Taming the traffic tides

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In an innovative study, we explore the challenges facing container depots in managing traffic surges and operational volatility. Collaborating with HCS Hamburger Container Service, we have developed a sophisticated probabilistic model that predicts hourly workload and traffic volumes with high accuracy, enabling dynamic resource allocation and improved operational efficiency.

The forecasting model, built on Bayesian Neural Networks, uses real-world data from a container depot alongside external data sources to effectively capture the interdependencies between a multitude of variables, such as truck arrival patterns and container specifics, while also accounting for the complexities and uncertainties associated with global trade fluctuations and port congestion. By introducing advanced forecasting techniques to depot management, we aim to initiate industry-wide discussions on the future of predictive analytics in container logistics, paving the way for more resilient and adaptive container depot operations with the help of data-driven solutions.

Real-life innovation

Since the global shipping industry began recovering from the COVID-19 pandemic, containerized trade volumes surged in 2021 before experiencing a steady decline, culminating in their lowest levels by 2023. Now, as the industry embarks on a path of gradual recovery, it confronts new challenges in managing inland logistics and depot operations effectively.

At the heart of this evolving landscape are container depots, critical components of the inland logistics network. These facilities serve as essential hubs for the management of containers owned by leasing and shipping companies, providing storage, safety checks, and maintenance services. Their role as hinterland buffers is crucial in balancing the peaks and bottlenecks experienced at ports. While these facilities are designed to maximize efficiency and space productivity, they are not immune to the fluctuations in container traffic. Companies like HCS Hamburger Container Service have been facing significant challenges as they navigate surges in demand for their services.

To address these complexities and uncertainties, we have partnered with HCS to develop an innovative solution aimed at managing periods of high volatility while also optimizing day-to-day operations. HCS has provided us with extensive operational data from one of their depots, which is strategically situated within the Port of Hamburg (with private rail and barge connections). The dataset includes comprehensive information on the daily traffic of container trucks, a critical component of depot operations.

With over three decades of expertise in the repair and stock-keeping of empty containers, HCS stands as a vital partner in our research initiatives. This collaborative effort underscores the importance of advanced forecasting techniques in managing the complexities of container depot operations and in ensuring that our solutions are both practical and industry-focused. By merging hands-on knowledge with scientific expertise, this joint effort demonstrates the power of collaboration in tackling the complexities of depot operations, making sure our forecasting solutions are both innovative and aligned with the real-life operational needs of container depots.

Forecast and act preemptively

The day-to-day operation of a container depot is subject to seasonal and daily traffic fluctuations, leading to challenges in workforce planning, equipment allocation, and space utilization. Factors like congestion at ports and container truck traffic compound this unpredictability. For operators, accurately forecasting these peaks and troughs has always been a complex task.

In traditional forecasting methods, a deterministic approach assumes fixed outcomes based on historical data, often overlooking the inherent variability in real-world operations caused by uncertainties. To address this limitation, we based our model on Bayesian Neural Networks, which capture the interdependencies between variables such as truck arrival patterns, container details, and external factors like port schedules and information from pre-announcement data interfaces (e.g., the TR02 one in the Port of Hamburg). Due to its ability to estimate unknown parameters and quantify the associated uncertainty in a principled manner, our method offers a more robust and dynamic solution for mitigating the uncertainties that traditional models often overlook. Since the predictions are continuously updated as new data arrives, the model can help the depots respond more effectively to unexpected peaks in the upcoming traffic volume that would otherwise catch them off-guard.

For example, by predicting potential congestion early, operators can make proactive decisions about resource allocation or truck arrival schedules, reducing the risk of bottlenecks that could disrupt depot efficiency. The ability to forecast and act preemptively reduces operational risks, improves service delivery, and helps depots stay on top of fluctuating demand.

Given the volatile nature of inland logistics, tighter operational planning and resource adjustments are necessary to maintain smooth operations. With a probabilistic model, operators can ensure that

Photo: Canva

the facility is prepared for potential traffic increases, ensuring the facility's resources are always in optimal use.

Complex supply chains

Operational forecasting doesn't just benefit single depots – it's scalable across networks. Our model can be applied to multiple facilities, enabling a cohesive view of traffic across a company's entire logistics operation (provided the facilities keep records of their operational data, which then can be used for developing a customized forecasting model). This flexibility is particularly useful for companies managing complex supply chains or multiple hubs where traffic volume can shift rapidly between locations.

Additionally, forecasting models like ours can contribute to the sustainability of logistics operations. By optimizing truck movements and container handling, depots can reduce fuel consumption, lower emissions, and minimize unnecessary container moves, aligning with broader industry goals for reducing environmental impact.

Furthermore, with accurate predictions of traffic flow and container handling, depot operations can be structured to maximize the effectiveness of available personnel. This approach allows for dynamic adjustments to workflow, such as identifying non-essential tasks that can be temporarily postponed during expected busy periods or staff shortages, consolidating tasks or temporarily adjusting processes to match the workforce with anticipated demand. Even when short-staffed, by focusing on core operations and providing employees with advance notice of expected busy periods, workers can better prepare mentally and physically for challenging shifts. This foresight may help reduce the impact of understaffing on individual workers, potentially lessening fatigue and improving overall safety. While it cannot completely offset the challenges of staff shortages, this method can help create a more supportive work environment by demonstrating a commitment to employee well-being through informed planning and communication.

Respond (more) effectively

Integrating advanced forecasting models into depot operations is no longer just an option; it's becoming ever more essential in today's dynamic logistics landscape. As container flows become more unpredictable and global trade continues to evolve, the ability to predict, plan, and manage traffic surges will be critical for maintaining smooth operations and delivering high-quality service.

Our forecaster offers a robust solution that not only enhances operational performance but also contributes to risk management and sustainability. As depots face increasing pressure to operate efficiently while minimizing environmental impact, advanced forecasting tools will play a crucial role in helping operators meet these challenges.

By investing in predictive technologies and data-driven approaches, the logistics industry can enhance its ability to navigate uncertainties and optimize depot operations. While external factors may still affect the flow of goods, these advanced tools enable depots to respond more effectively to disruptions, potentially minimizing their impact and maintaining operational efficiency – even in challenging circumstances. ■

Emin Nakilcioğlu completed his BSc in mechanical engineering at the Istanbul Technical University and his MSc in mechatronics at the Hamburg University of Technology. During his master's degree, he specialized in intelligent systems, robotics, and deep learning. Since August 2020, he has been a Research Associate at the Fraunhofer Center for Maritime Logistics and Services, contributing to artificial intelligence- and data-driven digital innovations in maritime logistics. His work focuses on developing solutions for automatic speech recognition, natural language processing applications, time-series forecasting and workload prediction, alongside providing software development and technical support for maritime-specialized projects.