Decarbonizing the Norwegian Aquaculture Fleet: A Location-Routing Approach

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Abstract

Norway has committed under the Paris Agreement to reduce greenhouse gas emissions by 55% by 2030, with a long-term goal of achieving a 90-95% reduction by 2050, compared to 1990 levels. As Norway's second-largest industry, aquaculture has a significant environmental footprint, with well-boat operations accounting for about a third of the sector's emissions. Decarbonizing the vessel fleet is thus a critical challenge in meeting Norway's emission goals. Transitioning to zero-emission fuels, such as hydrogen or ammonia, presents a promising solution. However, the adoption of zero-emission propulsion for wellboats is hindered by the lack of fueling infrastructure for zero-emission fuels.

To address this challenge, we formulate a location routing problem, considering the location of fueling stations and the routing of aquaculture vessels. The aim is to decide the location of fueling stations, which routes to serve, and the number of necessary vessels to satisfy demand. The objective is to minimize the total costs, i.e. the sum opening costs of fueling stations, vessel costs and routing costs. We solve the problem using an exact and a heuristic solution approach. In the exact method we employ an iterative procedure where subtour elimination constraints are relaxed and added to the problem when needed. Our heuristic method follows a two-step approach where it first determines the station locations, and secondly, solves a pure routing problem.

We present results from a case study inspired by the aquaculture operations in Lofoten and Vesterålen. Our results show that the proposed heuristic approach provides near-optimal solutions much faster than the exact method, especially for larger instances. For instances that are not solved to optimality by the exact method, the heuristic provides both better lower bounds and upper bounds.