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Net Zero Port Operations: A Literature Review and Conceptual Framework

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Abstract. With the increasing awareness of climate change, decarbonization has become a pivotal challenge in the maritime industry. Policies such as The European Green Deal aim at climate neutrality in 2050 and set ambitious intermediate goals for the upcoming decades. As the essential nodes in the international logistics network and one of the main contributors of emissions in the maritime industry, ports have to take the responsibility for achieving net zero in their operations, in which “net zero” refers to a state in which the greenhouse gases (GHG) going into the atmosphere are balanced by removal out of the atmosphere, to halt global warming.

There is some research close to the aim of net zero port operations such as general decarbonization research, emission control or reduction, and sustainability. Existing literature presents systematic reviews on technical and operational measures to reduce GHG and improve energy efficiency, while less attention is paid to conceptualizing operational challenges on the way to net zero ports. Operational problems arising from port operations are incorporated with explicit environmental considerations like emissions and alternative fuels, with operations research taking a central role in the optimization of these complex decision problems.

In this work, we conduct a literature review of the operational problems to reach net zero ports integrating our findings into a conceptual framework and research agenda on the topic. We categorize detailed modeling challenges for port operations and put an emphasis on energy management in which the uncertainty of energy (e.g., generation and price) requires further exploration as energy supply is always fluctuating and the demand is also hard to predict due to operational complexity. A trade-off between emission-related considerations and operational efficiency also draws attention. The application of bi-objective or multi-objective optimization of net zero considerations and port operation efficiency can help decision-makers to gain better insight into the trade-off between environmental and business objectives. In many problems, machine learning is integrated with classic optimization approaches to help solving these operational problems with high uncertainties and diverse data sources.

Keywords: Net zero · Port call operations · Operations research.