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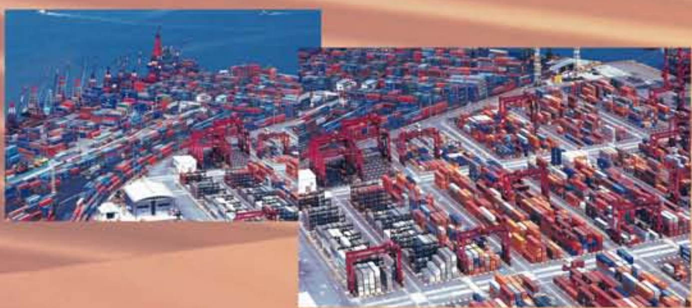
Container Terminal Storage Management by Stochastic Program Model

Background

A measurement of the efficiency of a container terminal is the duration-of-stay of visiting vessels. If the storage layout and the loading plan are working well together, the productivity of the terminal can be increased and the duration-of-stay needed for each visiting vessel will be reduced.



Unlike the import containers, which all arrive in a counted batch, the export containers arrive one by one in a random manner. In addition, the quantities of different groups of containers are not known until the cut-off day as the volume of exportation to different countries changes so fast. The task of space allocation in such an uncertain environment is challenging to a port planner. To the best of our knowledge, most of recent researches are focused on the re-arrangement of containers in which all containers for in an unsorted manner. Re-marshalling or buffer space is then utilised for sorting before loading. The adaptation of such a "sharing" storage policy (i.e. pre-marshalling strategy) may be advantageous due to simplification in operations. In addition the uncertainty in the arrival patterns of the containers can be ignored at the first planning stage. However, a great effort and time for re-handling is needed to marshal the containers.

Problem Formulation

We propose a hybrid storage policy by dividing the area into a set of dedicated zone and a sharing zone (refer to the figure).

In the dedicated zones, all containers are of the same class and can be loaded without any re-handling. This thus can reduce workload and increase the productivity of the terminal. A shared zone is utilized for collection in case the dedicated zones are full. In the shared zone, since the containers to be loaded into different areas on board ship are mixed up, re-handling may be needed.

Here comes our problem: ***how large is the optimal space that should be reserved for dedicated zones for the collection of arriving containers so that total time and costs will be minimized with regard to the future re-handling effects of using a shared storage space?***

The following notations are used in our model.

x_n : Dedicated space of group n $(n = 1, 2, ..., N)$ expressed as number of containers (*1st stage decision variable*).

p_k : Probability of scenario $k \left(p_k \geq 0, k = 1, 2, ..., K; \sum_{k=1}^{K} p_k = 1 \right)$.

$d_n{}^k$: Realization of demand quantity of container to class n under scenario k.

$y_n{}^k$: Number of containers of group n in sharing zone (*2nd stage decision variable*) under scenario k.

M : Total available capacity

We formulate a two-stage model as the following for our dedicated-sharing model.

$$\min_{x, y^k \{k = 1, 2, ..., K\}} \quad \alpha^T x + \sum_{k=1}^{K} p_k [\beta e^T y^k] \tag{1}$$

$$s.t. \quad e^T x + e^T y^k \leq M \quad \text{for } k = 1,2,3,...,K \tag{2}$$

$$x + y^k \geq d^k \quad \text{for } k = 1,2,3,...,K \tag{3}$$

$$x, y^k \geq 0 \text{ and integer} \quad \text{for } k = 1,2,3,...,K \tag{4}$$

where $\alpha^T = [\alpha_1 \, \alpha_2 \dots \alpha_N]$, $e^T = [1 \; 1 \dots 1]$, $(d^k)^T = [d_1{}^k d_2{}^k \dots d_N{}^k]$,

$x^T = [x_1 \; x_2 \dots x_N]$, $(y^k)^T = [y_1{}^k \, y_2{}^k \dots y_N{}^k]$

Numerical results in our worked example showed that the proposed policy could generate significant savings over 60% in cost.

Conclusions

We proposed a hybrid storage policy combining both class-dedicated and shared storage strategies. The concept of recourse is applied whilst a stochastic programming model is presented for container terminal space allocation.