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Empirical Analysis of EOQ Procurement Model Based on AHP-entropy Weight Classification Management

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Abstract

Nowadays, X bakery suffers from high reordering costs and holding costs, which have become a major factor affecting its operating income, The optimization of raw material procurement in bakery should comprehensively consider seasonal fluctuations, capital occupation, inventory ratio and other issues. We use an optimization model that combines subjective AHP and objective entropy methods to perform ABC classification, and choose the inventory purchasing model according to the characteristics of each category, then we use the quantitative ordering model for class A materials and the Periodic ordering model for class B materials to analyze and calculate the economic order quantity, reordering point and other data. The optimized solution greatly reduces the cost of inventory and procurement, thus increases the profit for the bakery in terms of cost control.

Keywords

AHP; Inventory control; Entropy method; Economic order lot model; Purchasing optimization.

1. Introduction

X bakery was established in September 2010. mainly produce various desserts such as breakfast bread and French bread, also make various birthday cakes as well as wedding cakes. While the bread-making process is very complicated and uses a wide variety of ingredients, the cakes are designed with an even wider range of ingredients. Most of these raw materials are basically general ingredients, which can be used to make bread and cakes, while a few are non-general ingredients. Therefore, if we can improve the ordering of raw materials, we can save a lot of cost for the bakery.

2. X Bakery Purchase Management Status and Existing Problems

2.1. Insufficient Information

The lack of proper database management has led to the fragmentation of information and the lack of some basic data. Since a large amount of information is required to develop and execute purchasing plans, such as inventory information, supplier information and other production information, The bakery, however, does not use supply chain information sharing tactics and resource optimization strategies, which largely affects the scientific and economic nature of purchasing management decisions.

2.2. Rough Procurement Plan Development

Due to the wide variety of pastry materials and incomplete information required for purchasing, how to purchase cake ingredients becomes a complex and important issue, Use of regular wholesale purchasing for general raw materials. Usually at the beginning of each month, it is necessary to predict the total amount of raw materials required for this month's production, For special types of raw materials, purchases are organized according to production needs, this

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has resulted in a large backlog of general-purpose feedstock supplies, while production could be halted if some specialty feedstocks are lacking.

3. The ABC Classification Optimization Model Based on Analytic Hierarchy Process

3.1. The Limitations of the Traditional ABC Classification Method

ABC classification is the specific application of Pareto's law in warehouse management, In the warehousing policy, the way in which goods are classified and controlled during the warehousing process depends on their relative importance. The traditional ABC classification uses the same economic indicators for evaluation, ignoring factors such as the temporal and technical nature of the material, making the classification lose satisfactory credibility and accuracy. In order to achieve a differentiated warehousing management strategy and establish a decision-making framework that allows companies to focus their limited resources on priority commodities, the ABC classification urgently needs to be improved.

3.2. Principle of AHP-based ABC Classification Optimization Model

Analytic Hierarchy Process (AHP) is a decision-making method for multi-objective and multi-criteria problems. It decomposes the elements related to decision making into objective, criterion and solution levels. On this basis, qualitative and quantitative analysis is performed.

To address the limitations of the traditional ABC classification method. We constructed an optimal model combining AHP and ABC classification to maximize the reliability and validity of the analysis. The research ideas are as follows: first, construct the index model with analytic hierarchy process; second, construct the judgment matrix; third, determine the relative weight of each level; fourth, test the consistency of each judgment matrix; fifth, calculate the composite weight; sixth, conduct ABC classification and sorting according to the weight results.

3.3. Application of AHP-ABC Classification Method in Cake Store Management

3.3.1. Determination of Evaluation Index System

The first step of Analytic Hierarchy Process is to construct the recursive index model. According to the characteristics of bakery material management and the author's prior investigation related to cake store practitioners, a single target multi-criteria structural model is constructed to determine the importance of each material. The target layer of the model is the rational sorting and purchasing of supplies for cake shops (A); to simplify the analysis process, the criterion layer (B) is summarized into four factors: Amount of capital consumption (B1), Out of stock impact degree (B2), Ordering lead time (B3), and Difficulty of procurement (B4); the program layer (C) is all the storage materials required by the cake store to produce cakes and bread. Due to the large number of categories, only part of materials are selected for analysis. They are eggs (C1), blueberry fruit filling (C2), golden dragonfish oil (C3), aluminum-free baking powder (C4), mango fruit filling (C5), high dairy cream (C6), whole wheat premix (C7), Yuli cheese filling (C8), dairy cream (C9), cheese pudding (C10), large package of plate and fork set (C11), black sesame cut sugar (C12), marshmallow (C13), yellow peaches cans (C14), chocolate (C15), and baking soda (C16). The final classification hierarchy model is shown in Figure 1.

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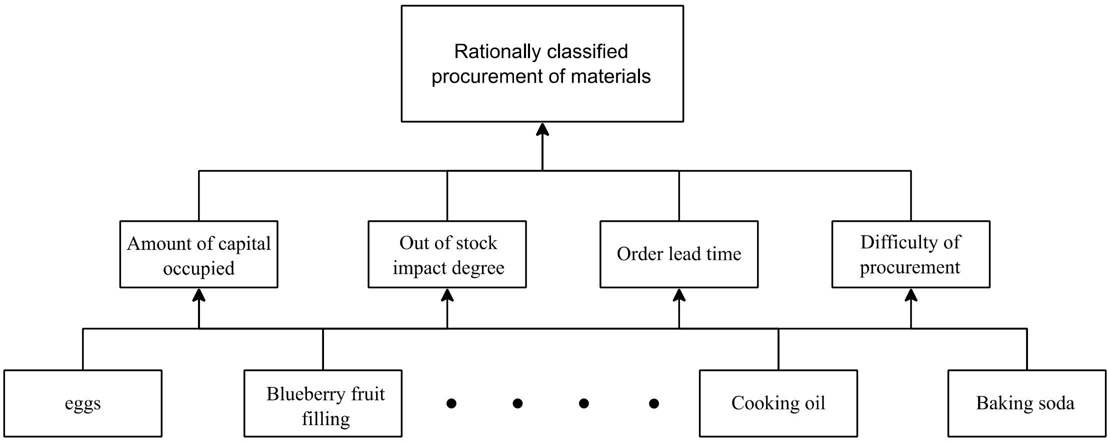

Figure 1. Hierarchical classification model of bakery supplies

3.3.2. Determination of First-level Indicator Weights

(1) Define target layer A and evaluation factors B1, B2, B3 and B4.

(2) Construct the judgment matrix. The data for the judgement matrix was obtained through an online interview with several staff members in the bakery. After comparing each element in the criterion layer one by one, we judge the relative importance of the element, and then summarize the data and take its average value. The judgment matrix obtained is shown in Table 1.

Table 1. Judgment Matrix

A1	B1	B2	B3	B4
B1	1	0.5	2	4
B2	2	1	4	8
B3	0.5	0.25	1	2
B4	0.25	0.125	0.5	1

(3) From equation (1)(2), weights of each indicator are calculated.

$$\overline{W_i} = \left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} \tag{1}$$

$$W_i = \overline{W_i} / \sum_{j=1}^{n} \overline{W_j} \tag{2}$$

Importance ranking indicators are obtained according to the above formula: $W2 = 0.5333 > W1 = 0.2667 > W3 = 0.1333 > W4 = 0.0667$.

3.3.3. Consistency Checking

After the matrix is established according to the relative importance table of elements and the weight calculation formula, the eigenvector corresponding to the maximum feature root in the matrix is obtained through the calculation of Equation (3) (4) (5), the feature vector value is the corresponding evaluation index weight. Random consistency index CR was used for consistency test.

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} a_i W^T / W_i \tag{3}$$

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$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{4}$$

$$CR = \frac{CI}{RI} \tag{5}$$

The results show that the evaluation matrix results meet the requirements .W= (0.2667, 0.5333, 0.1333, 0.0667).

3.3.4. Determination of Weights for Material Indicators

The final index weights are calculated as shown in Table 2.

Table 2. Matrix of indicator weights

Wi								
	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	C(7)	C(8)
B1	0.111	0.108	0.097	0.097	0.083	0.083	0.070	0.072
B2	0.130	0.101	0.101	0.087	0.087	0.073	0.073	0.058
B3	0.134	0.081	0.094	0.071	0.065	0.065	0.065	0.065
B4	0.101	0.056	0.050	0.141	0.175	0.056	0.056	0.056
W	0.124	0.098	0.096	0.091	0.089	0.073	0.070	0.063
	C(9)	C(10)	C(11)	C(12)	C(13)	C(14)	C(15)	C(16)
B1	0.056	0.056	0.042	0.042	0.028	0.028	0.014	0.014
B2	0.058	0.058	0.044	0.044	0.029	0.029	0.015	0.015
B3	0.065	0.066	0.053	0.066	0.029	0.033	0.033	0.017
B4	0.049	0.047	0.047	0.055	0.035	0.027	0.033	0.017
W	0.058	0.058	0.047	0.045	0.029	0.029	0.018	0.015

4. Entropy Method-ABC Classification Method in the Management of X Bakery

Entropy is a measure of the degree of disturbance in a system. Entropy weight method is a mathematical method to calculate the complete index based on fully considering the information provided by various factors. As an objective method to determine the weights, it is mainly based on the amount of information each index conveys to the decision maker. For the objective weights, we designed and collected questionnaires for contemporary cake college students' consumption groups, and 356 questionnaires were distributed in this survey. When conducting the default value processing of the questionnaires, if there were a large amount of missing data in the questionnaires, the whole questionnaires were invalidated, after screening we get the valid samples. This process is implemented by SPSS26. In 356 valid questionnaires, there were 4 missing data, so 352 valid data were finally taken.

The entropy weight method is implemented as follows, and the software is implemented using python 3.8.

4.1 Investigators scored X_{ij} for each evaluation indicator, and X_{ij} represents the score of the i-th expert for the j-th index, then normalize the results, and the normalized results for each evaluation index can be expressed as follows.

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$$y_{ij} = \frac{x_{ij} - min(x_{ij})}{max(x_{ij}) - min(x_{ij})} \tag{6}$$

From this, the standardization matrix can be obtained.
4.2 Based on the standardization matrix, the indicator entropy is calculated as follows

$$H_j = -\frac{1}{lnm}\sum_{i=1}^{m} f_{ij} lnf_{ij} \tag{7}$$

In the expression, f_{ij} denotes the characteristic weight of the i-th object under the j-th index
4.3 Based on the information entropy, the weights of each index are

$$v_j = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j} \tag{8}$$

where H_j denotes the entropy of the j-th indicator, V_j denotes the weight of the j-th indicator, and n denotes the number of indicators.
Thus, the weight diagram of X bakery determined by entropy weight method can be obtained, as shown in Table 3.

Table 3. Entropy weighting indexes

Target layer	Guideline layer		Program level	
	Indicators	Weights	Program level	Weights
Material rational classification procurement	Amount of funds tied up	0.394	eggs	0.076
			Blueberry Filling	0.071
			Golden Dragon Fish Oil	0.097
			Aluminum-free baking powder	0.081
	Out of stock impact level	0.242	Mango Fruits Filling	0.060
			High-dairy cream	0.071
			Whole wheat premix	0.072
			Yuli Cheese Filling	0.047
	Order lead time	0.147	Creamy butter	0.051
			Cheese Pudding	0.063
			Disc and fork set large package	0.054
			Black Sesame Cut Sugar	0.058
	Ease of procurement	0.217	Marshmallow	0.050
			Canned yellow peach	0.050
			Chocolate	0.054
			Baking Soda	0.045

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5. AHP-entropy Weight Combination Model

The article uses the multiplicative combination method for the combination assignment, and the final calculation formula of index weight is:

$$W_j = \frac{w_j v_j}{\sum_{i=1}^{n} w_i v_i} \tag{9}$$

By calculating the feedback data of student questionnaires corresponding to the index system established in this paper, the objective vector of the index system for evaluating pastry procurement materials determined by the entropy weight method was obtained. Therefore, the subjective weights determined by the AHP method and the objective weights determined by the entropy weight method were combined through the synthesis of equation (9) to obtain the combined weight vector.

Table 4. Combined weight vectors

Target layer	Guideline layer	AHP	Entropy	Combine	Program level	AHP	Entropy method	Combine
Material rational classification procurement	Amount of funds tied up	0.53	0.39	0.68	eggs	0.124	0.076	0.141
					Blueberry Filling	0.098	0.071	0.103
					Golden Dragon Fish Oil	0.096	0.097	0.138
					Aluminum-free baking powder	0.091	0.081	0.110
	Out of stock impact degree	0.27	0.24	0.21	Mango Fruits Filling	0.089	0.060	0.079
					High-dairy cream	0.073	0.071	0.078
					Whole wheat premix	0.070	0.072	0.075
					Yuli Cheese Filling	0.063	0.047	0.043
	Order lead time	0.13	0.15	0.06	Creamy butter	0.058	0.051	0.043
					Cheese Pudding	0.015	0.063	0.014
					Plate fork group large package	0.058	0.054	0.046
					Black Sesame Cut Sugar	0.045	0.058	0.039
	Sourcing Difficulty	0.07	0.22	0.05	Marshmallow	0.047	0.050	0.035
					Canned yellow peaches	0.029	0.050	0.022
					Chocolate	0.029	0.054	0.023
					Baking Soda	0.018	0.045	0.012

Based on the weights of each index calculated above, the improved classification results of the AHP-entropy weight method are shown in Table 5.

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Table 5. Combination improvement classification results

goods	Weighted fund	Amount ratio	Sort by	Percentage of accumulated amount	Percentage of cumulative number of items	Classification results
eggs	168.8	0.2818	1	0.2818	0.097	A
Golden Dragon Fish Oil	110.2	0.1839	3	0.4657	0.125	A
Blueberry Filling	82.4	0.1375	2	0.6033	0.224	A
Aluminum-free baking powder	65.94	0.1101	4	0.7133	0.296	A
Mango Fruits Filling	41.03	0.0685	5	0.7818	0.315	B
High-dairy cream	37.25	0.0622	6	0.844	0.401	B
Whole wheat premix	29.92	0.0499	7	0.8939	0.506	B
Yuli Cheese Filling	13.02	0.0217	8	0.9157	0.608	B
Creamy butter	12.5	0.0209	9	0.9365	0.658	B
Plate fork group large package	11.27	0.0188	11	0.9553	0.701	B
Black Sesame Cut Sugar	9.264	0.0155	12	0.9708	0.728	C
Marshmallow	6.3	0.0105	13	0.9813	0.821	C
Canned yellow peaches	3.924	0.0066	14	0.9879	0.846	C
Cheese Pudding	3.45	0.0058	10	0.9936	0.912	C
Chocolate	3.276	0.0055	15	0.9991	0..963	C
Baking Soda	0.54	0.0009	16	1	1	C

6. The EOQ Model-based Procurement Program Design

6.1. Demand Plan for Class A Materials

Although the demand for Class A materials is not large, they have a high capital utilization and a relatively consistent demand rate. Except for some minimum purchase quantity requirements for materials, they basically meet the requirements of the quantitative ordering system. For this type of material requirement planning management, the ideal ordering solution is to find an economic order quantity in order to balance the order cost and inventory cost, and ultimately minimize the total cost. That is, the method of quantitative ordering is adopted.

When using the quantitative ordering method, two parameters, Q and R, must be determined in advance for each order. Each order item must take into account the economic order of the EOQ series and the minimum order quantity of the supplier. According to the economic ordering model, The order quantity with the lowest inventory cost and ordering cost is:

$$Q = \left(2DC_3 / C_1\right)^{1/2} \tag{10}$$

In the formula: Q-optimal order quantity

D-Annual demand of material

C1-Material inventory cost

C3- single order cost

The reorder point R is calculated by the formula:

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$$R = \bar{d} * (L + Ls) \tag{11}$$

In the formula: R - reorder point
d-Average daily demand
L-Purchase lead time
Ls-Number of days of safety stock required
Total annual ordering cost is

$$TC = Dk + DC3 / Q + QC1 / 2 \tag{12}$$

Where: k - unit price per unit of commodity

The purchase quantity based on economic ordering can be calculated according to equation (10). Bakery's refrigerator charges and warehouse depreciation have been equally distributed to different commodities. In order to cope with market fluctuations and unreliability of supplier supply, it is also necessary to establish a certain amount of safety stock. Safety stock can be obtained through statistical analysis. Inventory quantities can be used to secure the purchase cycle for emergency orders. Table 6 is the calculation results of economic order quantities and reordering points for category A goods. (Eggs unit-case, Goldfish oil unit-barrel, blueberry compote unit-bag, aluminum-free baking powder unit-bag)

Table 6. Calculation results of economic ordering lot and reordering point of Class A materials

Products	eggs	Golden Dragon Fish Oil	Blueberry Filling	Aluminum-free baking powder
Unit price	200	40	22	9
Inventory costs	70	50	50	50
Ordering Fees	5	3	2	5
Annual demand	180	360	360	1000
Number of days of safety stock	7	7	7	7
Economic order quantity	5	7	5	19
At the order point	4	14	10	50
Total annual subscription cost	36355	14729	8189	9738

6.2. Procurement Plan for Class B Materials

After using the AHP-entropy weight combination model to determine the weights, the demand for materials aggregated by weighting ratio tends to be lower, but still accounts for a certain percentage of procurement funds. Having a large amount of such materials does not lead to a significant increase in material inventory costs and capital employed. However, due to the long-term and continuous demand for such materials, it is obviously pointless to calculate the demand too carefully every time. In addition, suppliers are usually reluctant to accept small order requests for such raw materials of relatively small value. Therefore, a periodic ordering model should be used for this type of material. The advantages of using this model are: first, No need to monitor inventory at any time, saving the workload of the planner; second, common raw materials with low value and short shelf life, such as high-fat milk creamer and creamer, mostly come from the same supplier. In this way, purchasers can combine multiple types of

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material orders on a regular basis. Combining orders not only reduces shipping costs, but also allows for price discounts.

For the periodic order system model, the two main parameters that need to be determined in advance are the interval P and the target inventory T. If the interval is too short, the order volume is often too small and the planning effort too high; if the interval is too long, it can easily lead to a large number of orders and a large inventory in the warehouse. Therefore, an appropriate range of orders is needed. In this type of material, many have a minimum order quantity of 5 barrels or 6 boxes with an order multiple of 2 boxes. Combining the demand rate for confectionery ingredients and the supplier's Minimum batch requirement, the suitable order interval is six days. For a regular order system, the equation for calculating the target inventory level is:

$$T = T_L + \bar{d}t + L_I \tag{13}$$

In the formula: T-Target stock quantity

T_L-Minimum inventory

dt-Average daily demand (constant)

t -Ordering cycle (days)

L_1-Safety stock

The setting of the target inventory is that when the goods ordered at the current time point arrive at the warehouse according to the order lead time, except for the safe inventory, our other inventory just runs out. This is exactly the definition of the reorder point. Therefore, the value of the reorder point of the regular order model is the value of the target inventory, i.e., in terms of quantity, the reorder point R is equal to the target inventory.

$$R = T \tag{14}$$

According to the above formula, procurement parameters of category B items can be obtained as shown in Table 7.

Table 7. Calculation results of economic order quantity and reordering point of B type goods

Raw materials	Mango Fruits Filling	High-dairy cream	Whole wheat premix	Yuli Cheese Filling	Creamy butter	Plate fork group large package
Order cycle	7	7	7	7	7	7
Minimum stock	2	2	1	0.5	6	1
Average daily demand	2	2	1	0.5	6	1
Safety stock	3	4	0.5	0.1	4	0.5
Unit price	52	20	80	150	12	50
Target inventory level	19	20	8.5	4.1	52	8.5

6.3. Order Plan for Class C Ingredients

Class C ingredients are used only for the production of birthday cakes with special needs. The demand for such ingredients arises in the production of bread with special taste needs,

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Therefore, such materials are sometimes rarely used or even not used at all, but sometimes consumed in large quantities. This requirement feature belongs to typical related requirements, and since the quantity of this demand is predictable and the demand is intermittent, there is no need to have a safety stock. Before calculating the raw material target inventory, it is necessary to know the cake production cycle plan, the raw material stratification list and the inventory data. The key to the calculation is to find out the relationship between general ingredients and special ingredients, process each cake's demand layer by layer, calculate the total demand for each cake, and then find out the net requirement by combining the inventory and expected arrivals. The calculation formula is: net demand = total demand - expected arrivals - available inventory.

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