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Port Throughput Prediction based on ARIMA Model and Holt-Winters Exponential Smoothing Method

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ABSTRACT

Port throughput is a key indicator of port operation efficiency and economic contribution. Accurate forecasting helps improve port management and risk control. This paper uses monthly container throughput data of Shanghai Port from 2013 to 2023 to compare the ARIMA model and Holt-Winters exponential smoothing method. After trend and stationarity tests, ARIMA (1,1,2), Holt-Winters additive, and multiplicative models are constructed. Model performance is evaluated using MAE, RMSE, and MAPE. The results show that the Holt-Winters multiplicative model performs best and is used to forecast throughput from January to June 2025.

KEYWORDS

Port Throughput Forecasting; Shanghai Port; ARIMA Model; Holt-Winters Exponential Smoothing.

1. INTRODUCTION

Ports play an important role in international trade and regional economic development. Port throughput is a key indicator of port operation efficiency, and accurate forecasting can support logistics planning, resource allocation and risk management. However, port throughput is affected by economic conditions, trade demand, climate and other uncertain factors, which makes accurate prediction difficult.

Many forecasting methods have been applied to port throughput prediction. Liu and Jiang[1] proposed an improved multilayer perceptron model for port throughput forecasting and obtained better performance than the traditional MLP model. Liu and Zeng[2] compared exponential smoothing, multiple linear regression, elasticity coefficient and grey forecasting methods for container throughput prediction. Wang et al.[3] used LSTM and ARIMA models to predict Shanghai Port container throughput and found that LSTM achieved better fitting accuracy. Gao et al.[4] applied the Jackknife model averaging method to forecast container throughput of major Chinese ports. Tang and Li[5] combined the grey GM(1,1) model with Markov chain to improve medium- and long-term forecasting accuracy. Xiao et al.[6] proposed a selective deep ensemble model to capture the nonlinear characteristics of container throughput. Ayesha et al.[7] compared SARIMA, seasonal methods and Prophet in shipping demand forecasting.

Based on previous studies, this paper uses monthly container throughput data of Shanghai Port from 2013 to 2023 and compares the ARIMA model with the Holt-Winters exponential smoothing method. The aim is to identify a suitable forecasting model and provide reference for port operation and planning.

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2. RESEARCH DESIGN

The research process focuses on the prediction of port throughput. First, the importance of port throughput forecasting is explained and the research objective is clarified. Second, the ARIMA model and Holt-Winters exponential smoothing method are introduced as the main forecasting tools. Third, monthly container throughput data of Shanghai Port from 2013 to 2023 are collected and used as the empirical sample.

In the modeling stage, an ARIMA model is established after trend and stationarity tests. Holt-Winters additive and multiplicative models are also constructed by using the exponential smoothing module in SPSS. The models are then compared according to goodness-of-fit and forecasting error indicators. Finally, the model with the best performance is used to forecast the throughput of Shanghai Port from January to June 2025. In order to keep the paper concise, the original formulas, flow charts, and detailed data tables are omitted in this abridged version.

3. MODEL DESCRIPTION

3.1. ARIMA Model

ARIMA is a classical method for non-stationary time-series analysis. A complete ARIMA model is usually written as ARIMA(p, d, q), where p is the autoregressive order, d is the differencing order, and q is the moving-average order. In port throughput forecasting, the autoregressive part reflects the relationship between current throughput and historical observations, the differencing part is used to remove non-stationarity, and the moving-average part describes the influence of previous random errors.

The main steps of ARIMA modeling include stationarity testing, differencing, order identification, residual diagnosis, and forecasting. If the original series is non-stationary, it must be transformed by differencing until it becomes stationary. The orders p and q are then determined according to the autocorrelation function and partial autocorrelation function. After the model is built, the residuals should be tested. If the residual series is close to white noise, the model is considered valid and can be used for prediction.

3.2. Holt-Winters Exponential Smoothing

The Holt-Winters method is a time-series forecasting approach designed for data with trend and seasonal patterns. It is an extension of exponential smoothing and contains three components: level, trend, and seasonality. The model includes a level smoothing parameter, a trend smoothing parameter, and a seasonal smoothing parameter. These parameters determine how strongly recent observations affect the estimated components.

There are two common forms of the Holt-Winters method. The additive model is suitable when seasonal fluctuations remain relatively stable over time. The multiplicative model is suitable when seasonal fluctuations change proportionally with the level of the series. Since port container throughput often shows both growth trends and seasonal changes, both the additive and multiplicative models are tested in this study.

4. DATA SOURCE

Shanghai Port is located where the Yangtze River meets the East China Sea. It is one of China's major coastal hub ports and an important gateway for international trade. The port has functions such as loading and unloading, storage, transfer, and passenger transport. Its container throughput has

remained among the highest in the world for many years, which makes it a representative case for port throughput forecasting.

This study uses monthly container throughput data of Shanghai Port from 2013 to 2023. The data are collected from the Ministry of Transport of the People's Republic of China. The sample covers eleven years of monthly observations and contains clear trend and seasonal information, which is suitable for comparing ARIMA and Holt-Winters models.

5. MODEL CONSTRUCTION AND EVALUATION

5.1. Construction of the ARIMA Model

A trend test is first conducted on the monthly throughput series of Shanghai Port. The results show that the data have an overall upward trend and clear seasonal fluctuations. Declines frequently appear from December to the following March, especially in the first quarter. A sharp decline from the end of 2020 to the first half of 2021 may be related to the impact of the COVID-19 pandemic, the slowdown of international trade, and stricter epidemic-control measures for imported goods.

The correlation test shows that the original series is non-stationary. Therefore, first-order differencing is applied. After differencing, the series fluctuates around a relatively stable mean, and most autocorrelation coefficients fall within the confidence interval. According to the autocorrelation and partial autocorrelation results, the ARIMA model is finally determined as ARIMA(1,1,2).

5.2. Construction of the Holt-Winters Models Brushwork

Two Holt-Winters models are established: an additive model and a multiplicative model. By using the exponential smoothing module in SPSS, the smoothing parameters are estimated and the models are compared. According to the criteria of a larger R-square value and a smaller normalized BIC value, the Holt-Winters multiplicative model is selected as the better Holt-Winters specification.

5.3. Forecasting Accuracy Comparison

The forecasting accuracy of the models is evaluated by mean absolute error (MAE), root mean square error (RMSE), and mean absolute percentage error (MAPE). MAE measures the average absolute deviation between predicted and actual values. RMSE reflects the dispersion of prediction errors. MAPE measures the overall percentage error and is easy to compare across models.

The empirical results show that the Holt-Winters multiplicative model obtains lower MAE, RMSE, and MAPE than ARIMA(1,1,2). Therefore, it is selected as the best model in this study. The reason may be that the multiplicative Holt-Winters model can directly capture both trend and seasonal components, while the ARIMA model mainly relies on differencing and residual structure to describe the time series.

Because the monthly container throughput of Shanghai Port has obvious trend and seasonal characteristics, the multiplicative Holt-Winters model is more suitable than the additive model. It can better reflect proportional seasonal changes and is finally used to forecast Shanghai Port throughput from January to June 2025.

6. CONCLUSION

This paper compares the ARIMA model and Holt-Winters exponential smoothing method for forecasting monthly container throughput of Shanghai Port from 2013 to 2023. The results show that the Holt-Winters multiplicative model performs better than ARIMA(1,1,2) in terms of MAE, RMSE, and MAPE. It can more effectively adapt to the trend and seasonal changes in the data.

The findings have practical significance for port operation management, logistics scheduling, resource allocation, and strategic planning. More accurate throughput forecasts can help managers arrange port capacity, improve operational efficiency, and respond to market changes.

This study also has limitations. First, only historical throughput data are used, while external factors such as the macroeconomic environment, trade policy, climate change, and international shipping conditions are not fully considered. Second, the study focuses only on Shanghai Port, so the conclusions need to be further verified using data from other ports. Future research can combine Holt-Winters models with machine learning methods, introduce more explanatory variables, and explore long-term and cross-port forecasting applications.

REFERENCES

[1] Liu, M. M., & Jiang, Y. (2021). Research on port throughput forecasting based on an improved multilayer perceptron model. *Software Engineering*, (3), 39-42+35.

[2] Liu, Y. Q., & Zeng, M. (2018). Research on forecasting methods for port container throughput. *Logistics Engineering and Management*, (8), 85-87.

[3] Wang, F. W., Zhang, X. B., Yan, J. C., & Ji, Z. (2022). Forecasting container throughput of Shanghai Port based on LSTM. *Navigation of China*, *45*(2), 109-114.

[4] Gao, Y., Zhou, J. H., Wang, H. T., & Zhang, H. H. (2020). Forecasting Chinese port container throughput based on the Jackknife model averaging method. *Journal of Systems Science and Mathematical Sciences*, (4), 729-737. [in Chinese]

[5] Tang, T. C., & Li, L. (2020). Forecasting Shanghai Port container throughput based on a grey Markov model. *Logistics Sci-Tech*, (3), 105-108+114.

[6] Xiao, J., Wen, Z., Liu, B., Li, C. Y., Wang, Y. D., & Huang, J. (2022). Research on a hybrid forecasting model for container throughput based on selective deep ensemble learning. *Systems Engineering—Theory and Practice*, (4), 1107-1128.

[7] Ayesha, U., Farookh, H., & Muhammad, S. (2021). Container shipment demand forecasting in the Australian shipping industry: A case study of the Asia-Oceania trade lane. *Journal of Marine Science and Engineering*, *9*(9), 968. https://doi.org/10.3390/jmse9090968.