The Hong Kong Polytechnic University
Department of Logistics and Maritime Studies
Research Seminar

Optimization Design in Green Shipping

by

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(Conducted in English)

Abstract:

Air emissions from ships have become an important issue for green shipping. To mitigate shipping emissions, it is necessary to investigate and analyze green shipping measures. This thesis focuses on Emission Control Areas (ECAs) and Vessel Speed Reduction Incentive Programs (VSRIPs) involving two green shipping measures, the use of low-sulfur fuel and slow steaming, respectively. Three main research problems are addressed in this thesis, including one problem regarding ECA regulations in Chapter 2 and two problems based on the VSRIP in Chapters 3 and 4.

Chapter 2 explores a holistic liner shipping service planning problem that integrates fleet deployment, schedule design, and ship routing, considering the effect of ECAs. The aim of this study is to minimize the total cost, including fixed cost and fuel cost, for liner shipping companies while complying with the ECA regulations. We propose a nesting algorithmic framework to address this new and challenging problem. Semi-analytical solutions are derived for the ship routing problem, which are used in schedule design. Tailored algorithms are applied to solve schedule design problems, and the solutions are used in fleet deployment. The fleet deployment problem is then addressed by a dynamic programming-based pseudo-polynomial time algorithm. Numerical experiments demonstrate that considering the effect of ECAs in liner shipping operations management can reduce the total costs by 2%, which is significant considering that the annual operating cost of a shipping network by a shipping company can be as high as several billion dollars.

Chapter 3 addresses a schedule design problem faced by liner shipping companies under VSRIPs. It proposes a mixed-integer non-linear mathematical model for the minimization of the total cost, consisting of fuel cost, as well as operating cost, minus dockage refunds. The model balances three determinants, i.e., the compliance of VSRIPs, the speed limit (the maximum physical speed of ships and the upper speed limit imposed by VSRIPs), and the limited number of ships. An enumerative algorithm and a piecewise-linear approximation algorithm are developed, based on some properties of the non-linear model. The computational results show that the enumerative algorithm is suitable for solving the problems with a large number of routes and a small number of ports with VSRIPs, while the piecewise-linear approximation algorithm is efficient in solving the problems with a small number of routes and a large number of ports with VSRIPs. Moreover, this study can obtain the optimal or near-optimal solution with lower total cost for the schedule design of liner shipping companies considering VSRIPs.

Chapter 4 studies how to design suitable dockage refunds (subsidies) for ships participating in a VSRIP at a port under government policies. We first present a base case without the VSRIP, and then three major cases (no government intervention, sharing subsidy policy, and air emission tax policy) are evaluated based on the adoption of the VSRIP. A subsidy game is formulated with the aim to maximize the port profit (related to revenue from original and new ships, port subsidy, and air emission tax) and minimize the government cost (related to social cost of air emissions, part of subsidy provided by government, and air emission tax). We analyze the policy implemented by the government, the fixed subsidy per ship visit designed by the port, and the number of ships participating in the VSRIP in the equilibrium state. The results report that the government policy is determined by the total increased fuel consumption caused by per unit subsidy provided for each ship visit. We also find that the port profit will increase and the government cost will decrease by the VSRIP under different policies. Moreover, some meaningful insights are also outlined by analyzing several factors such as the social cost of air emissions per ton fuel, and the subsidy sensitivities of original and new ships.

Bio:

Zhuge Dan received her Bachelor Degree in Accounting from Zhejiang Normal University (2014) and Master Degree in Management Science and Engineering from Shanghai University (2017). She is currently pursuing her Doctor of Philosophy under the supervision of Dr. WANG Shuaian (Hans). Her interested research areas include port logistics, shipping optimization and ship emission management.

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All are welcome!