Optimal design of the maritime network

1 Context

This Ph.D. thesis is part of the digital transformation of maritime transport project (projet Transformation Numérique du Transport Maritime (TNTM) in French) funded by the PIA (Programme d'Investissement pour l'Avenir). The TNTM project is led by CMA CGM, a world leader in the maritime transport sector, with a consortium of 8 partners (5 industrial partners and 3 academic partners).

The objective of the TNTM project is to optimize logistics flows for environmental and competitive purposes by integrating real-time data, processing it and integrating it into the optimization algorithms.

2 Motivation

Maritime transport has become very globalized in recent years. A model of mega alliances has also been set up to pool fleets of ships and port coverage on several continents. The main players operate between 500 and 700 ships with a total capacity of between 3 and 4 million TEUs (Twenty-Foot Equivalent Units). They serve some 520 commercial ports worldwide and manage more than 200 shipping lines. They also use third-party feeders to serve smaller ports in order to reload volumes on the main lines.

Moreover, maritime transport is an activity subject to very strict national (depending on the country of call) and international (imposed by the International Maritime Organization (IMO) in particular) regulations. The regulations on CO2 emissions are constantly being tightened up year after year, with the aim of reducing the emissions of ships in operation more and more. All this in an economic context that is constantly and rapidly changing, such as the period we are currently experiencing, with an unprecedented year of crisis linked to COVID followed by an equally unprecedented recovery in activity.

Indeed, a shipping company must frequently review the structure of its maritime network to ensure that it is economically efficient and reduce its environmental impact while maintaining a competitive commercial offer. The objective of this thesis is to define the services (shipping lines in the form of rotations allowing to serve a set of ports) with the assignment of ships with the adapted sizes for these different services allowing to carry all the container flows.

3 The subject of the thesis

In this thesis, we are interested in the development of optimization algorithms to define the optimal design of the shipping network. The central problem that will be studied is known in the literature as the Liner Shipping Network Design Problem (LSNDP [1, 2, 3]), which is an NP-hard problem.

First, it will be necessary to understand the different operational constraints and business rules provided by the industrial partner (in this case CMA CGM). A review of the state of the art will be conducted in order to analyze the various models and solving approaches proposed and to study their relevance with respect to the problem posed in the context of the project. In fine, the objective is to define the model(s) allowing the integration of all the objectives, constraints and business rules. These models can be expressed using different formalisms resulting, for example, from constraint programming [4] or integer linear programming [5].

In a second step, from the proposed models, we will develop solving algorithms while taking into consideration the objectives of reduced runtime and compatibility with operational needs. The solving algorithms can be based on exact approaches (linear programming, column generation, etc.), approximate methods such as metaheuristics or hybrid methods.

References

[1] M. Christiansen, E. Hellsten, D. Pisinger, and C. Vilhelmsen. Liner Shipping Network Design. *European Journal of Operational Research*, 286(1), 2019.

[2] B. D. Brouer, J. F. Álvarez, C. E. M. Plum, D. Pisinger, and M. M. Sigurd. A base integer programming model and benchmark suite for liner-shipping network design. *Transportation Science*, 48 (2):281–312, 2014.

[3] C. V. Karsten, D. Pisinger, S. Røpke, and B. D. Brouer. The time constrained multi-commodity network flow problem and its application to liner shipping network design. *Transportation Research Part E: Logistics and Transportation Review*, 76:122–138, 2015.

[4] F. Rossi, P. van Beek, and T. Walsh. *Handbook of Constraint Programming*. Elsevier, 2006.

[5] J. K. Karlof. *Integer Programming: Theory and Practice*. CRC Press, 2019.

4 General information and application

Location: University of Aix-Marseille, Faculty of Sciences, Computer Science and Systems Laboratory (LIS – Laboratoire d'Informatique et Systèmes – UMR 7020), COALA team, Marseille (France)

Supervision:

- Djamal Habet djamal.habet@univ-amu.fr (co-supervisor)
- Cyril Terrioux cyril.terrioux@univ-amu.fr (co-supervisor)
- Hamza Ben Ticha HO.HBENTICHA@cma-cgm.com (monitor)
- Salem Ben Ramdane HO.SBENRAMDANE@cma-cgm.com (monitor)

Start date: Fall 2022

Remuneration: The monthly salary will be around 1 600 €.

Profile: The candidate should have a Master's degree or an engineering degree with strong skills in computer science (especially in algorithmics and programming), artificial intelligence, constraint programming, combinatorial optimization and/or operations research. Expertise in modeling will be a plus.

Submission of application:
The documents required for the application are as follows:

- CV (maximum 3 pages),
- Transcripts of marks, results and rankings of the Master's degree or equivalent (first and second years),
- Letter of motivation,
- Reference letters.

Applications must be submitted before July 12, 2022 as a single pdf file sent by email to Cyril Terrioux (cyril.terrioux@univ-amu.fr).