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An adaptive large neighborhood search heuristic for fleet deployment problems with voyage separation requirements

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ABSTRACT

In this paper we propose an adaptive large neighborhood search heuristic for a ship routing and scheduling problem with voyage separation requirements. The voyage separation requirement is modeled as the minimum time elapsed between two consecutive sailings on a trade, and yields solutions with voyages fairly evenly spread over the planning horizon. Voyage separation requires the schedule of each ship to be synchronized with those of the others, since the start of service of a voyage could affect the feasible start time of another voyage. The proposed heuristic is compared with an exact algorithm on several instances, and yields good quality solutions within relatively short computation times.

1. Introduction

In maritime transportation, the efficient use of the vessels is recognized as one of the most important factors influencing company profit. Operating a ship is costly and extra sailings with the sole purpose of repositioning the vessels should be kept at a minimum since these do not generate income. The fleet deployment problem consists of finding an optimal way of using available vessels to service all transport requirements and exploit spot cargo opportunities in the freight market. In the problem studied in this paper, ship routes are not given a priori, and it is important to determine at what time the cargo is transported, which yields a ship routing and scheduling problem. The terms "fleet deployment" and "routing and scheduling" will be used interchangeably in this paper.

Our problem stems from Saga Forest Carriers (now referred to as Saga), a Norwegian shipping company transporting forest products and break bulk cargoes around the world. The operations of Saga are difficult to categorize in one of the usual industrial, tramp or liner categories. This company operates on fixed routes on a regular basis, but also takes on additional voyages in the spot market. Saga operates a fleet of around 25–30 ships on 10 trades. A trade consists of two geographical regions where cargo is loaded in one and discharged in the other. In "Trade 1" of Fig. 1, cargo is loaded at several ports in Europe and discharged on the west coast of North America. With each trade are associated a given number of voyages which should be performed during the planning horizon. A voyage consists of one sailing of a trade and has an associated time window, which yields a lower and an upper time limit on the start of service. The voyages on the same trade must be fairly evenly spread. This requirement arises from the need of ensuring regular sailings without overly restricting the deployment planning. In order to achieve the required spread, one option is to narrow the time windows until the spread is satisfactory.

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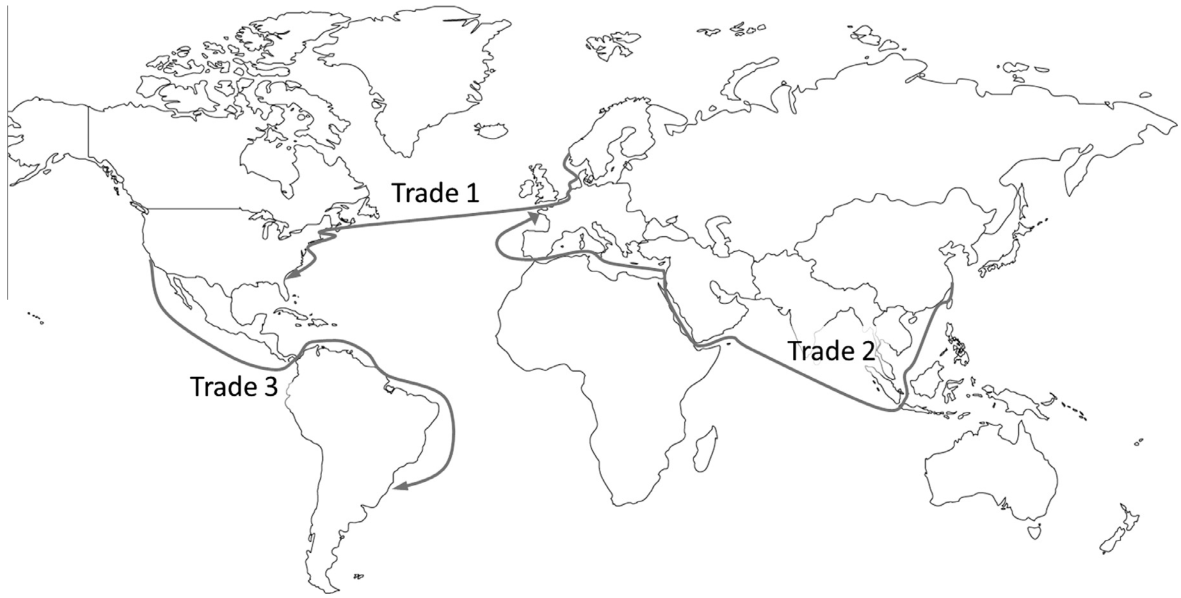

Fig. 1. Map showing three trades. A trade consists of a loading and a discharging region. Multiple voyages are sailed on each trade within the planning horizon.

However, this may lead to an expensive or even infeasible deployment solution. Another option is to leave the time windows wide and add constraints on the length of time between the start of two consecutive voyages. This is called the voyage separation requirement. In this paper, because a fixed number of voyages have to be performed, we only impose a minimum time between two consecutive voyages. By setting the required spread at a level that fits well with the time windows and the required number of voyages, a fairly evenly spread can be achieved without using an upper bound on the number of days between two consecutive sailings. In addition to the voyages of their liner services, Saga also accepts some optional voyages in the spot market to which they charter out ships. The optional voyages do not have a voyage separation requirement.

The result of the voyage separation requirement is illustrated through an example that shows how these constraints link the schedule of each ship to every other one. Table 1 gives the time windows and the start of service of voyages associated with the three trades illustrated in Fig. 1. The minimum spreads for trades 1, 2 and 3 are seven, 21 and 28 days, respectively. Fig. 2 illustrates the vessels activity during the planning horizon. Note that voyage 4 on trade 1 is not served by any of the vessels in the fleet, and a ship from the spot market is therefore chartered to serve it. The time window, i.e. the time interval during which the sailing may start, of voyage 2 on trade 2 is between days 29 and 49. Even though ship 1 is available on day 29, it has to wait until day 36 to start service since the start of voyage 1 on trade 2 is on day 15, and trade 2 has a minimum spread of 21 days. Thus, the voyage separation requirement creates a dependency between the ship schedules. Drexl (2012) categorizes this type of dependency as operation synchronization.

Operation synchronization is encountered in areas different from ship routing and scheduling. For example, in vehicle routing with transshipment, the cargo must first arrive at a transshipment location before it can be picked up (Mues and

Table 1
Voyages with time windows and start of service. Parentheses around the actual start time mean that the voyage is served by a chartered vessel.

Trade	Voyage	Early	Late	Actual
1	1	1	14	1
1	2	15	28	15
1	3	29	42	29
1	4	43	56	(43)
1	5	57	70	64
2	1	1	21	15
2	2	29	49	36
2	3	57	77	57
3	1	1	28	1
3	2	29	56	43
3	3	57	84	71