materials. Based on the data, this study verifies the good properties of the ordering and transporting scheme. Firstly, for selecting optimal suppliers, the model constructed in this study calculates the importance ranking of all suppliers through the AHP in terms of the weight of essential indicators such as supply quantity and ordering rate. Secondly, as for the minimum number of suppliers, through 0-1 integer programming of the relationship between the raw material loss and the weekly production capacity, this study calculates that the number of suppliers that meetings weekly production requirements is at least 38. According to the relationship between the total quantity of raw materials ordered and the weekly production capacity of the enterprise, this study obtains the optimal ordering scheme by the 0-1 integer programming method. At the same time, as regards to the relationship between the supplier's weekly supply quantity and the transporter's loss quantity, this study obtains the most appropriate transporting scheme through the 0-1 integer programming method.

This study found that selecting high-quality suppliers and formulating the optimal ordering and transporting schemes could play a crucial role in maximizing the interests of the construction and decorative plate enterprise. Enterprises can reduce production costs from the source and achieve a virtuous cycle, to effectively improve the whole cost control system. At the same time, this study has strong practical significance and good academic value. For one thing, results of this study are universal and help to provide scientific solutions to the raw material problems existing in production enterprises. Different enterprises can solve the optimal solution of raw material supplier, ordering, and transporting with reference from the existing data. For another, this study fills the current research gap, since linear programming theory is introduced as the theoretical support, and the exclusive mathematical model is constructed for the problem of ordering and transporting raw materials to control production costs. Future research is suggested to introduce time series to analyze suppliers' availability and changing rules, explore how the enterprise's production capacity is affected by objective factors, and adjust the existing raw material ordering and transporting plan to increase the production capacity.

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