A tabu search heuristic for ship scheduling problems

Jarl Eirik Korsvik[1], Kjetil Fagerholt[1,2,3] and Gilbert Laporte[4]

[1] Department of Marine Technology, Norwegian University of Science and Technology, Trondheim, Norway

[2] Department of Industrial Economics and Technology, Norwegian University of Science and Technology, Trondheim, Norway

[3] Norwegian Marine Technology Research Institute (MARINTEK), Trondheim, Norway

[4] Centre de recherche sur les transports, Universite de Montreal, Canada

Abstract

We present a planning problem faced by many shipping companies dealing with transport of bulk products. These shipping companies typically have a certain amount of contract cargoes that they are committed to carry, while trying to maximize the profit from optional spot cargoes. In order to ensure quick decision support to the planner, we propose an efficient tabu search heuristic to solve the problem. We will report results were the heuristic solution appoach is tested on real-life instances of the problem.

1 Introduction

International trade depends heavily on maritime transportation. Estimates from the academic members of the International Association of Maritime Economists indicate that 65% to 85% of international trade is borne by ships. We also see several trends like population growth, increasing standard of living, rapid industrialization, exhaustion of local resources, road congestion and elimination of trade barriers that contribute to the continuing growth in maritime transportation. Among the most important functions in many shipping companies is the planning of routes and schedules for their ships. Proper routing and scheduling is sometimes crucial, as a modest improvement in fleet utilization can result in large profit improvements. Despite this, relatively little research and commercial developments in ship routing and scheduling can be found, see the review in (Christiansen, Fagerholt and Ronen, 2004).

In this paper, we present an important short-term routing and scheduling problem faced by many tramp shipping companies transporting bulk products. The planners in the shipping company daily solve a ship routing and scheduling problem that is a version of the multi-vehicle pickup and delivery problem with time windows (m-PDPTW) described by Desrosiers et al. (1995).

In most studies on ship routing and scheduling problems found in the literature exact methods are used. Very often, authors report on methods where feasible single ship schedules are generated a priori and then the problem is solved as a set partitioning problem, see for instance (Bausch et al., 1998), (Kim and Lee, 1997) and (Fagerholt, 2001). For larger problem instances, this solution method requires too much computational time to make it useful in a practical planning situation. Therefore, we have proposed an efficient tabu search heuristic to solve these ship scheduling problems. There has been limited research on local search-based heuristics for ship scheduling problems. The only contribution known to the authors is the one in (Brønmo et al., 2007). However, within related routing problems, such as the vehicle routing problem with time windows (VRPTW), the dial-a-ride problem with time windows and the multi-vehicle pickup and delivery problem with time windows, numerous heuristics have been developed. In later years tabu search heuristics have been considered by many authors to be the most efficient approach for a number of problems, see for instance (Cordeau and Laporte, 2003), (Cordeau, Laporte and Mercier, 2001), and (Nanry and Barnes, 2000).

In the next section, we will give a more detailed description of the ship scheduling problem and the context of the planning situation. Then we will briefly present the proposed heuristic, computaional study and in the last section we will give a summary and some concluding remarks.

2 The ship scheduling problem

A shipping company operating in the tramp market usually has a set of mandatory contract cargoes it is committed to carry, while trying to maximize the profit from optional spot cargoes. Each cargo consists of a given amount of a given product that should be picked up and delivered at specified loading and unloading ports. Time windows are given for the loading of the cargo, and sometimes on the unloading. Quite often, the time windows are multiple, as they usually span several days and some ports are closed for service during nights and weekends. There may be compatibility constraints restricting some ships from carrying given products. There are also compatibility constraints between specified ships and loading/unloading ports due to for instance draft restrictions. The latter compatibility constraints can in some cases be dependent on the load on board the ship.

The planners in the shipping company daily solve the ship routing and scheduling problem. Solving this ship scheduling problem is also closely connected to negotiating spot cargoes. At random intervals offerings for new spot cargoes will come from different brokers in addition to notices about contract cargoes from the shippers. When the planner is contacted about a potential spot cargo, he or she must first determine if the fleet has capacity to lift the cargo. To do this, the planner often also re-optimizes the fleet schedule including the new cargo(es). Simultaneously, the planner may perform a quick sensitivity analysis indicating the marginal value of the potential cargo. Armed with this knowledge he or she can confidently start the negotiation process with the broker.

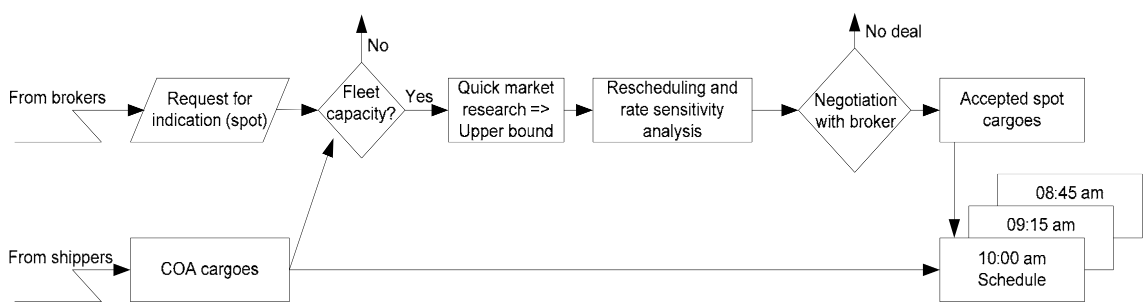

Figure 1 Scheduling (including spot cargo negotiation) workflow at a typical shipping company

The scheduling process including the spot cargo negotiation, summarized in Figure 1, is the core business for many shipping companies. Traditionally, most shipping companies follow a manual approach combined with simple spreadsheets. However, having access to an optimization-based planning tool for the scheduling process will be of great value to shipping companies. Since the process of negotiating spot cargoes sometimes is performed within a very short time (i.e. during one phone call with the broker), the optimization algorithm must work fast.

3 The solution approach

Due to the dynamics of the ship scheduling problem and the need for quick decision support, we propose an efficient tabu search algorithm. The algorithm is based on the ideas from (Cordeau and Laporte, 2003) and (Cordeau, Laporte and Mercier, 2001). Starting from an initial solution s_0, the algorithm moves at a given iteration from s_i to the best solution in a neighborhood $N(s_i)$ of s_i. An important feature of the approach is the possibility of exploring infeasible solutions during the search. This relaxation mechanism facilitates the exploration of the solution space and is particular useful for tightly constrained instances, which is the case for many ship scheduling problems. To avoid cycling, solutions possessing some attributes of recently visited solutions are declared forbidden or tabu for a number of iterations, unless they constitute a new incumbent. As is common in such algorithms, a continuous diversification mechanism is put in place in order to reduce the likelihood of being trapped in a local optimum.

4 Computational study

We will present results were the tabu search heuristic is tested on real-life instances of the ship scheduling problem. We will compare our results with both the exact method and the multi-start local search heuristic described in Brønmo et al. (2007).

5 Summary and concluding remarks

A ship scheduling problem is described, and an efficient tabu search heuristic is proposed to solve the problem. Ship scheduling problems are often tightly constrained and an important feature of the approach is the possibility of exploring infeasible solutions during the search.

Computational tests on real-life instances, including comparisons with both the exact methods and the multi-start local search heuristic described in (Brønmo et al., 2007), will be presented.

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