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Study on Production Planning Demand Model Based on SPSS Statistical Analysis

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Abstract: *The decisions of small and medium-sized enterprises on production and inventory management have a direct influence on operating costs and their survival. It is of great significance to reduce inventory reasonably and reach reasonable service levels to ensure that enterprises meet the requirements of the business. Therefore, we conduct the data analysis for the historical sales demand and price of ten types of petty commodities in the past three years. A time series analysis is performed by using the weekly prediction model according to the periodic demand to make a reasonable production plan prediction. The regression relationship between inventory, actual demand, and the predicted price is fit. The result shows that the capital occupied by inventory is reduced and the production plan is reasonably predicted. The enterprise's production plan can be scientifically planned and adjusted to make correct decisions through data analysis and modeling based on the result of this study.*

Keywords: *demand prediction model, regression analysis, time series analysis, production decision*

1. Introduction

Demand prediction is the basis for enterprise manufacturers to make decisions on supply chain management. Many internal and external factors affect demand prediction. The demand prediction is classified into medium and short-term prediction, medium-term prediction, long-term prediction, qualitative prediction, and quantitative prediction [1]. Demand prediction needs to pre-estimate the demand of each type of commodity, infer, forecast, and estimate it in the future time. The accuracy of demand prediction is determined by the scientificity of prediction methods and the reliability of data. Effective demand prediction requires reliable and comprehensive data. We conduct the medium-term prediction for the selected products by focusing on analyzing the historical data of hundreds of petty commodities of an enterprise in the past three years. The data include the sales volume and unit price of each type of product. With the causal analysis and historical mapping methods in the quantitative prediction method, the relevant factors are found based on the historical data. With the assumption that there is a functional relationship between the actual demand in the previous week and the inventory, a regression model is established for prediction. Assuming that the periodicity of historical data lasts into the future, weekly demand prediction is conducted in the exponential smoothing method in time series analysis to show a relatively stable trend or periodicity characteristics [2]. For the historical mapping method, the future data shows the same or at least a similar pattern. There are many prediction methods on this principle, such as the moving average method and the exponential smoothing method. Quantitative prediction is required for quantifying future demand in the management of production and operation enterprises.

2. Key Factors of Production Plan Prediction

As the most important part of enterprise production management, a production plan requires many factors to achieve the balance between demand and supply. There are many constraints in the process of making production plans, such as manpower, equipment, materials, methods, environment, and others. Prediction is the process of providing the most possible view of future market demand under the assumed conditions, such as technology, price, marketing, expenditure, sales, and competitors. Prediction is the process of making a plan one step ahead and a managerial decision on the optimal allocation of enterprise resources according to the demand prediction [3]. Accurate demand prediction is to provide timely and effective services according to the demand of customers to improve customer satisfaction. Moreover, a loss of sales can be avoided which results in a loss of customers and a decline in service level. The

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prediction results directly affect the arrangement of the production plan. Prediction errors may lead to the loss of sales and overstock of inventory which demand funds and higher storage costs [4]. Improving the prediction accuracy contributes to reducing the safety inventory and improving the inventory management level.

The historical daily demand data of hundreds of petty commodities in the recent three years are analyzed in this study. The data is processed according to the weekly sequence. Considering the frequency, quantity, sales unit price, and other factors of demand for the commodities requires many types of historical data including the frequency of the occurrence of demand, cumulative quantity, and sales units. The data are filtered, cleared, and sorted out to analyze the sales demand for various petty commodities and their demand. To analyze the data, ten types of petty commodities are chosen as the research objects as shown in Table 1.

Table 1: Frequency of occurrence, total demand, and unit sales price of ten products

Product code	Frequency	Total demand (piece)	Unit Sales Price (Yuan)
1	1224	3011	861
2	540	1439	724
3	955	1585	851
4	573	1223	746
5	620	2213	737
6	612	1099	906
7	384	1090	810
8	418	2601	688
9	464	1094	501
10	346	2657	722

3. Weekly Prediction Model in Production Plan

Time series analysis is for quantitative prediction. Data analysis is conducted based on historical data, which is rarely affected by subjective factors. This method is appropriate when the basic demand pattern does not change much between years. Time series methods include the simple moving average method, weighted moving average method, and exponential smoothing method [5]. There is a lag trend in the moving average method and exponential smoothing method due to their calculation theory, which needs adjusting the smoothing constant. The simple moving average method is to average the data in a certain period for prediction. The weighted moving average method regards time as a series and allocates different weights to each component of the data with the sum of all weights of 1. The exponential smoothing method allocates a large weight to the data near the prediction period with the weight decreasing from near to far according to the exponential law [6].

We take product No. 1 for demand prediction and testing. First, it is assumed that the demand changes periodically without considering other influencing factors and each product is independent of the other without restriction. Most commodities have a sales validity period that is relatively long, so the demand is regarded as a long-term existence. The demand for one type of commodity has nothing to do with that for any other commodity. Weekly statistics on daily demand is shown in Fig. 1.

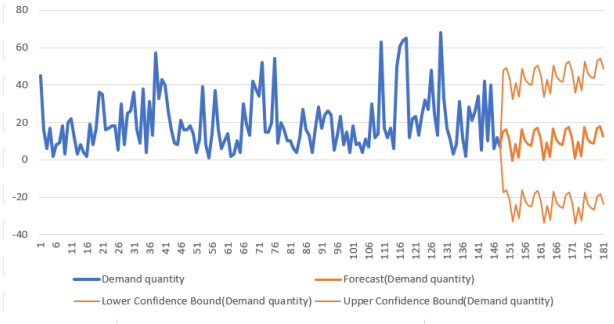

Figure 1: Trend change chart and trend prediction of demand in the first 148 weeks of Product No.1.

This product has a growth trend and fluctuation characteristics. The cubic exponential smoothing algorithm smoothes a time series consecutively by using a smoothing coefficient. In Eq. (1), F_{n+1} is the

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smoothing value of the week n, that is, the predicted value of the week $n+1$, A_n is the actual demand of the week n, α is the exponential smoothing coefficient. If α is small, the prediction results are less sensitive to the latest developments, indicating that the model values historical information. The prediction is made by using the predicted values and observed values in the previous period and with α. The prediction recurrence of one-time smoothing is calculated as Eq. (1) [7].

$$F_{n+1} = \alpha A_n + (1-\alpha) F_n \tag{1}$$

As α is too small, the curve of the predicted value is too smooth (Fig. 2), which does not reflect the transformation of the trend, and has a large deviation from the actual value.

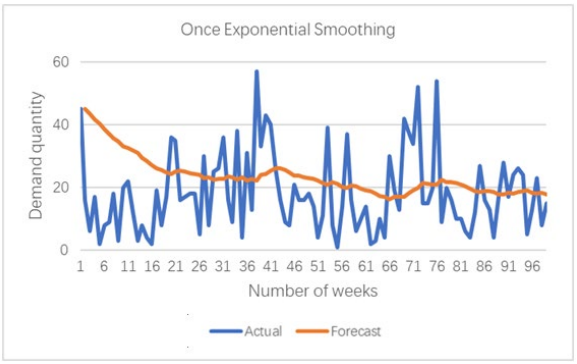

Figure 2: Comparison between prediction results and actual values of primary exponential smoothing method of Product No.1.

This result shows that the one-time exponential smoothing model does not apply to the demand prediction of products with large fluctuations. Thus, we consider three-times smoothing and establish the model as following equations [8]. Y_{n+1} is the predicted value of the following week n calculated at the end of the week $n+1$.

$$Y_{n+1} = a_n + b_n + c_n \tag{2}$$

$$F_{n+1}^3 = \alpha F_{n+1}^2 + (1-\alpha) F_n^2 \tag{3}$$

$$a_n = 3F_n^1 - 3F_n^2 + F_n^3 \tag{4}$$

$$b_n = \frac{\alpha}{2(1-\alpha)^2}[(6-5\alpha)F_n^1 - 2(5-4\alpha)F_n^2 + (4-3\alpha)F_n^3] \tag{5}$$

$$c_n = \frac{\alpha}{2(1-\alpha)^2}(F_n^1 - 2F_n^2 + F_n^3) \tag{6}$$

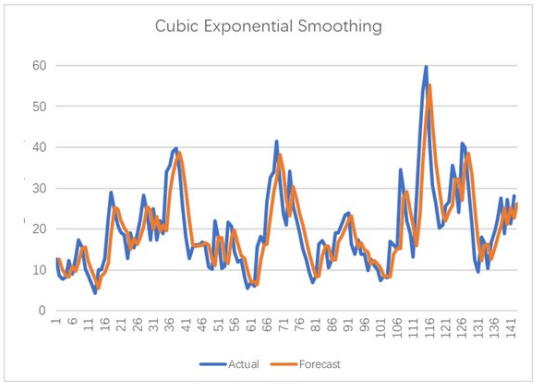

Figure 3: Comparison between the prediction results of cubic exponential smoothing models and the actual values of the data in the first 140 weeks of Product No.1.

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The weekly demand data for the first 140 weeks is selected with $\alpha = 0.36$. After the model is established, the predicted value is compared with the true value, and the trend chart is used to see whether the data is consistent (Fig. 3).

SPSS is used to check the fitting effect of the cubic smooth model [9]. The model fitting result is shown in Table 2. $R^2 = 0.813$, and the prediction effect is acceptable.

Table 2: Test of goodness of fit of weekly prediction model for Product No.1 by cubic exponential smoothing method

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile						
					5	10	25	50	75	90	95
Stationary R-squared	.009	.	.009	.009	.009	.009	.009	.009	.009	.009	.009
R-squared	.813	.	.813	.813	.813	.813	.813	.813	.813	.813	.813
RMSE	2.685	.	2.685	2.685	2.685	2.685	2.685	2.685	2.685	2.685	2.685
MAPE	9.533	.	9.533	9.533	9.533	9.533	9.533	9.533	9.533	9.533	9.533
MaxAPE	41.943	.	41.943	41.943	41.943	41.943	41.943	41.943	41.943	41.943	41.943
MAE	1.898	.	1.898	1.898	1.898	1.898	1.898	1.898	1.898	1.898	1.898
MaxAE	9.864	.	9.864	9.864	9.864	9.864	9.864	9.864	9.864	9.864	9.864
Normalized BIC	2.062	.	2.062	2.062	2.062	2.062	2.062	2.062	2.062	2.062	2.062

It is verified by practice that the demand prediction is made by using the cubic exponential smoothing method, and prediction by the cubic exponential smoothing model with a single smoothing coefficient is the most accurate [10]. The predicted value coincides with the actual value, and the change in the trend of the predicted value also coincides with the actual value. The weekly prediction effects of other products are not explained due to a large amount of data.

4. Regression Analysis of Short-term Actual Demand

Data regression analysis is to study the correlation between variables. Statistical data is used to judge and analyze the correlation between variables and obtain rules for generating models [11]. The general form of the multiple linear regression model is

$$Y = b_0 x_1 + b_2 x_2 + \cdots + b_m x_m + \varepsilon, \varepsilon \sim N(0, \sigma^2) \tag{7}$$

A regression model is established through statistical data for prediction to improve the accuracy of judgment. The linear regression equation is established as a functional model of the relationship between variables by using the least square method. We use the linear regression model for the prediction of inventory control to take reasonable and effective means and find the advantages and disadvantages of the existing inventory and control the inventory within a reasonable range without affecting customer satisfaction. Then, the occupation of working capital and the cost of warehouse management can be saved. Therefore, inventory control is of great significance to the normal operation and development of enterprises. The quantity of safety inventory depends on the uncertainty of supply and demand, customer service level, shortage cost, and inventory holding cost. If the customer service level is high, the safety inventory increases, leading to lower shortage costs and higher inventory holding costs. On the contrary, if the customer service level is low, the safety inventory decreases, leading to higher shortage costs and lower inventory holding costs;

There is a relationship between inventory and service level as (Service level=1 - shortage/actual demand). A large shortage refers to a small inventory and a lower service level. The regression relationship between the weekly planned quantity and the actual weekend demand is established with the early observation data to achieve a balance between the inventory and the service level. For product No.1, the inventory cost can be minimized to achieve a service level of at least 85%. For the 90−100 weeks of demand data, the relationship is observed between the weekly prediction volume and the actual weekend demand. A scatter chart is shown in Fig. 4.

Through regression analysis, a regression equation is fitted. Considering the actual application process, the integer problem is optimized to reduce the error and ensure the balance between inventory and service level. The test of goodness of fit is carried out with SPSS. $R^2 = 0.813$ in Table 3 indicates that the goodness of fit is good. $F = 5636.455$ (Table 4), and the probability level $p = 0.000$ of the test shows that it is statistically significant at a significant level of 0.05.

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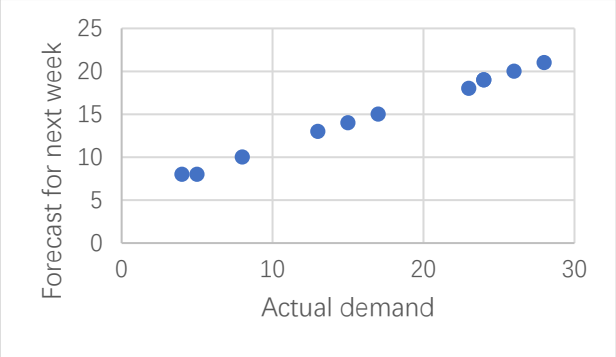

Figure 4: Scatter Chart of the Relationship between Next Week's Actual Demand and Next Week's Predicted Value to Reach the 0.85 Service Level Conditions

Table 3: Goodness of fit of the unary linear regression model between the weekly actual demand and next week's predicted value

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.998	.998	.202

a. Predictors: (Constant), Actual demand

Table 4: Significance Test Results of Unary Linear Regression Model

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	229.633	1	229.633	5,636.455	.000[b]
	Residual	.367	9	.041		
	Total	230.000	10			

a. Dependent Variable: Predicted value

b. Predictors: (Constant), Actual demand

The coefficient of the linear regression model is obtained through analysis as shown in Table 5. The linear relationship between the actual weekly demand and the number of weekly production for the next week is constructed. In the equation, x refers to the "weekly actual demand" of this product every weekend, that is, the planned production is calculated according to the actual demand of a week.

Table 5: Regression coefficient test

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.593	.139		40.155	.000
	Actual demand	.553	.007	.999	75.076	.000

a. Dependent Variable: Predicted value

Based on the method, five types of products are selected, and the weekly demand predicted value is obtained through the time series analysis. The predicted demand, actual demand, and inventory shortage are statistically analyzed, and a short-term regression equation is established to achieve a service level of more than 85%. Table 6 shows the comprehensive results of the five types of products.

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Table 6: Comprehensive results of five types of products

Product No.	Average quantity in production plan/(piece/week)	Average actual demand/(piece/week)	Average inventory/(piece/week)	Average service level
1	18.03	13.61	4.34	86.74%
2	8.62	6.99	3.06	88.94%
3	9.49	7.68	1.48	87.08%
4	7.32	5.06	2.71	86.59%
5	13.25	12.52	2.03	87.49%

5. Conclusion

Enterprise production needs to improve the demand prediction and production plan. In this study, the accuracy of demand prediction is improved, the ratio of dead goods in inventory is reduced, and the inventory turnover rate is increased. Thus, the inventory holding cost reduces. In the time series analysis method, historical data is used for prediction. It is assumed in this method that recent historical data is related to the future trend. The prediction result of the cubic exponential smoothing model applies to the weekly demand prediction of the company's products with the simple calculation and the prediction result. It also allows a more accurate production plan. It is required to consider that the average service level must be above 85% while reducing inventory cost and lowering inventory level. Regression analysis is conducted based on short-term historical data, indicating that the prediction simulation effect is ideal.

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