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Modal split in offshore supply network under the objective of emissions minimization

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ABSTRACT

We study modal split under the objective of emissions minimization in the transportation of cargo from centralized vendors in the oil and gas industry to decentralized supply bases on the Norwegian coast. The supply network includes direct road transport and a sea route along the coast. To gain insight into modal split decisions between road and sea transport from the shipper's perspective multi-period mixed integer optimization models are formulated. Particularly the models give possibilities to examine how weekly demand patterns at supply bases, cargo commitments to sea transport, storage possibilities at supply bases, and shipper's responsibility for a certain share of vessel capacity may effect the emissions and the modal split. Experiments on real data from an oil and gas company operating offshore show that the size of the share of vessel capacity and the possibility for storage at supply bases are the major determinants for a larger shift to environmentally friendly sea transport. The models can be used as means for making decisions regarding how a shipper can commit to sea transport to achieve less emissions.

Introduction

One measure to optimize environmental performance of logistics networks is to use more energy-efficient transport modes. In transport policy documents (EC, 2011) a mode shift from road to sea is considered to give environmental gains. Large cargo owners face an expectation of moving more cargo from road to sea in order to reduce the environmental footprint, and transport providers ask for commitments from shippers to establish new sea transport solutions with more environmentally friendly ships and improved service. Within the field of research on modal split in freight transportation (PROMIT, 2007; Meixell and Norbis, 2008; Chiara et al., 2008; Eng-Larsson and Kohn, 2012; Truschkin and Elbert, 2013) there are works in particular studying modal split between road and sea (Hjelle, 2010; Psaraftis and Kontovas, 2010; Panagakos et al., 2014). The literature considering the shipper's perspective primarily examines transport mode characteristics that impact mode choice. Further, the focus has mainly been on costs and other service requirements rather than on emissions.

This paper explores modal split as an allocation of transport demand between road and sea from an environmental perspective of a shipper. We consider a supply network where a set of demand points may be served by sea transport, with vessels having large capacity allowing cargo consolidation, and by road transport with door-to-door service and small vehicle capacity. We study from a shipper's perspective how different determinants impact modal split and emissions. The scientific contribution of this paper is twofold; (1) in its methodological approach and (2) in giving insights in determinants for split

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between road and sea transport in offshore supply network with time-varying demand. In our work we introduce vessel capacity share as a new determinant for modal split. We assume that it is possible to share vessel capacity among several shippers transporting consolidated cargo on the same network. Our approach allows a single shipper to choose the share size yielding a modal split solution with a certain emissions reduction. To generate modal split solutions for various demand patterns and vessel share sizes, we develop multi-period mixed integer optimization models with emissions minimization objectives. This approach lets a shipper bear larger responsibility for emissions, also yielding the ship owner economic incentives to establish regular sea transportation. Experiments on real based scenarios yield managerial insights in how different determinants including vessel capacity share size impact emissions through modal split.

The rest of the paper is organized as follows. Section 'Determinants of modal split' presents supply network and determinants for modal split. Emissions calculations are described in Section 'Emissions calculations'. In Section 'Multi-period modal split models' the multi-period modal split models are presented. Experiments and analyses of results are carried out in Section 'Experiments and analyses'. Finally, conclusions are drawn in Section 'Conclusions'.

Determinants of modal split

In this paper we study the opportunities for minimizing emissions in transport of cargo from centralized vendors in the oil and gas industry to decentralized supply bases at the Norwegian coast by increased use of sea transport. In the following subsections we describe the structure of supply network (Section 'Supply network'), the determinants which may influence on modal split decisions from a shipper perspective (Sections 'Demands', 'Sea transport commitments', 'Storage possibilities' and 'Vessel capacity share'), and formulate research objectives (Section 'Research objectives').

Supply network

In the offshore oil and gas supply network, cargo is delivered to offshore installations from vendors via onshore supply bases. The flow of cargo is initiated by demands at the offshore installations whose main activities are drilling and well operations, and production of oil and gas. In this paper we study a part of Statoil's upstream supply network from vendors to supply bases. Being the largest offshore operator at the Norwegian continental shelf (NCS) with approximately 50 installations, Statoil as a shipper deals with large volumes of cargo sent from the Stavanger area where around 80% of the oil service industry is located (Konkraft, 2004) to seven supply bases along the coast. Currently the main volumes (around 90%) are transported directly from vendors to the supply bases by road. Multimodal transportation by road and railway is available for some of the bases. However, due to the inland railway structure in Norway such transport solution implies long distances, and is therefore not considered. At present, sea transport is used for large sized cargo unsuitable for transport by road, large volumes that are not time critical, and cargo to the bases located far north. There is no regular sea transportation to supply bases along the coast. However, Statoil examines how to achieve regular deliveries to supply bases by sea.

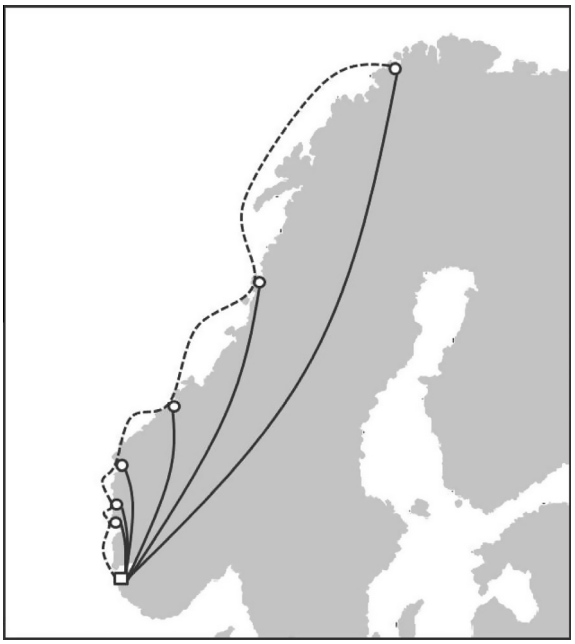

Fig. 1. Offshore supply network.