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Determining contract orders to fit a certain load profile for Liner Shipping Scheduling Problem

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In this report, we describe how to generate contract orders that create a load profile with a certain inter-port load characteristic σ_c (that is, the standard deviation of the load variation among the various inter-port arcs of the trip) for the case of the Speed Scheduling and Order Selection Problem (SSOSP).

We determine the contract orders by the following steps:

Step 1. Create the target contract load profile of the ship (with the desirable σ_c) by defining $\bar{z}_i, i = 1, \dots, n$, that is the load when the ship departs from port i

Step 2. Generate G, a set of contract orders. Note that each contract order $j \in G$ is associated with a quantity, a pick-up port, and a delivery port

Step 3. Solve the mixed integer linear programming problem described below by Eqs. (1) to (5), to select the appropriate contract orders among those in G. The selected contract orders minimize the sum of the differences of $z_i - \bar{z}_i$, where z_i is the actual contacts load of the ship when it departs from port i carrying the selected orders. Note that for the selected contract orders $z_i - \bar{z}_i \geq 0$ in order to preserve problem linearity

Regarding Step 1 we select $\bar{z}_i \sim N(Q/2, \sigma_c), i = 1, \dots, n-1$ and $\bar{z}_n = 0$.

Regarding Step 2, each contract order of G is generated using appropriate uniform distributions to select the pick-up port, the trip length and the contract order size. For this step we generated 1000 random contract orders ranging from 300 to 3,000 TEUs with a trip length ranging from 1-10 ports. To describe formally the mixed integer linear programming problem of Step 3, let:

- n : The number of ports
- G : Set of all randomly generated contract orders
- $\bar{z}_i$: Target load on the ship when it departs from port $i \in N$
- Q : The capacity of the ship
- p_i^j : The pickup quantity of order $j \in G$ at port $i \in N$
- d_i^j : The delivery quantity of order $j \in G$ at port $i \in N$
- v_j : Binary decision variable, receives value 1 if order $j \in G$ is selected to be realized, otherwise receives value 0
- z_i : Decision variable, is the actual load on the ship when it departs from port $i \in N$

Note, that $p_n^j, j \in G$ and $d_1^j, j \in G$ are assumed to be equal to zero, since the ship cannot pickup contract orders from the last port nor deliver at the first port. Objective function (1) minimizes the total difference between the target contract profile and the actual contract profile.

$$min \sum_{i=1,\dots,n} (z_i - \bar{z}_i) \tag{1}$$

Subject to:

$$z_i - \bar{z}_i \geq 0, \quad i = 1, \dots, n \tag{2}$$

$$z_{i+1} = z_i + \sum_{j \in G} (p_{i+1}^j - d_{i+1}^j) v_j, \quad i = 1, \dots, n-1 \tag{3}$$

$$0 \leq z_i \leq Q, \quad i = 1, \dots, n \tag{4}$$

$$v_j \in \{0,1\}, \quad j = 1, \dots, G \tag{5}$$

As mentioned before, constraint (2) ensures that the actual load on the ship when it departs from port i will be greater or equal to the respective target load, and is used to preserve problem linearity. Constraint (3) defines the change of the actual load on the ship when it departs from port $i+1$. Constraint (4) safeguards that the actual load on the ship is equal or greater than zero and it does not exceed the ship's capacity. Constraint (5) defines permitted values of the binary decision variables v_j.

Note that applying the above steps the average value of the difference $z_i - \bar{z}_i$ values for all σ_c was equal to 1.15% of $\bar{z}_i$, i.e. the target contract load profile of the ship per port i. The latter deviation is acceptable for the purposes of the conducted experimental analysis.