Liner Shipping Fleet Repositioning

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Liner shipping fleet repositioning consists of moving vessels between services in a liner shipping network in order to better orient the overall network to the world economy, and to ensure the proper maintenance of vessels. Thus, fleet repositioning involves sailing and loading activities subject to complex handling and timing restrictions. The objective of the problem is cost minimization, which translates nearly directly into the minimization of CO_2 emissions and pollution. Additionally, it is important that all cost elements, including the ones that are only loosely coupled with activity choices, can be accurately modeled.

Numerous liner shipping fleet repositioning problems are solved each year by the world's shipping firms without the assistance of any decision support, even though humans can require between two to three days to find a reasonable solution. Finding optimal repositionings is important in helping shipping firms move towards their goal of greater eco-efficiency.

Unlike the Fleet Deployment Problem (FDP) [8], in which vessels are matched to services, and the Liner Shipping Network Design Problem (LSNDP) [1], liner shipping fleet repositioning problems have been given little attention in the literature. Indeed, the problem is not mentioned even in Christiansen, et. al's detailed and comprehensive reviews of liner shipping optimization [3] and maritime transportation [2]. As in fleet repositioning, airline disruption management [5, 7] has a variety of activities with objectives that are linked to action duration, such as the speed at which an airplane flies. However, airplane routes lack the cyclical structure of liner shipping services, as well as the notion of empty equipment repositioning.

Liner vessel shipping networks consist of multiple *services*, which are circular routes that visit a sequence of ports on a weekly schedule. That is, each port on a service is visited by a vessel on the same day each week, and a service is assigned as many vessels as are necessary to maintain weekly frequency. Liner shipping fleet repositioning problems involve a number of vessels, each with an initial and goal service. Each vessel must be repositioned to its goal service from its initial service as cheaply as possible. Given the high expense of repositioning, the goal of liner shipping fleet repositioning problems is to find a scenario of activities, which involve continuous sailing time and cost configuration decisions, associated with a lowest cost optimization model.

Figure 1 shows a subset of a fleet repositioning problem from our industrial partner in which a vessel is repositioned from its service in Asia (CHX) to a new service in South America called

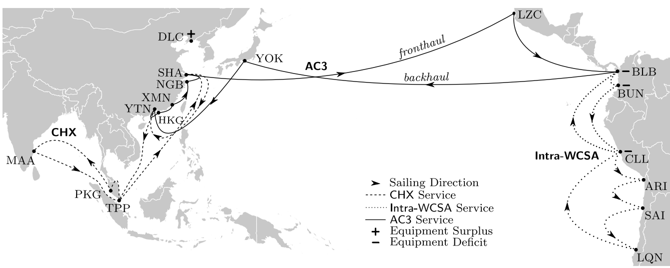

Fig. 1: A real world repositioning from our industrial partner. A vessel is repositioned from the CHX service, through the AC3 service to Intra-WCSA.

ID	# Ves.	# SOS	Port Fees	# Equip.	Cabo.	# Act.	DS	DS_{LP}	DI	LP
1	2	0	Yes	0	Yes	182	63.99	65.24	62.91	**57.76**
2	3	0	Yes	0	Yes	252	247.9	269.45	264.1	**230.7**
3	1	1	Yes	3	Yes	255	26.70	**11.63**	30.66	16.00
4	3	2	Yes	0	Yes	471	**672.9**	802.6	-	-
5	2	2	Yes	3	Yes	491	**130.2**	241.1	280.5	582.3
6	3	3	Yes	0	Yes	501	411.9	**399.2**	3064	3997
7	3	2	No	1	Yes	617	1506	**1106**	4441	3410
8	3	2	Yes	1	No	617	2061	**1712**	4828	5046
9	3	2	Yes	1	Yes	617	2098	**1785**	4741	5035
10	3	2	Yes	3	Yes	677	4172	**4139**	-	-

Table 1: Experimental results in CPU seconds using different heuristics in LTOP with a timeout of 2.5 hours. Each instance has several parameters including the number of vessels, sail-on-service opportunities, port fees and cabotage restrictions.

the Intra-WCSA. Rather than näively sailing across the Pacific, the repositioning was cleverly designed to utilize an existing service, the AC3, in order to move the vessel to South America. Sailing on existing services, like the AC3, saves money and reduces CO_2 emissions.

At a high level, a fleet repositioning problem consists of a set of a tuple $\langle S, V, I, G, E \rangle$, where S is the set of services, V is the set of vessels, $I : V \rightarrow S$ assigns each vessel an initial service, $G : V \rightarrow S$ assigns each vessel a goal service, and E represents the set of equipment movement opportunities. The goal is to move all vessels in V to their goal service in G at minimal cost.

We performed a computational study of a real-world liner shipping fleet repositioning scenario confronted by our industrial partner using Linear Temporal Optimization Planning [9], a method that provides linear cost optimization to automated planning [4]. Various repositioning activities are modeled within the LTOP framework as a combination of a linear optimization model and a planning action. We constructed a number of instances based on the scenario with varying levels of realism, using data on vessel fuel consumption and port costs from the ENERPLAN dataset [6]. The running times of LTOP on these instances is shown in Table 1[1].

We tested LTOP using a variety of domain independent and domain specific heuristics (DS, DS_{LP}, DI, and LP) to guide LTOP's branching and node selection. Instance 6 is the instance most similar to the our case study, and is solvable in under 400 seconds with DS_{LP}, domain specific heuristics with some of LTOP's domain indepedent heuristics disabled. More work is needed examining the scaling of LTOP, as well as in adding more real world components to the model. We also intend to model the problem as a MIP, despite the big-M constraints necessary to model the logical aspects of the problem, and compare this with LTOP.

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[1] Our study was run on 2 GHz AMD Opteron 2425 HE processors with 4 GB of RAM and CPLEX 12.2 as an LP solver.