

# Toward Optimizing In-port Tugboats Trajectories

Leila Niyazi <sup>a,\*</sup>, Marc Vigo<sup>b</sup>, Anna Mujal-Colilles<sup>a</sup>, Marcella Castells-Sanabra<sup>a</sup>,  
Clara Borén<sup>a</sup>

<sup>a</sup> Department of Nautical Science and Engineering, UPC-Barcelona Tech, Barcelona, Spain.

<sup>b</sup> Department of Computer Science, UPC-Barcelona Tech, Barcelona, Spain.

\* Corresponding author: leila.niyazi.ourimi@upc.edu

Studying tugboat manoeuvres is essential, as they result in varying emissions depending on the manoeuvring conditions which include: stand by, pulling or pushing conditions at any engine order and free sailing when the tug is before or after the manoeuvre. These activities have a direct impact on fuel consumption and greenhouse gas (GHG) emissions. By understanding the emissions linked to each operational mode, we can enhance fleet efficiency, reduce environmental impact, and improve port operations. Given the substantial role of maritime transport in global GHG emissions, optimizing tugboat operations is crucial for promoting more sustainable shipping practices.

To optimize tugboat manoeuvres in port areas, it is essential to have a deep understanding of their activities and operational modes. This includes tracking key events such as call time, the initiation of manoeuvres, the completion of manoeuvres, and berthing time. In some cases, tugboats may proceed directly to another operation immediately after finishing the previous one. By utilizing AIS (Automatic Identification System) data along with auxiliary datasets (field campaign data collected by an onboard observer, geographical information of the port, and trajectory's data), we can analyze tugboat trajectories and effectively detect each stage of their operations. This allows us to optimize the overall process by minimizing service time and reducing emissions released into the environment.

The main goal of this research is to conduct a preliminary analysis of tugboats and ships AIS data to characterize the manoeuvres between them within the port. This involves a series of tasks including data cleaning, time clipping, resampling, interpolation, visualization, calculation of distances between tugboats and the ship they assist, as well as feature selection. The study analyses both dynamic and static information from port tugs' AIS data.

This research proposes a robust methodology for using raw AIS data to identify and classify tugboats in-port manoeuvres within a framework for high resolution spatial planning. A field campaign aboard Azabra, tugboat vessel in the port of

Barcelona, over a five-month period between March and July 2024 was conducted. A total of 46 maneuvers are analyzed. Of these operations, 57% were dedicated to arrival and berthing procedures, while 43% focused on departure and unberthing tasks. In 48% of cases, the tugboat was positioned at the bow of the vessel being tugged, in 43% of cases at the stern, and in 9% of cases either at the side or on standby. By analyzing the plots and trajectories, preliminary findings suggest that a ship's arrival or departure can be easily recognized based on its speed and distance patterns. During manoeuvres to enter the port and approach the berthing area, or to leave the port after unberthing, the ship and the tugboats move at nearly the same speed (over 2 knots) while maintaining a distance no greater than the ship's length. Clearly, when the tugboats are navigating independently (free sailing mode), their speed and distance exceed these limits. Once the ship is berthed, its speed drops to 0 or, at most, 0.1 knots. During both arrival and departure operations, when tugboats are pushing or pulling the ship, both maintain a speed below 2 knots.