Power Allocation Influence on Energy Consumption of a Double-Ended Ferry

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ABSTRACT

Fuel is one of the highest cost items while operating a ship, and its combustion results in air emissions polluting environments. Finding ways to increase shipping operations efficiency without compromising the provided service quality is necessary for economic and environmental reasons. This study first used data analysis to find hidden information in one-year navigation data of a double-ended ferry operated along the Swedish coast. The case study ferry was operated using both bow and stern engines partly loaded. A new feature of the power ratio is defined to describe the influence of engine power allocation on total fuel consumption. Then, different machine learning methods are used to establish the ship’s total fuel consumption model due to influences of external factors such as wind and sea currents, etc., together with the power ratio. The established machine learning model is used to find the most efficient operation of allocating power to different engines. It shows that, in theory, up to 35% fuel savings can be achieved for the case study vessel. These findings can further aid with the operational planning for the scope of Eco-driving.

KEY WORDS: Energy efficiency; machine learning; exploratory data analysis; XGBoost; double-ended ferry

INTRODUCTION

Double-ended ferries are an alternative to bridges or tunnels for transporting passengers and cars over water. They are used for commuting in big cities like New York (Siferry 2022), London (TRL 2022), and connecting islands along the coast. Double-ended ferries can achieve this task on short routes where maneuverability may be difficult (Waterhouse, 2016), and relieve road congestion (Leung et al., 2017). The objective in maritime transport is to reduce CO₂ emissions by at least 40% by 2030 and to pursue efforts to reach 70% reduction by 2050, compared to the 2008 setup by IMO (2018). Maritime authorities also push regional ferries to become more environmentally friendly and save fuel costs. It becomes important to investigate how to operate these vessels to reduce energy consumption. For this purpose, a fundamental problem is establishing a reliable performance model to describe those ferries’ fuel consumption in terms of their operational profiles, such as allocation of engine load, ship speed, etc. Different models have been researched in the maritime community to address this problem.

Empirical formulas are often used to determine a ship’s resistance from the ship type and dimensions. For example, those developed by Holtrop and Mennen (1982) or Hollenbach (1998) are often used to predict how much power is required. They are well suitable for ship design purposes, but do not consider operational factors and dynamics that should be optimised in a vessel operation. Alternatively, computational fluid dynamic simulations can predict resistance and power, but they need high computational effort (Carlton, 2007). Nowadays, data driven strategies have been widely investigated for predicting energy demand in ships by using recorded measurements and operational data. Digitalization in the shipping industry has led to large amounts of data collected that can be used to improve ships’ energy performance. Examples of this can be found in Blueflow (2022) and YaraMarine (2022), which aim to promote eco-driving by exploiting hidden trends inside the data.

Data driven methods often rely on statistical (Mao et al., 2016) or supervised machine learning methods (Lang et al., 2022) to build models describing ship energy performance. These methods are fast, and their reliability lies in the quality and amount of the data (Corrales et al., 2018). Making the best use of these large quantities of data allows for determining data driven strategies from data information. The data driven models using decision Trees (Laurie et al., 2021) and Artificial Neural Networks (Karagiannidis and Themelis, 2021) have proven useful in predicting power demand and energy consumption of ships (Zhang et al., 2019).

Therefore, this paper aims to investigate the optimal allocation of engine/propeller operations for the double-ended case study ferry. First, a machine learning framework is developed to model the ferry’s fuel consumption in terms of its operational parameters and encountered