Transportation Research Part D 57 (2017) 10–22

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Environmental performance of speed optimization strategies in offshore supply vessel planning under weather uncertainty

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ARTICLE INFO

Keywords:
Green maritime logistics
Emissions
Speed optimization
Supply vessel operations
Ship routing and scheduling
Weather uncertainty

ABSTRACT

Supply vessels serving oil and gas installations at sea are a major emission source of greenhouse gases in offshore logistics. Speed optimization strategies applied in tactical vessel planning significantly reduce fuel consumption and thus emissions. Nevertheless, the environmental performance of these strategies in rough weather conditions is difficult to estimate as the duration of supply vessel operations is weather dependent. In this paper we develop a simulation-optimization tool which estimates the average fuel consumption for weekly vessel schedules. The schedules are constructed by using speed optimized vessel voyages which are simulated under different weather conditions. Results of experiments on real instances show that rough weather conditions increase fuel consumption and costs. The application of speed optimization strategies reduces fuel consumption both in winter and summer, but the reduction may be at the expense of a fixed vessel cost increase in the winter season.

1. Introduction

Emissions from logistics activities are an increasing concern. Emissions are calculated based on fuel consumption. CO_2 emissions are linearly dependent on fuel consumption, hence a reduction of fuel consumption yields reduced emissions. There exists a wide body of research on emissions reduction in maritime transportation that has rapidly increased in recent years (Christiansen et al., 2013; Bouman et al., 2017). Emissions reduction in shipping can be achieved through technical and operational measures. For vessels, speed is a key determinant for fuel consumption, and slow steaming is an important research topic within green maritime transportation (Psaraftis and Kontovas, 2013, 2014; Kontovas, 2014; Bouman et al., 2017). Bouman et al. (2017) in their review report potential CO_2 reduction from slow steaming up to 60% in liner shipping. However, speed optimization for offshore supply vessels incorporated in planning their routes and weekly schedules has been studied just recently (Norlund and Gribkovskaia, 2013).

Supply vessel operations, where cargo is transported by supply vessels on a regular basis from supply bases to offshore installations, have mainly been studied from a cost minimization perspective (Fagerholt and Lindstad, 2000; Halvorsen-Weare et al., 2012; Shyshou et al., 2012; Halvorsen-Weare and Fagerholt, 2011). Good planning of supply vessel activities is important to ensure that offshore installations get what they need when needed. Missing supplies may lead to very costly reductions in oil and gas production or delays in drilling activities. Since supply vessel operations are a major source of emissions in the offshore upstream logistics, emissions reductions means should be considered within the planning process. One way to reduce fuel consumption from supply vessels is speed optimization on vessels' voyages. Applying speed optimization strategies in construction of weekly sailing schedules for supply vessels may yield up to 25% reduction in fuel consumption and corresponding emissions reductions (Norlund

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http://dx.doi.org/10.1016/j.trd.2017.08.002

Fig. 1. Location of the Sleipner area in the North Sea.

and Gribkovskaia, 2013).

The speed optimization strategies developed in Norlund and Gribkovskaia (2013) exhibit a good performance under the assumption of ideal weather conditions at sea. However, weather conditions are constantly changing. Fig. 1 shows the location of the Sleipner area in the North Sea, and Fig. 2 presents wave heights during the year 2012 for this area. In the winter months the wave height is on average higher and with larger fluctuations than in the summer season. Norwegian Meteorological Institute has collected weather data for this area since 1957, and looking at wave height data from 1957 to 2013 for the Sleipner field, we find that in December and January the average of the wave heights is above three metres while from May to August the average wave height is below one metre. The standard deviation varies from 0.75 m in July to 1.56 m in January. Fuel consumption and time spent on sailing and servicing installations increase in high waves. Moreover, when wave height is more than 4–5 m, industry practice is that service at installations is not performed due to safety considerations, and a vessel should wait. Hence, weather may impact fuel consumption and thus performance of speed optimization strategies differently during the year.

In this paper we study how weather impacts fuel consumption in supply vessel operations, and in particular how speed optimization strategies in supply vessel planning perform when accounting for varying weather conditions. The planning of weekly supply vessel schedules in a deterministic context is a challenging task in itself as it involves integrated routing and scheduling decisions requiring development of combinatorial optimization tools. Adding stochasticity into the problem increases the complexity. In order to evaluate speed strategies for different seasons, we develop a simulation-optimization tool which estimates average fuel consumption of weekly vessel schedules generated for various weather conditions. The contribution of this paper is twofold: first in development of a tool for estimating fuel consumption (and hence emissions) taking weather into account, and secondly in evaluation of speed optimization strategies performance under weather uncertainty.

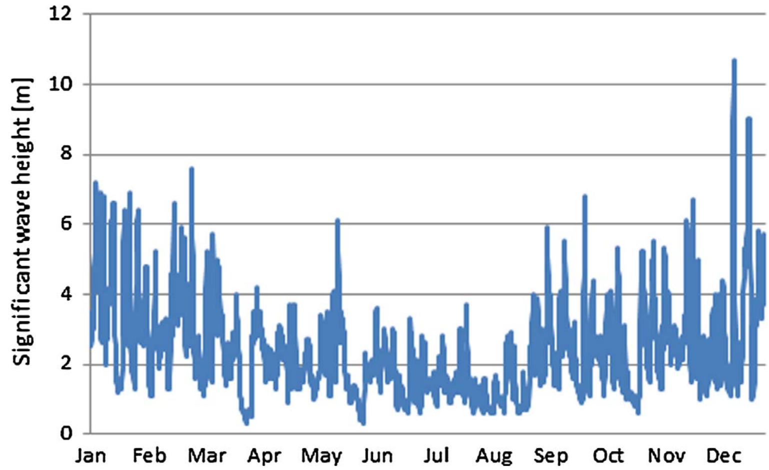

Fig. 2. Significant wave heights at Sleipner offshore field in 2012.