DECISION-SUPPORT FOR WINTER NAVIGATION OPERATIONS

Ketki Kulkarni[1,2] (Ketki.kulkarni@aalto.fi)

Mashrura Musharraf[1]

Cong Liu[1]

Pentti Kujala[1]

[1]Marine and Arctic Technology, Aalto University

[2]HUMLOG Institute, Supply chain management and social responsibility, Hanken School of Economics.

Introduction

Winter navigation in the Baltic Sea involves ensuring safety and efficiency of vessel traffic in ice-covered waters. Icebreakers are often employed to create safe directed pathways (dirways) for vessels to complete their journeys through thick ice fields. Icebreakers are a limited and expensive resource and the number of vessels waiting for assistance often outnumber the available icebreakers. Icebreaker usage also greatly affects the energy consumption of the traffic system. Due to this, the icebreaker management is required to prioritize assistance mission, considering the overall waiting time and fuel consumption while ensuring safety. This decision-making is currently handled entirely by human experts (captains of icebreakers) based on their years of experience. The decisions require careful consideration of several dynamic factors including weather elements (wind, pressure, currents), ice conditions (topography, thickness, concentration) and vessel characteristics (ice class, hull type, deadweight). There is potential for a data-based tool to support the experts in making these complex decisions. This work describes the development of a simulation model built in collaboration with the Finnish Transport and Infrastructure Agency (Väylävirasto) to visualize and compare alternate traffic scenarios in winter navigation in the North Baltic Sea (Bay of Bothnia).

Materials and methods

A simulation modelling approach is employed to capture the different parameters related to environmental conditions and traffic flows. The vessels, ports and icebreakers are modelled as agents, who communicate with each other throughout the winter. The discrete-event simulation paradigm is used to model events related to changing ice conditions, moving dirways and changing speeds of vessels. The effective ice encountered by vessels is estimated using mathematical equations for equivalent ice thickness. A case study focused on the Bay of Bothnia is used to verify and validate the simulation model. The simulation is run for 1 month of the 2018 winter. Automatic Identification System (AIS) data is processed to obtain traffic flow information. The ice data is obtained from ice charts from the Finnish Meteorological Institute (FMI).

Results

The proof-of-concept simulation model was successfully verified and validated using the historical data for winter 2018. Alternate operational strategies involving varying number of icebreakers, varying number of vessels in the system and different percentages of propulsion power for vessels and icebreakers were experimented with. The results highlighted the complex nature of the winter navigation system, where the impact of change in variables on individual users of the system such as merchant vessels is captured on the traffic system as a whole. Further validation of the model is ongoing, with consideration of more winters (mild, average, and severe) over the last 15 years. Different case studies involving multiple objectives such as energy efficiency and minimization of waiting times are also being worked on.

Implications on sustainable maritime operation

The simulation model helps analyze scenarios with alternate operational strategies, quantifying their impact on waiting time and fuel consumption. This allows decision-makers to make more sustainable choices while also maintaining their service level. The model is also expected to help plan future icebreaking resources by using predictions of future ice conditions and incorporating ship design changes in compliance with Energy Efficiency Design Index (EEDI).

References:

1. Kulkarni, K.; Kujala, P.; Musharraf, M.; Rainio, I. Simulation Tool for Winter Navigation Decision Support in the Baltic Sea. Appl. Sci. 2022, 12, 7568. https://doi.org/10.3390/app12157568
2. A. Kondratenko, K. Kulkarni, F. Li, M. Musharraf, S. Hirdaris, P. Kujala, Decarbonizing shipping in ice by intelligent icebreaking assistance: A case study of the Finnish-Swedish winter navigation system, Ocean Engineering, Volume 286, Part 2, 2023, 115652, ISSN 0029-8018, https://doi.org/10.1016/j.oceaneng.2023.115652