JKSCI

한국컴퓨터정보학회논문지
Journal of The Korea Society of Computer and Information
Vol. 28 No. 5, pp. 155-161, May 2023
https://doi.org/10.9708/jksci.2023.28.05.155

Prediction Oil and Gas Throughput Using Deep Learning

Sangseop Lim*

*Professor, Div. of Navigation Convergence Studies, Korea Maritime and Ocean University, Busan, Korea

[Abstract]

97.5% of our country's exports and 87.2% of imports are transported by sea, making ports an important component of the Korean economy. To efficiently operate these ports, it is necessary to improve the short-term prediction of port water volume through scientific research methods. Previous research has mainly focused on long-term prediction for large-scale infrastructure investment and has largely concentrated on container port water volume. In this study, short-term predictions for petroleum and liquefied gas cargo water volume were performed for Ulsan Port, one of the representative petroleum ports in Korea, and the prediction performance was confirmed using the deep learning model LSTM (Long Short Term Memory). The results of this study are expected to provide evidence for improving the efficiency of port operations by increasing the accuracy of demand predictions for petroleum and liquefied gas cargo water volume. Additionally, the possibility of using LSTM for predicting not only container port water volume but also petroleum and liquefied gas cargo water volume was confirmed, and it is expected to be applicable to future generalized studies through further research.

▸ **Key words**: Short-term forecasting, LSTM, deep learning, oil and gas throughput, port efficiency

[요 약]

우리나라 수출의 97.5%, 수입의 87.2%가 해상운송으로 이뤄지며 항만이 한국 경제의 중요한 구성요소이다. 이러한 항만의 효율적인 운영을 위해서는 항만 물동량의 단기 예측을 통해 개선시킬 수가 있으며 과학적인 연구방법이 필요하다. 이전 연구는 주로 장기예측을 기반으로 대규모 인프라투자를 위한 연구에 중점을 두었으며 컨테이너 항만물동량에만 집중한 측면이 크다. 본 연구는 국내 대표적인 석유항만인 울산항의 석유 및 가스화물 물동량에 대한 단기 예측을 수행하였으며 딥러닝 모델인 LSTM(Long Short Term Memory) 모델을 사용하여 RMSE기준으로 예측성능을 확인하였다. 본 연구의 결과는 석유 및 가스화물 물동량 수요 예측의 정확도를 높여 항만 운영의 효율성을 개선하는 근거가 될 수 있을 것으로 기대된다. 또한 기존 연구의 한계로 컨테이너 항만 물동량뿐만 아니라 석유 및 가스화물 물동량 예측에도 LSTM의 활용할 수 있다는 가능성을 확인할 수 있으며 향후 추가 연구를 통해 일반화가 가능할 것으로 기대된다.

▸ **주제어**: 단기예측, LSTM, 딥러닝, 석유 및 가스화물 물동량, 항만 효율성

• First Author: Sangseop Lim, Corresponding Author: Sangseop Lim
*Sangseop Lim (limsangseop@kmou.ac.kr), Div. of Navigation Convergence Studies, Korea Maritime and Ocean University
• Received: 2023. 04. 07, Revised: 2023. 04. 24, Accepted: 2023. 04. 28.

http://www.ksci.re.kr pISSN:1598-849X | eISSN:2383-9945

I. Introduction

Maritime transport plays a crucial role in international trade for South Korea, as the country is heavily dependent on exports. According to data from the Korea Maritime Institute, in 2020, 97.5% of South Korea's exports and 87.2% of its imports were transported by sea.[1] Maritime transport is a vital component of South Korea's economy and international trade, enabling the country to connect with markets around the world and facilitating the movement of goods and resources essential to its economic growth and development.

To effectively perform the functions of a port, demand forecasting to prevent shortages or excesses in port infrastructure must be conducted prior. There are some reasons why demand forecasting is important prior to investing in seaport development. First, Accurate demand forecasting can help with the planning and design of seaport infrastructure, ensuring that the port is designed to meet the projected demand. This can help to avoid overbuilding or underbuilding the port, which can be costly.[2] Forecasting provides a critical foundation for planning port infrastructure and operations, and should be the starting point for all other strategic and operational decisions. Second, Demand forecasting can also help with ensuring that the seaport has the necessary capacity to handle the projected demand. This can help to avoid congestion and delays, improving the efficiency of the port and reducing costs for port users.[2] According to UNCTAD, accurate demand forecasting is key to the efficient utilization of port capacity.[3] Last, Demand forecasting can also help with investment decisions related to seaport development. This can help to ensure that financial resources are directed towards projects that are most likely to generate a return on investment. Demand forecasting is a crucial aspect of seaport investment, as it informs the sizing and timing of investment decisions.[4-5]

Overall, demand forecasting is important prior to investing in seaport development because it can help with planning and design, ensuring that the port is built to meet the projected demand. It can also help with ensuring that the port has the necessary capacity to handle the demand, and can help with investment decisions by directing resources towards projects that are most likely to generate a return on investment. However, previous research on demand forecasting has mainly focused on long-term predictions.

Short-term forecasting is important for improving operational efficiency, supply chain coordination, and risk management in seaports. By providing real-time information on cargo volumes and vessel arrivals, port operators can optimize the allocation of resources, improve supply chain coordination, and mitigate the impact of risks associated with port operations.

Despite the importance of short-term forecasting for port throughput, research in this area has not received much attention. Previous short-term forecasting studies have mainly focused on time series analysis such as ARIMA or SARIMA, and recently, hybrid models combining artificial neural networks and ARIMA have been attempted. However, they have shown limited improvement in prediction performance. [6-8]

Previous studies have focused on long-term forecasting of port throughput, and among the short-term forecasting studies, time series models have been dominant, mostly targeting container port throughput.

This study uses the Long Short Term Memory (LSTM) model, one of the deep learning models, to perform short-term forecasting on the petroleum throughput of the representative oil port in Korea, Ulsan Port. LSTM is widely used in natural language recognition fields such as speech and handwriting recognition, and is advantageous for learning due to the time series pattern of language, such as words and sentences. The structure of LSTM can also be applied to time series analysis, and its performance in time series forecasting is known to be superior to that of conventional artificial neural network or ARIMA models. Therefore, this study aims to achieve significant improvement in short-term forecasting through the application of LSTM to port throughput, and it is expected to contribute to the efficiency of port operations by increasing the accuracy of port throughput forecasting.

II. Previous Studies

Short-term forecasting can help improve the operational efficiency of seaports by providing real-time information on cargo volumes and vessel arrivals. This information can be used to optimize the allocation of resources, such as labor and equipment, and to improve the planning and scheduling of port operations. Short-term forecasting can also improve supply chain coordination by providing timely information on cargo movements to other stakeholders, such as shipping lines, freight forwarders, and cargo owners. This can help reduce delays and improve the reliability of the supply chain. Additionally, short-term forecasting can be used to manage risks associated with port operations, such as congestion, delays, and weather disruptions. By providing real-time information on cargo volumes and vessel arrivals, port operators can take proactive measures to mitigate the impact of these risks.

Short-term forecasting of throughput in oil ports is important for several reasons. The accurate short-term forecasts of oil throughput are critical for ensuring that the port can efficiently manage its resources and handle the expected volume of cargo. Without accurate forecasts, the port may be either overburdened with excess cargo, leading to bottlenecks and delays, or underutilized, leading to idle capacity and wasted resources. In addition, oil port operators need to make informed decisions regarding storage and transportation capacity, given the variability of oil demand and supply.[9]

Accurate short-term forecasts of throughput can help operators optimize their capacity allocation, which can lead to significant cost savings and improved operational efficiency. The accurate short-term forecasts of oil throughput can help port operators and stakeholders in the supply chain plan and manage their activities more effectively. This can include scheduling deliveries, managing inventories, and coordinating with other stakeholders in the supply chain to ensure that products are delivered on time and at the required volumes.

Farhan and Ong(2018) proposes a method for predicting seasonal container throughput at intervention ports using SARIMA (Seasonal Autoregressive Integrated Moving Average) models. The paper applies variable selection techniques and model tuning to improve the performance of the SARIMA model. The results of this paper demonstrate that using the SARIMA model is an effective method for predicting seasonal container throughput at intervention ports, and that the use of variable selection techniques and model tuning can improve the model's prediction accuracy even further.[10]

Awah et al.(2021) proposes a practical way to predict the optimal container throughput that a port can physically process/attract, taking into account a certain level of terminal operational efficiency through random forest (RF) and multilayer perceptron (MLP) models. Research variables are derived at the port operation level and are characterized by including ship delivery time, ship draft time, container stay time, berth productivity, container storage capacity, and custom reporting time.[11]

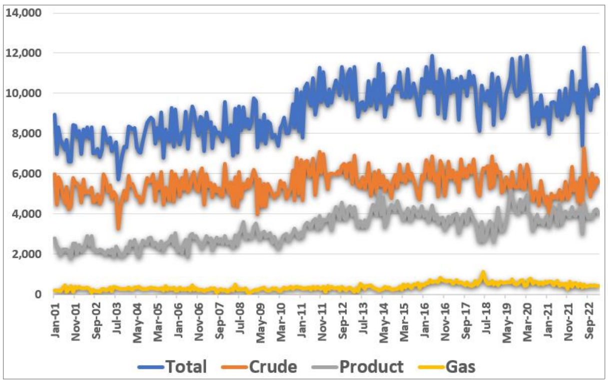
Shankar et al.(2020) proposes a method of predicting container timeliness using LSTM (Long Short-Term Memory) networks. The paper solves the time series prediction problem of container throughput by using an LSTM model that learns various features and data properties generated in container terminals. The paper evaluates the performance of the LSTM model by comparing it with other prediction models, namely regression analysis, ARIMA, and Exponential Smoothing. The experimental results show that the LSTM model performs better than the other models. Therefore, this paper demonstrates that the LSTM network is a suitable choice for the timeliness prediction problem in container terminals.[12]

Tan et al.(2021) propose a method for predicting container throughput using Grey model and ESN, which are RNN-based models. The paper discusses two prediction methods, including regression-based and machine learning schemes, for predicting container throughput. In addition, the paper compares the performance of the Grey model and ESN model and shows that the ESN model has higher accuracy.[13]

The previous studies reviewed so far have focused on short-term forecasting of container cargo volumes in seaports. In this study, we will attempt short-term forecasting of crude oil, petroleum products, and liquid gas cargo volumes at the Port of Ulsan.

III. Research Design

This study attempts to predict the demand for petroleum ports by predicting the volume of oil and gas cargo in the port of Ulsan through prediction analysis, and to contribute to the efficient operation of the port. By highlighting the importance of short-term prediction in port operation, this study will demonstrate its necessity and differentiation. The data necessary for short-term prediction of oil and gas cargo volume were collected from the Port Logistics Information Center (https://new.portmis.go.kr) for monthly data on oil and gas cargo volume in Ulsan from January 2001 to December 2022. A total of 266 monthly time series data from January 2001 to December 2022 were used for analysis, and the training set and test set were divided at a ratio of about 8:2, with approximately 216 training data used from January 2001 to December 2018, and about 48 test data used from January 2019 to December 2022. Typically, for neural network models, the training set and test set are divided at a ratio of 7:3 or 8:2 for training. Therefore, the data was separated according to the corresponding ratio for prediction. The trend and descriptive statistics of oil and gas cargo volume in the port of Ulsan are shown in Fig.1 and Table 1.



Source : PORT-MIS
Fig. 1. Oil and Gas Throughput Volume of Ulsan

Table 1. Descriptive Statistics of Oil and Gas Throughput in Ulsan Port

Statistic	Total	Crude	Product	Gas
Observations	266	266	266	266
Mean	9104.08	5485.53	3251.79	366.75
Std. error	78.41	40.69	47.60	10.35
Median	9170.45	5488.09	3247.53	320.45
Std. dev.	1278.82	663.57	776.27	168.78
Kurtosis	-0.73598	-0.20601	-0.96996	0.80029
Skewness	-0.00526	0.04517	0.07258	0.84638
Jarque-Bera	6.00466	0.56083	10.66094	38.85693
P-value	0.04967	0.75547	0.00484	0.00000

In this study, we attempts short-term prediction of port cargo volume through LSTM, one of the deep learning models by using TensorFlow2 under Python 3.7. Existing artificial neural network models, including recurrent neural network models, have a fatal weakness known as gradient vanishing or exploding. However, LSTM is a deep neural network designed to solve the gradient problem by replacing each node with a memory cell, which adjusts the output values obtained from previous learning processes through input, forget, and output. To select the optimal model, we will apply the k-fold cross-validation method to set hyper-parameters and use RMSE as comparison criteria. The paper compares the final prediction results and demonstrate the superior short-term prediction performance of the LSTM model and its applicability to port cargo volume prediction.

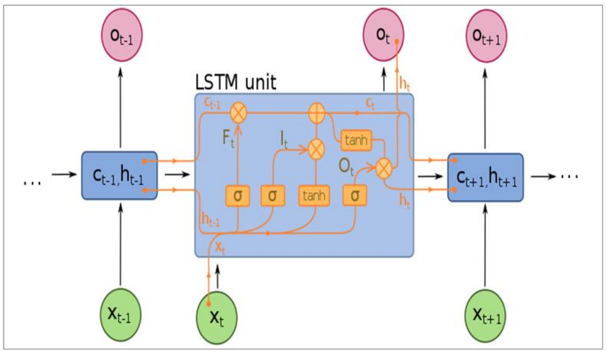


Fig. 2. Structure of Long and Short Term Memory

IV. Results and Coclusions

This study performed short-term predictions for the throughput volume of oil and gas cargo at Ulsan Port using LSTM. This paper used RMSE (root mean squared error, $\sqrt{\frac{1}{n}\sum(y_i-\hat{y_i})^2}$) as an indicator to verify the prediction performance, and the results are shown in Table 2. It is compared the actual data with the predicted values in Fig. 3.

Table 2. Performance of LSTM

	Total	Crude	Petrolume	Gas
RMSE	617	508	352	46

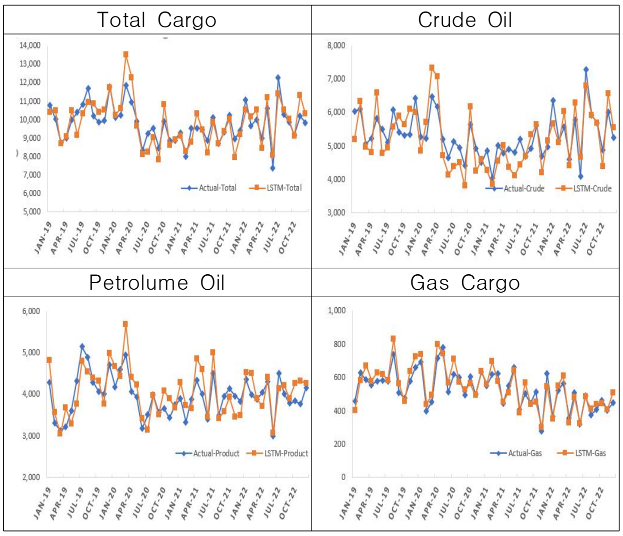


Fig. 3. Prediction of Oil and Gas Throughput in Ulsan Port

The experimental results of short-term prediction in this paper show that the prediction performance of LSTM is quite significant, and it is expected to establish goals and plans for improving the efficiency of port operation through short-term prediction of oil and gas cargo volume.

This study applied LSTM to predict short-term oil and gas cargo volumes in Ulsan, one of the representative petroleum ports in Korea. Long-term prediction of port cargo volume has been given more weight in the past studies, while relatively less attention has been paid to short-term prediction.

Prediction of port cargo volume is essential in the large-scale investment of sea ports, and accurate prediction through scientific methods is crucial.

This study showed that the performance of LSTM model in predicting port demand can be scientifically utilized and is excellent in terms of prediction performance. In addition, short-term prediction can achieve port efficiency not only in container ports but also in oil and gas ports, demonstrating the distinctiveness of this study compared to other studies.

The study acknowledges that there are other ports in Korea that handle oil and gas besides Ulsan, such as Yeosu and Daesan. Therefore, future research should consider examining these ports to complement the research conducted in this study. It is important to note that the performance of the LSTM model in predicting short-term port demand may differ when applied to different ports. Thus, a reevaluation of the model's performance in predicting demand for other ports is necessary to verify its effectiveness. Moreover, it is suggested that a comparison of the LSTM model with other forecasting models can be conducted to determine the strengths and weaknesses of each model. This comparison will provide a better understanding of the capabilities of each model in predicting short-term port demand. The study acknowledges that the use of data solely from Ulsan port may limit the generalizability of the findings to other ports. Therefore, future research should include data from other ports to improve the generalizability of the findings. It is important to note that the data used in this study covers only a limited period, and the results may vary if the study is conducted using a longer timeframe. Therefore, future research should consider using data covering a more extended period. Overall, the study highlights several directions for future research to build on the findings of this study and improve the accuracy and generalizability of the forecasting models.

ACKNOWLEDGEMENT

This work was supported by the Korea Maritime And Ocean University Research Fund in 2020.

REFERENCES

[1] Korea Maritime Institute, "Korea Port and Shipping Report," March, 2021.

[2] D. Dragan,, K. Abolfazl, I., Marko, P. Vlado, and K. Tomaž. “Throughput forecasting of different types of cargo in the adriatic seaport Koper,” Maritime Policy & Management, Vol. 48, No.1, pp.19-45, 2021. DOI: 10.1080/03088839.2020.1748242

[3] UNCTAD. “Review of Maritime Transport,” 2021.

[4] J. Alen, H. Svjetlana, and J. P. Tanja, “Traffic Demand Forecasting for Port Services,” Promet-Traffic & Transportation, Vol.23, No.1, 2011. DOI: 10.7307/ptt.v23i1.149

[5] P. Langen, J. Meijeren, and L. Tavasszy., “Combining Models and Commodity Chain Research for Making Long-Term Projections of Port Throughput: An Application to the Hamburg Le Havre Range,” European Journal of Transport and Infrastructure Research, Vol.12, No.3. 2012. doi:10.18757/ejtir. 2012.12.3.2968.

[6] Y. Rashed, H. Meersman, E. Van de Voorde, and T. Vanelslander,, “Short-term forecast of container throughout: An ARIMA-intervention model for the port of Antwerp,” Maritime Economics & Logistics, Vol.19, pp.749–764, 2017. DOI: 10.1057/mel.2016.8

[7] K. Mokhtar, S.M. Mhd Ruslan, A. Abu Bakar, J. Jeevan, and M.R. Othman, "The Analysis of Container Terminal Throughput Using ARIMA and SARIMA," In: Ismail, A., Dahalan, W.M., Öchsner, A. (eds) Design in Maritime Engineering. Advanced Structured Materials, vol 167. Springer, Cham. 2022. DOI: 10.1007/978-3-030-89988-2_18

[8] H. K. Chan, S. Xu, and X. Qi, "A comparison of time series methods for forecasting container throughput," International Journal of Logistics Research and Applications, Vol. 22, No. 3, pp.294-303, 2019. DOI: 10.1080/13675567.2018.1525342

[9] J.E. Kim, J.H. Oh, and S.H. Woo, "An introduction of new time series forecasting model for oil cargo volume," Journal of Korea Port Economic Association, Vol.34, No.1, pp.81-98, 2018. DOI : 10.38121/kpea.2018.03.34.1.81

[10] J. Farhan, and G. P. Ong, “Forecasting seasonal container throughput at intervention ports using SARIMA models,” Maritime Economics and Logistics, Vol. 20, pp.131-148, 2018. DOI:10.1057/mel.2016.13

[11] P.C. Awah, H Nam, and S. Kim, "Short Term Forecast of Container Throughput: New Variables Application for the Port of Douala," Journal of Marine Science and Engineering. Vol.9, No.7 2021. DOI: 10.3390/jmse9070720

[12] S. Shankar, P.V. Ilavarasan, S. Punia, and S.P. Singh, "Forecasting container throughput with long short-term memory networks", Industrial Management & Data Systems, Vol. 120 No. 3, pp. 425-441. 2020. DOI: 10.1108/IMDS-07-2019-0370

[13] N. D. Tan, H. C. Yu, L. N. B. Long and S. You, "Time series forecasting for port throughput using recurrent neural network algorithm," Journal of International Maritime Safety, Environmental Affairs, and Shipping, Vol.5, No.4, pp.175-183, 2021. DOI: 10.1080/25725084.2021.2014245

Authors

Sangseop Lim received the B.S. degree in ship engineering and M.A. and Ph.D. degrees in shipping management from Korea Maritime and Ocean University, Korea, in 2007, 2014 and 2018, respectively.

Since 2020, Dr. Lim is currently assistant professor in the Division of Navigation Convergence Studies at Korea Maritime and Ocean University, Busan, Korea. He is interested in shipping finance, shipping market forecasting and risk management.