Towards Energy-Efficient Port Services: A Pilot Course on Sustainable Maritime Operations

Josep Ribet[1,*], Marcella Castells-Sanabra[1], Clara Borén[1], Mustafa Taner Albayrak[2], Anna Mujal-Colilles[1]

[1] Department of Nautical Science and Engineering. Barcelona School of Nautical Studies (FNB). Universitat Politècnica de Catalunya – BarcelonaTech
[2] Department of Maritime Management, Piri Reis University, Istanbul, Turkey
Orcid Number: 0000-0001-5614-4917
e-mail: josep.albert.ribet@upc.edu
* Corresponding author

Keywords: Sustainable navigation, Tugboat operations, Manoeuvre optimization, Emissions

Topics: Maritime Education and Training.

The transition toward sustainable navigation has become a central challenge for the contemporary maritime sector. Ports constitute critical hotspots of atmospheric emissions due to the concentration of large-scale vessel operations, land-based equipment, and auxiliary port vessels that operate continuously throughout the year, including pilotage vessels, bunkering barges, vessel-waste collection services, mooring and unmooring services and harbour tugboats. International empirical studies indicate that tugboats can represent between 10% and 40% of total in-port emissions, depending on port size and operational patterns (Ergüven et al., 2023). Tugboats are characterized by high-power-demand manoeuvres, frequent transients load, and prolonged low-RPM operation—conditions that reduce engine efficiency and increase emissions of CO_2, NO_x, SO_x and particulate matter (Ortega-Piris et al., 2022).

The TUG-EMI project (https://cremit.upc.edu/en/projectes/tugemi) aims to develop a precise and cost-effective methodology to calculate and predict emissions from harbour tugboats, as well as to propose operational strategies to reduce them. To achieve this, it combines AIS data, field-campaigns, interviews, and manoeuvre simulation. Based on field-campaign data, the results reveal significant differences in fuel consumption, and consequently emissions, associated with the navigation behaviour of individual skippers operating the same tugboat. Moreover, tugboats are frequently operated at speeds that deviate from their optimal (economical) speed; specifically, 98.7% of the time they travel at an average of 1.7 knots above the economic speed (see Figure 1). Based on these findings, offering specialised training for future maritime professionals and port operators in sustainable navigation practices could represent an effective strategy for mitigating operational inefficiencies and their associated environmental impacts.

The main objective of this study is to introduce a pilot training on course sustainable maritime operations, designed to provide trainees with the knowledge required to develop optimised manoeuvring strategies that enhance energy performance and emissions reduction. The programme is based in the regulatory frameworks of the International Maritime Organization (IMO, 2023), the port sustainability principles promoted by UNCTAD (UNCTAD, 2024), and n the environmental protection obligations established under UNCLOS, notably Articles 192 and 194 (UNCLOS, 1982).

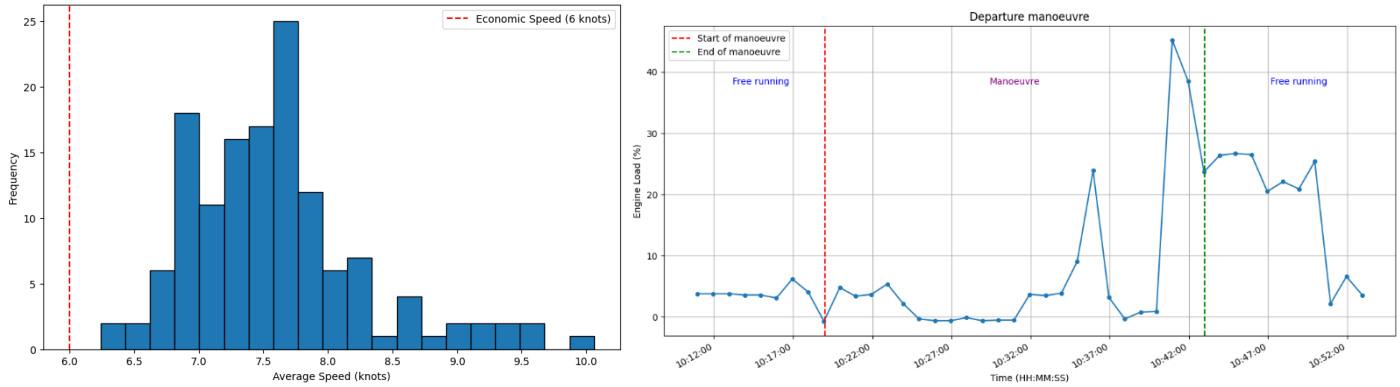

Figure 1. Left: Frequency distribution of average speeds of one tugboat between the tug change operations in 2024 at the Port of Barcelona. Right: Engine Load Profile during single departure manoeuvre.

The training programme incorporates a navigation and manoeuvring simulator scenarios that reproduces real operating conditions within a safe and controlled environment. The pilot training programme comprises two stages. The first stage focuses on assessing active professionals' current knowledge, attitudes, and behaviours related to sustainability in maritime and port operations. The second stage consists of an intervention phase, which delivers enhanced training in low-impact manoeuvring techniques, including trajectory optimisation, thrust modulation, and standby-time reduction. This study presents the outcomes of a specialized Vocational Education and Training (VET) pilot course delivered to eight maritime professionals involved in port operations. The course material was based on adapted training materials originally developed under the Greenport Project for piloting. The data collected in the briefing, debriefing and post-training assessment are analysed in detail, and a series of improvements for next course editions are proposed. The post-implementation evaluation assesses the extent to which idle-engine waiting period and thrust-modulation practices can be reduced, as well as their influence on fuel consumption and emissions. This initiative positions harbour tugs as a strategic agent for port-level decarbonisation and offers a replicable framework for other ports and other service vessels.

References

Ergüven, O., Bayırhan İ., Deniz C. & Gazioğlu C.(2023). Role of port tugs in ship-borne emissions: An analysis in Turkey's Izmit Bay. International Journal of Environment and Geoinformatics, 10(2), 180-186. https://doi.org/10.30897/ijegeo.1300605

International Maritime Organization. (2023). 2023 IMO Strategy on Reduction of GHG Emissions from Ships (Resolution MEPC.377(80)). https://tuit.cat/eunfc

Ortega-Piris, A., Diaz-Ruiz-Navamuel, E., Martinez, A. H., Gutierrez, M. A., & Lopez-Diaz, A.-I. (2022). Analysis of the concentration of emissions from the Spanish fleet of tugboats. Atmosphere, 13(12), Article e2109. https://doi.org/10.3390/atmos13122109