TU Berlin | FG Logistik | Straße des 17. Juni 135 | H90 | 10623 Berlin

Fakultät VII | Wirtschaft und Management
Institut für Technologie und Management

Fachgebiet Logistik

Leitung
Prof. Dr.-Ing. Frank Straube

Sekretariat H 90 Raum H 9105
Straße des 17. Juni 135
10623 Berlin

Telefon +49 (0)30 314-78555
Telefax +49 (0)30 314-29536
straube@logistik.tu-berlin.de

Wissenschaftliche Mitarbeiter
Manuel Weinke
weinke@logistik.tu-berlin.de

Peter Poschmann
poschmann@logistik.tu-berlin.de

Berlin, March 2022

Research Project SELECT: AI-based Prediction of Estimated Times of Arrival for Inland Vessel Transportation

Status of ETA prediction development

High uncertainty regarding the arrival time of inland vessels

The planning and control of inland waterway transport are currently still affected by a high degree of uncertainty. This is caused by the many dynamic influencing factors, such as water levels, lock and berth utilization, which influence the process times in inland shipping. Due to the high complexity, manual estimates in many cases do not allow reliable statements on actual journey or arrival times. In addition, inland shipping today still lacks suitable communication facilities that enable the exchange of status information between the numerous actors.

In order to increase the robustness, efficiency and reliability of inland waterway transport and enhance its attractiveness, the estimation and the exchange of precise arrival times (Estimated Times of Arrival, ETA) is an essential requirement. Precise ETA information not only allows to better synchronize the processes of the stakeholders involved, such as shipping companies, ports, freight forwarders and infrastructure operators but also to use resources such as ships, personnel and berths more efficiently. Furthermore, the handling of disruptions can be improved and existing risk buffers within the chain can be reduced. Against this background, the use of AIS data in combination with data-based methods such as machine learning (ML, a subfield of AI) offers great potential for significantly increasing the transparency of arrival times in inland shipping in the future.

Research project SELECT

In order to realize the aforementioned potentials and develop a corresponding digital solution, the Chair of Logistics at the Technische Universität Berlin togehter with various companies from the shipping industry, including BEHALA, Deutsche Binnenreederei, Duisburger Hafen (duisport) and HGK Shipping are currently working on the research project SELECT ("Smarte Entscheidungsassistenz für Logistikketten der Binnenschifffahrt durch ETA-Prognosen"). Within the project, a digital decision-making assistant for port operators and shipping companies is developed, which provides actors of inland shipping with ETA information using machine learning. The ETA prediction should cover not only the traveling process (including locking and resting times) but also turnaround times in the ports, which finally allows predicting complex ship journeys. In addition, the system should independently identify delays and disruptions and provide the actors with suitable recommendations for measures. In terms of the novelty of the approach used, the envisaged IT system is to be implemented as a demonstrator. The project is funded from 2020 to 2023 as part of the

Innovative Port Technologies (IHATEC) program of the German Federal Ministry for Digital and Transport (BMDV).

Data as a basis for the AI system

For the implementation of the AI-based system, extensive amounts of data for three years (2017 to 2019) was acquired. This comprises historical AIS data for specific inland waterway transport corridors such as the Rhine, Elbe, Mittelland Canal and Elbe Lateral Canal by the AIS provider FleetMon. Relevant information was extracted from the datasets containing over 200 million AIS messages (see Figure 1) and enriched with external influences. Vessel-related information such as an identification number, draught, length, width, trajectory or speed was integrated with environmental factors and infrastructure information. Central importance was thus given to influences such as the water levels along the routes, the weather data with influence on transport processes and notifications on infrastructure restrictions from the ELWIS systems regarding inland shipping messages such as lock obstructions and speed restrictions.

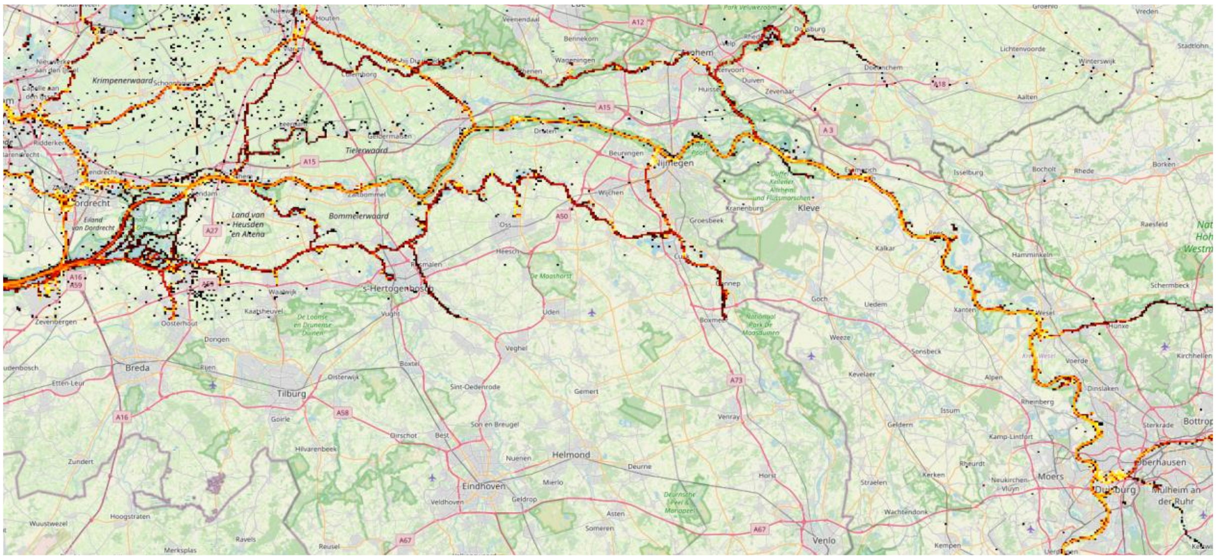

Figure 1: Heat map of AIS messages on the relation Duisburg to ARA ports

Several sub-models for the prediction of an entire trip

Initially, a suitable approach for ETA prediction was designed, in which the overall problem based on port-to-port transports was divided into several subproblems (see Figure 2). Each problem is represented by a separate model, which predicts the respective process duration and considers section-specific influencing factors. By combining the individual sub-models, the ETA at the port of destination (port-to-port prediction) and at defined intermediate points can then be estimated. In the project, the prediction of the turnaround time in sea or inland ports and thus the Estimated Time of Departure (ETD) represents an independent model due to the specific requirements. For the prediction of the travel times between the port of departure and destination, two different approaches for the segmentation of the process chain were identified. In approach 1, an overall model represents the complete route from the port of departure to the port of destination. An advantage is the better prediction of rest periods on a trip whose time and location are not known in advance. In approach 2, the route between the port of departure and the port of destination is divided into several sub-processes, which allows a more detailed consideration of local conditions such as water levels and messages on a section of the waterway.

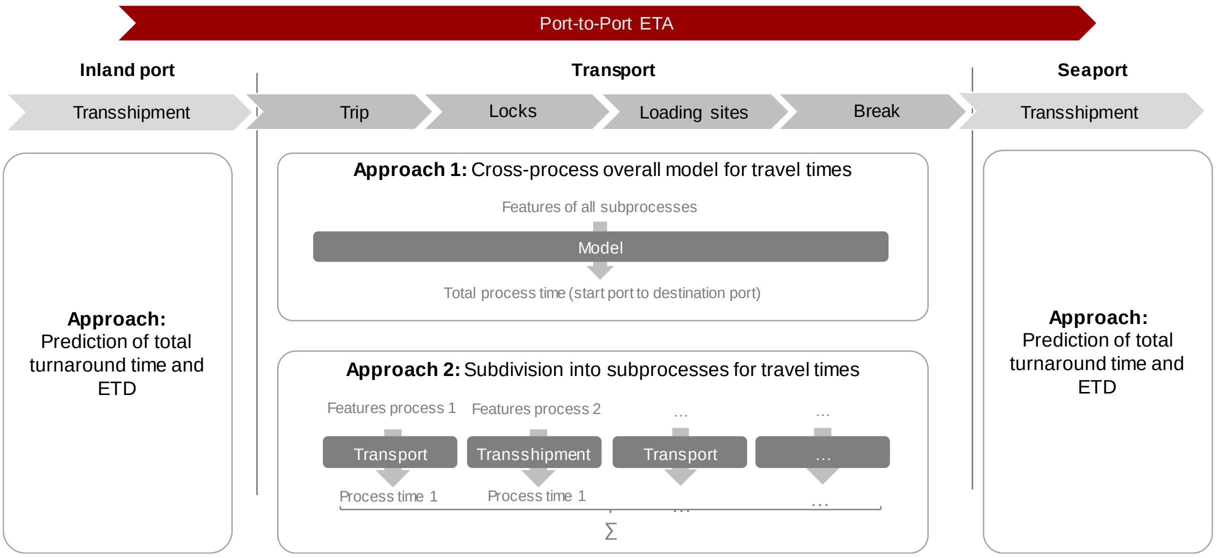

Figure 2: Division of the overall prediction into several sub-problems

Prediction of port-to-port travel times

For the implementation of the prediction, first of all an algorithm was developed which extracts related vessel journeys from the raw AIS data. For this purpose, representative pilot relations were defined together with the project partners as part of the requirements analysis. Due to the high importance, the Rhine (Rhine-Main area / Duisport – ARA ports) was defined as pilot relations. Furthermore, the relation from the port of Magdeburg to the port of Hamburg was chosen in order to investigate the special conditions of shipping on canals. Using defined geofences for the respective relations, a total of approx. 17,000 trips were initially extracted from the raw data.

The next step was to determine suitable input variables ("features") for the prediction. An essential basis for this was the expert knowledge of the participating practice partners. The features used vary depending on the route. On the canals, for example, the current average lock times but also disruption messages are highly relevant. On rivers such as the Rhine, water levels have an important influence. For all routes, vessel information such as MMSI, vessel type and draught, which can be obtained from AIS data, also form valuable information.

Different machine learning methods and approaches of modeling individual trips were explored to determine the most effective setups for ETA prediction. In particular, the capabilities and potentials of artificial neural networks for predicting arrival times were investigated. A comparison to alternative learning techniques such as linear regression, support vector machines, random forest, and gradient boosting was performed. A particular challenge was the high number of features in relatively small training datasets. For this reason, a recursive feature elimination was carried out in advance for each relation. Furthermore, a hyperparameter tuning with grid search was performed before training each model to find the best model configuration.

In the current state of development, the prediction already achieves high prediction qualities for most ship journeys (see Figure 3). For example, on the Duisburg - ARA ports route, approx. 82% of the journeys can be predicted with a maximum deviation of 5 hours. The mean absolute error (MAE) is 2.7 hours. The prediction is made at the time of the vessel's departure from the port of origin. Shipping on canals presents a more complicated problem, especially due to the waiting times at locks. On the Magdeburg – Hamburg route, the MAE is currently 8.2 hours with about 50 hours of travel time. A particular challenge in the ETA prediction for inland shipping is posed by the resting hours of the vessel staff, which are not known in advance and lead to high prediction errors for some cases.

In addition to a port-to-port prediction, an updatable prediction model was tested that is able to include information from the current journey. With this, the MAE on the route from Duisburg to ARA ports, for example, can be reduced to less than one hour. The use of artificial neural networks has shown promising results with the increasing availability of data. Nevertheless, the best results so far were achieved by Gradient Boosting and Support Vector Machines, which outperform artificial neural networks in the considered cases.

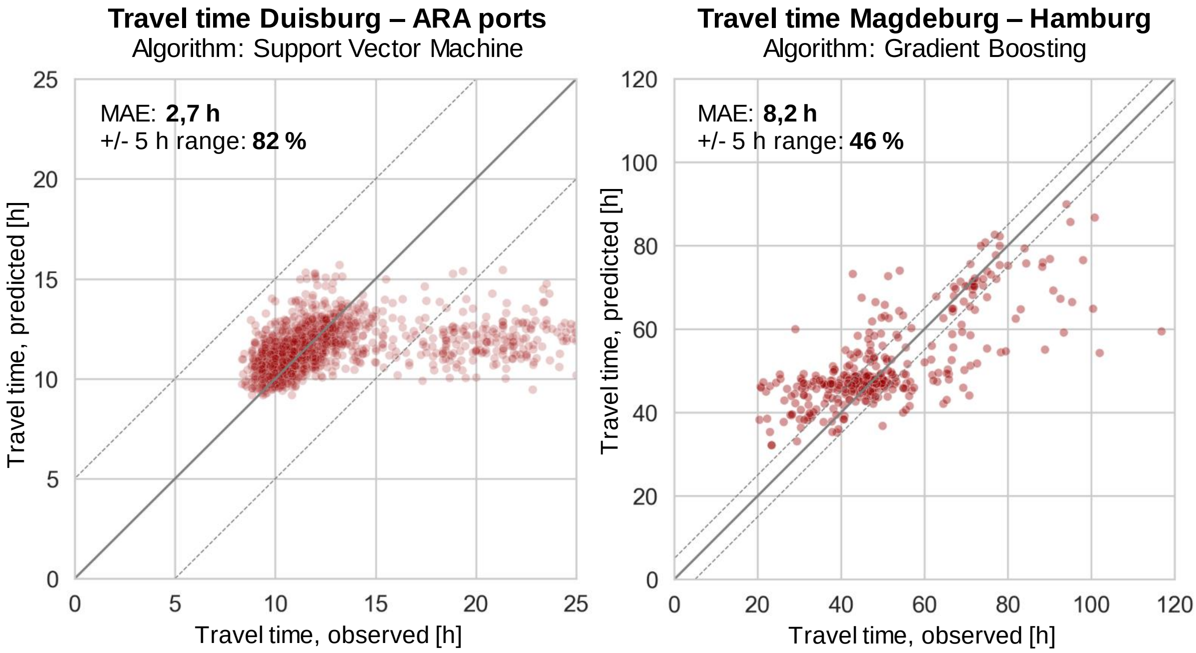

Figure 3: Current prediction quality for travel times

Prediction of turnaround-times in a seaport

In addition to the prediction of travel times, the prediction of lay times in ports plays a decisive role in predicting more complex tours. As a further sub-problem, the prediction of turnaround times and the Estimated Time of Departure (ETD) of inland vessels in seaports was therefore investigated. To develop the prediction model, approx. 3,300 port calls of inland vessels were first determined from the AIS data for the Port of Hamburg (see Figure 4). With regard to the focus of the project, only container ships were included in the first step. A turnaround consists of all processes between a ship's entry into the area of the seaport from the Elbe until it leaves the zone. In this process, a ship usually calls at several terminals in the port to unload and load containers. In addition, the transit time also includes other processes such as movements within the port between different terminals as well as rest periods and downtimes for maintenance purposes, which cannot easily be detected and lead to several outliers reducing prediction quality. The port calls extracted in this way take an average of 37 h, whereby port calls lasting several days are not uncommon. In the next step, the voyages were enriched with further data. These include temporal characteristics, weather data, tidal data, ship characteristics and turnaround times of past voyages. The terminals to be called were also assumed to be known (irrespective of the sequence and number of containers to be unloaded / loaded).

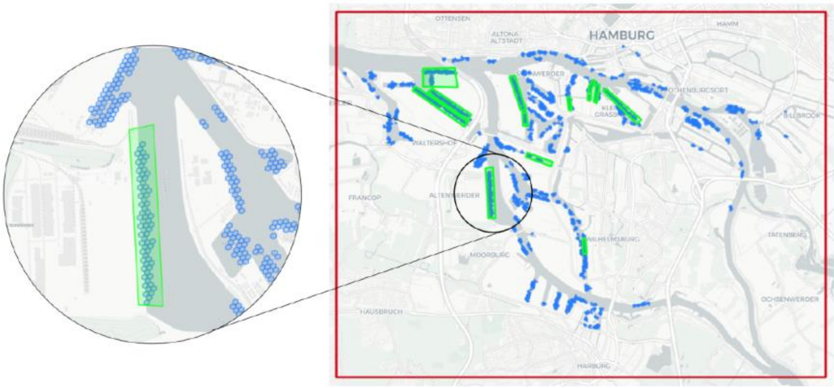

Figure 4: Clustering of vessel positions in the seaport of Hamburg

Subsequently, prediction models were implemented and evaluated using various ML methods and for different scenarios, which differ in terms of data availability. If only the terminals approached are known without further plan data, the MAE achievable is currently 11.9 hours (see Figure 5). Investigations also showed that a further increase in the prediction quality with a MAE of about 8 hours is possible if additional planning data is integrated into the prediction. Again, depending on the scenario and the quality metric considered, the Random Forest, Gradient Boosting and Support Vector Machines methods have proven to be optimal and similarly suitable.

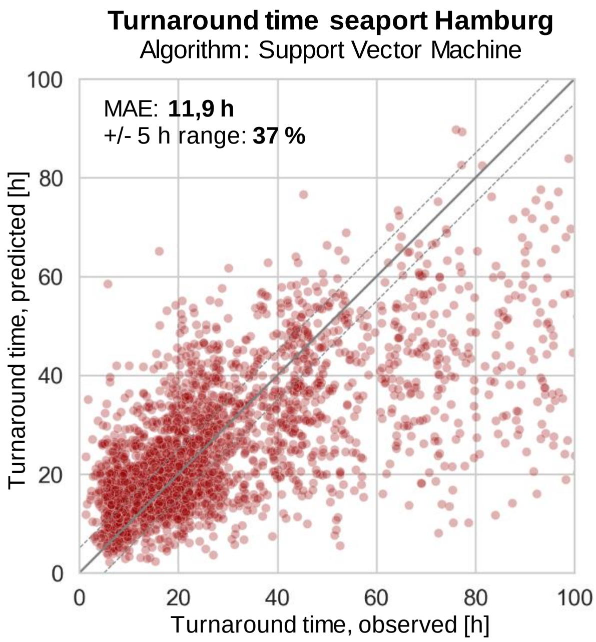

Figure 5: Current prediction quality for turnaround times

Conclusions and outlook

Overall, current project results show that the implementation of an AI-based ETA prediction for inland shipping is feasible. The availability of data, which in addition to AIS data also includes other publicly available and company-owned data, is a critical success factor. In the further stages of the project, the developed models are to be further improved. In addition, a demonstrator will be implemented, which will make the project results publicly available for testing.