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ANALYSIS OF TRIGGERS OF PORT CONGESTIONS USING A TREE-BASED MACHINE LEARNING CLASSIFIER AND EXPLAINABLE ARTIFICIAL INTELLIGENCE

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ABSTRACT

Increased maritime traffic leads to port congestion and negatively affects a demurrage rate, which refers to the percentage of vessels in a port's queue for more than a fixed time to load/unload. The demurrage rate indicates the level of port congestion and must be as low as possible. We suggest a methodology to possible derive triggers regarding a demurrage rate based on real data. To this end, we collect annual vessel data arriving and exiting the port of Ulsan, Republic of Korea, and combine it with berth and weather data. We use a tree-based machine learning classifier algorithm and explainable AI to evaluate and analyze demurrage patterns at the port of Ulsan. We then propose policy recommendations to reduce port congestion. Our results show that demurrage highly depends on berth type, previous and next ports, day of the week, availability of tugs or pilots, and entering time at port.

1 INTRODUCTION

Increasing maritime freight and demand has spurred competition among shipping operators for large containership orders. Congestion at ports is aggravated by the simultaneous arrival of large vessels and large amounts of cargo, produced by the employment of larger vessels in logistics, which increases maritime traffic. Ship quay cranes and yard tractor fleets may arrive at the berth or terminal at the same time, increasing congestion. This reduces port efficiency and leads to increase in ship turnaround time.

The effectiveness of overall port operations influences the vessel's demurrage time. Demurrage is liquidated damages for violating the contract's lay-time. Demurrage occurs when a ship delays longer than a full day to load/unload goods. Demurrage is the percentage of vessels waiting more than a fixed time (e.g., over 12 hours in the Republic of Korea) for loading/unloading. Deteriorating demurrage rates hurt port stakeholders and maritime logistics' competitiveness. It's thus vital to build strategic countermeasures to predict and reduce demurrage rates, which can increase port efficiency.

To this end, we propose a methodology using a tree-based machine learning classifier technique to analyze annual maritime traffic data in the Ulsan Port Authority (UPA), Republic of Korea. Finally, we predict the main triggers regarding a demurrage rate and develop a strategy to reduce a demurrage rate and improve port operations.

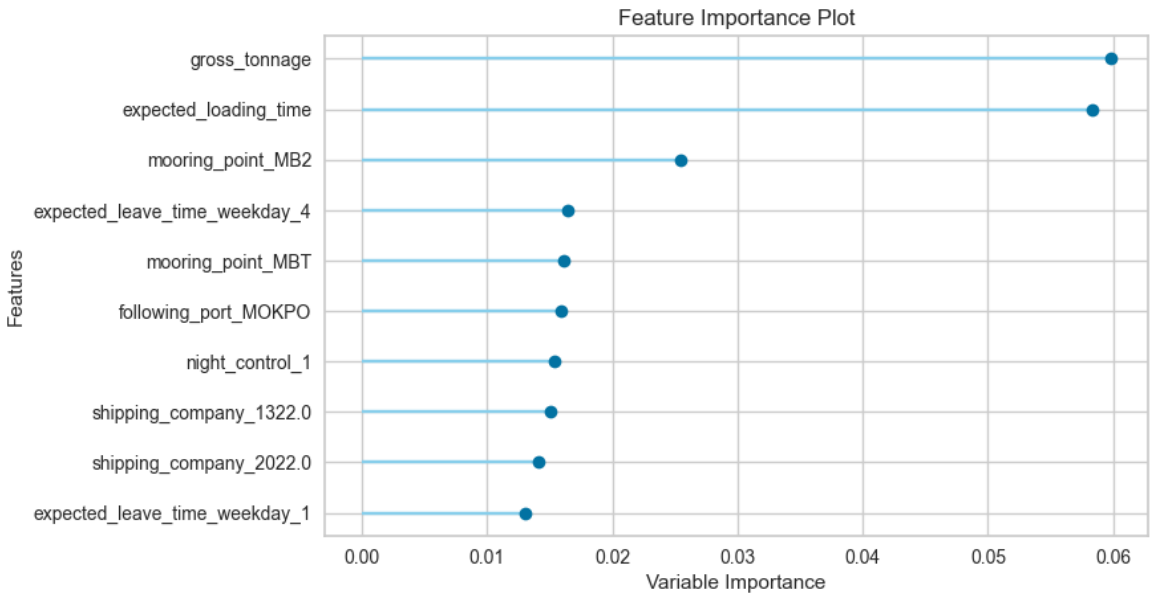
2 METHODOLOGY

To identify patterns regarding demurrage, we suggest a tree-based machine learning classifier algorithm such as Random Forest (RF), Extra Trees (ET), and Light Gradient Boosting (LGB) at the port of Ulsan and analyze the result using Shapley Additive exPlanations (SHAP). First, we gather vessel data for ships

arriving and departing from all 11 berths at the port of Ulsan and combined these datasets with the weather data. The collected data contain a total of 33 characteristics, consisting of 16 characteristics for vessel data and 17 characteristics related to weather data. Based on the collected data, we compare the performance of all tree-based classifiers and select the best model. After that, we analyze the result using SHAP (Lundberg and Lee, 2017). SHAP is a measurement mechanism for the influence of individual features on the prediction of a machine learning model. This mechanism proposes the feature importance analysis to determine the contribution to demurrage and the SAHP value analysis to combine feature importance with feature effects. For example, feature importance explains the contribution of whether a ship arrives at night to predicting demurrage, and the SHAP value analysis explains the effect of night arrival on demurrage. In our study, we analyze the demurrage patterns not only for the entire port of Ulsan but also for each of the 11 berths at the main port of Ulsan, and we propose insights to reduce the demurrage rate.

3 CONCLUSION

A methodology to evaluate and analyze the demurrage patterns of each berth as well as the entire port of Ulsan is proposed using the machine learning method such as a tree-based machine learning classifier and explainable AI mechanism. To this end, we select a tree-based machine learning classifier that best predicts a demurrage for each berth of at the port of Ulsan, and analyze its contribution and impact on the features. One of the features that determine the demurrage is the berth type, gross tonnage, expected departure date, and the type of the next port. Additionally, there is a high probability of demurrage if the arrival day is Thursday. Furthermore, insufficient tugs and pilots or vessels entering the port at night mainly end up the demurrage of a vessel at these berths. Therefore, to reduce a demurrage rate and port congestion, preparing additional tugs and pilot boats as well as modifying the vessel arrival schedule are highly required.



REFERENCES

Lundberg, S. M., & Lee, S. I. 2017. “A Unified Approach to Interpreting Model Predictions”. Advances in Neural Information Processing Systems, 30.