Production Scheduling of Small Batch Materials Based on BP Neural Network

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Abstract. In view of the production process of multi variety and small batch materials, six main materials were selected as the research object by using ABC classification method. On this basis, a prediction model based on BP neural network is constructed. The model is applied to six important material demand forecasting, and the results show that the average prediction error of BP neural network is only 1.96%. This method can help enterprises make reasonable production plans, so as to obtain greater profits.

Keywords: ABC classification; BP neural network; Demand forecast; Error rate

1 Introduction

With the evolving market economy, there's a growing demand for product diversification and uniqueness. Traditional mass production methods no longer suffice, prompting a shift towards small batch, multi-variety production as a crucial mode. This mode, characterized by diverse products, intricate structures, and limited output, necessitates adaptable production strategies aligned with market dynamics for enhanced economic growth.

However, challenges persist in the management of such enterprises, including inadequate infrastructure, underdeveloped systems, low levels of automation, and production delays, hindering optimal enterprise development. While most focus on production efficiency and product quality, neglecting product arrangement undermines profit margins. Accurate prediction and proactive management of material demand can significantly conserve resources and boost profitability.

Bo Zhou and Yunpeng Jing[1] analyze issues in small-batch production, proposing measures to optimize management based on product variety. P.Z.L[2] analyzed real small batch production, detailing production line change management in manufacturing processes, and built a simulation model for product manufacturing systems. Rezaei Jafar and Salimi Negin[3] studied the problem from different perspectives and proposed

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a new ABC inventory classification optimization model in the form of interval programming problems. Eraslan Ergun, Ic, Yusuf Tansel[4] proposed a novel IDSS for ABC classification, integrating new algorithms tailored to manufacturing company traits, in a modular structure with integrated database and ABC analysis modules. Lon Z G, Nurmaya S M, Jen H Y[5]. analyzed the industry of HMLV from an industry perspective, revealing the production sector and research areas, and classified the development work, validation types, and applications. Gao Yan[6] analyzed the formation process and characteristics of multi variety and small batch production modes, and constructed a quality control process suitable for multi variety and small batch production.

Tseng Tsui Yuan and Luo Qinglan[7] developed a BP neural network-based model for employee quality evaluation. It collects and processes daily performance data, predicting quality scores accordingly. Qian Chang, Tianhui Gao, and Jiaming Zhu[8] built BP neural network and fuzzy evaluation models for risk assessment and credit strategy planning in small to medium-sized enterprises, successfully resolving them. Minchao Li[9] confirmed BP neural network's effectiveness in automotive component demand prediction, addressing nonlinearities in influencing factors and enhancing prediction accuracy, surpassing traditional methods and enhancing prediction's scientific rigor.

This study adopts the ABC hierarchical management method to optimize profits by prioritizing high-capital materials. It identifies six critical materials and employs a BP neural network model for demand prediction. Through this approach, the study proposes a production plan that optimizes resource allocation, aiming to maximize enterprise profitability.

2 Data Sources and Analysis

2.1 Data Sources

In this paper, the data of the appendix to question E of the 2022 "Higher Education Society Cup" National College Students' mathematical modeling competition[10]

is taken as the research object.

Set the week in which the attachment data first appears on January 2nd, 2019 as the first week, and the subsequent weeks from Monday to Sunday, for example, January 7th to 13th, 2019 as the second week, and so on.

2.2 Data Preprocessing

There are 22453 records and 284 material codes in the annex. The dates are from January 2, 2019 to May 21, 2022, with a total of 1236 days, covering 177 natural weeks. Analyze the attachments with Excel pivot table and sort out the 177 week information of 284 materials, such as week, demand and sales unit price. Here, take 6004020900 materials with high sales unit price and high proportion of total funds as an example, as shown in Table 1.

Table 1. Weekly Information of Material 6004020900

Item No	Week	Demand	Average Selling Price
6004020900	43	2	6371.99
6004020900	44	2	6372.072
6004020900	45	4	6372.032
...	...	...	...
6004020900	174	7	6327.523
6004020900	176	5	6327.552
6004020900	177	13	6327.54

3 Focus on Materials

3.1 ABC Classification Method

The demand and sales unit price of materials are different, so the funds occupied are different. According to the amount of funds occupied in 177 weeks, the materials are divided into class A, class B and class C, giving priority to the materials with higher funds occupied.

3.2 Focus on Material Selection

According to the ABC classification method, The materials with 70% of the total amount are classified as class A, those with 25% of the value are classified as class B, and those with 5% of the value are classified as class C. The ABC analysis table is prepared. The results are shown in Table 2.

Table 2. ABC Classification Results

Item No	Fre-quency	Occupancy/RMB	Percentage of occu-pancy	Sort	Classifica-tion results
6004020918	620	5045407.557	4.0%	1	A
...	...	...	...	...	...
6004020725	106	962698.847	0.76%	47	A
6004010229	223	884878.940	0.70%	48	B
...		...	...	...	...
6004020493	191	143714.702	0.1138%	127	B
6004020795	15	141589.760	0.1121%	128	C
...		...	...	...	...
6004010396	1	489.93	0.0004%	284	C

The following materials are selected from the class A materials as the key materials,namely 6004020918, 6004020900, 6004010174, 6004010256, 600410008 and 6004020504.

4 Prediction Model

4.1 Bp Neural Network Model

This paper's BP neural network comprises three layers: input (material frequency, average sales unit price, weekly total price X_1, X_2, X_3), hidden, and output (demand result φ). See Figure 1 for the network structure.

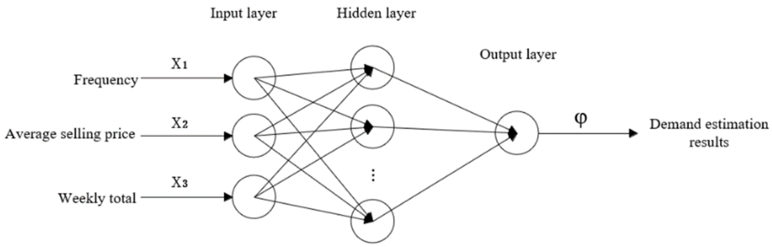

Fig. 1. Structure Diagram of BP Neural Network

The structure of BP neural network has a great impact on its performance, so it is necessary to design the structure and related parameters of the network reasonably. Based on known data, sigmoid function and function formula are selected here:

$$sigmoid(z) = \frac{1}{1-e^{-2}} \quad (1)$$

In this neural network, the inputs of any neuron in the hidden layer are:

$$y_j = S(\sum_{i=1}^{p} w_{ji}x_i) \quad (2)$$

In the formula: $S(\cdot)$ is the activation function, where $x_1, x_2, x_3 ... x_n$ are the inputs of neurons, and the inputs are generally independent variables that have a key impact on the system model. p is the number of input neurons; w_{ji} is the weight between the input layer neuron i and the hidden layer neuron j. Since there are few variables, a hidden layer is set here to get the k-th output neuron:

$$Y_k = S(\sum_{j=1}^{q} w_{kj}y_j) \quad (3)$$

In the formula: Y_k is the output through the activation function $S(\cdot)$; q is the number of output neurons; w_{kj} is the weight between hidden layer neurons and output layer neurons. w_{ji} and $w_{kj}$are the weights from input layer to hidden layer and from hidden layer to input layer respectively. Through the known three factors, predict one factor that needs to be solved. In order to better build the network, it is necessary to design the hidden layer.

$$S = \sqrt{pq} + \lambda \quad (4)$$

In the formula: p is the number of input neurons, q is the number of output neurons, λ is a constant, and the value range is 1~5. The calculated value range of S is 2~7, a hidden layer is set, the number of hidden layer neurons is 2, and the neural network is constructed.

4.2 Construction of Neural Network Model

According to the 177 week data of six materials, three types of data, including weekly frequency, average sales unit price and total weekly sales, are selected as input layer nodes. Each group selects 75% of the data as training samples, 15% of the data as validation sets and 15% of the data as test sets. In order to prevent the phenomenon of slow training speed and over fitting, the number of hidden layer neurons is 2, the output layer is 1 node, and the network structure is 3-2-1. The Levenberg Marquardt algorithm is used as the training algorithm. The maximum number of training iterations is set to 1000, the learning rate is 0.001, and the training gradient value is 0.0859. The training results of BP neural network model are shown in Figure 2.

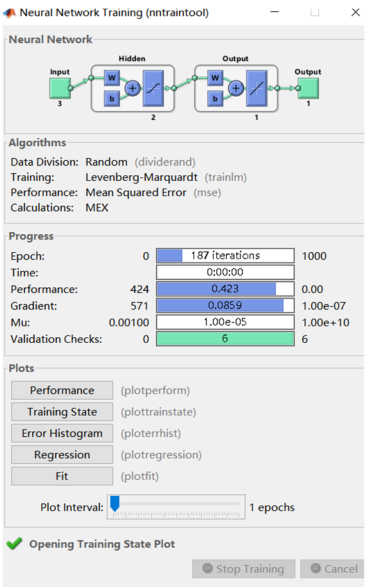

Fig. 2. Training Diagram of BP Neural Network

In the process of 187 iterations, the training of the neural network stopped after the root mean square decreased to the set value, and the mean square error was 0.423. The regression result is shown in Figure 3. The training regression output R value is close to 1 and the training result basically coincides with the expected target in a straight line, so the training effect is good.

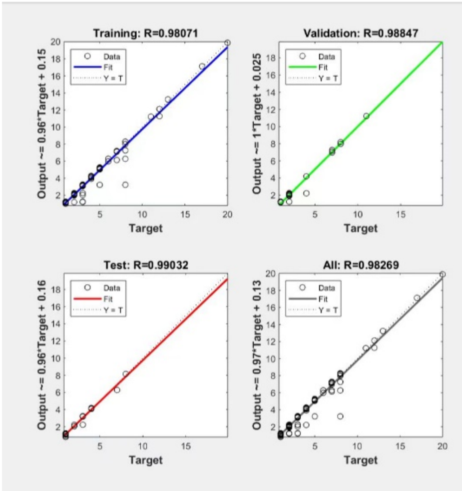

Fig. 3. Regression Results of Neural Network Training

4.3 Forecast Results

Using the frequency, average sales unit price, and weekly total price of six key materials as the training set and demand as the output set, a model is constructed. This model predicts demand values based on input. The BP neural model predicts error rates for materials 6004020918, 6004020900, 6004010174, 6004010256, 6004100008, and 6004020504 at 1.08%, 0.24%, 8.48%, 1.28%, 0.38%, and 0.29% respectively, with an average error rate of 1.96%. This indicates a satisfactory prediction effect, warranting the establishment of a neural network weekly prediction model for material demand.

5 Conclusion

Enhancing production management is crucial for multi-variety, small-batch product manufacturing. Improved production planning, especially for key materials, is essential for high-quality enterprise growth. Using the ABC classification method, six key materials are identified. BP neural network predicts their demand with 1.96% average accuracy, aiding efficient production planning, reducing inventory, and enhancing profitability.

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