Decision rules for the yard storage management

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1. Introduction

A maritime terminal is a basic node in the intermodal goods transportation network; for this reason, the company that manages the terminal has to optimise the flow of containers that passes through it and all relative handling operations in order to achieve the maximal global productivity, expressed in terms of some opportune economic indicators.

The flow of containers can be considered as split into import and export one. The import flow starts with the ship unloadings and continues with either transhipments or storing of containers in the yard for their successive departure by trucks or trains. The export flow concerns the loading of containers on board of the ships after having received and stored them in the yard.

Considering that most of the terminal operations originate from/are destined to the yard, it is evident that the yard plays a central role and impacts on the global productivity of the terminal itself. In fact, the efficiency and quality of management in the container yard operations influence all terminal operations that in turns are influenced by both the tactical choices of the terminal, related to the allocation of the available handling equipment and the scheduling of all activities, and the strategic ones, related to terminal's investment, for instances for enlarging the stoking area. Optimisation in the containers handling operations is hence crucial in the search for profitability (Peters, 2001).

We can say that storing containers in the yard and scheduling the containerships' load/unload operations are major correlated problems in maritime terminals. Many researchers face with these problems but, unfortunately, in the recent literature only some aspects of the handling operations have been approached, without considering the terminal as a complex system consisting of several integrated and correlated components; a more general view of the problem can be found in Gambardella et al. (1998) and Hayuth et al. (1994), where the authors present simulation models as support systems for testing the goodness of the management policies related to the transportation chains in intermodal container terminals.

In this work we focus on the export container flow and analyse the impact of the yard organisation on the stowage of containers in terms of unproductive containers movements on board; our aim is to minimise unproductivities together with the stop time of containerships at the terminal due to load/unload operations.

2. Problem definition

We deal with the Master Bay Plan Problem (MBPP), that can be defined as the problem of stowing a set C of containers of different types into a set, say L, of available locations of a containership together with the definition of their picking list in the yard.

The stowage of a containership involves different objectives; among others it is necessary to achieve the best conservation of goods during navigation, the best container allocation in order to optimise the available space and prevent damages to the containership, its crew and its equipment, and to reach the best economic results of the dispatching operations, that is to minimise the total stop time of the containership at the terminal.

We propose a 0/1 linear programming model for the minimisation of the total stop time of the containership, while the others objectives mentioned above are reached by introducing in the model different kinds of constraints concerning the size, the weight, the type and the destination of the containers, and their distribution for granting cross/horizontal/vertical equilibrium.

As soon as the yard is considered, referring to the *export storage management*, let us briefly describe the storage strategies that are mainly used.

Pre-marshalling strategy: export containers are assigned to a temporary storage area in accordance to their loading ship, or more generally their shipping line, as soon as they arrive at the terminal. When the shipping line sends the list of the containers to load on the containership, the yard manager defines, for the queuing containers, a storage plan in the pre-marshalling area, usually assigned near the containership; then containers are moved to this area, for instance twelve hours before the ship arrival, waiting for loading. This strategy is mainly used for saving space in the yard, since according to it, and considering only few terms of the containers status, it is possible to store containers in higher stacks. The main drawback of this strategy is that a large number of moves can be required in the temporary area for preparing the pre-marshalling one.

Sort and store strategy: the storage of the export containers is planned on the basis of all information included in their status, that is shipping line, loading containership, destination port, size and weight. A rolling plan is defined in order to maintain the storage condition in the yard, and some moves could be required to remove mixed storage conditions that sometimes can happen for shortage storage space reasons or for a change in the some containers status. With respect to the previous strategy, this one permits fewer containers shifting before the arrival of the containership, but requires a more complex storage management system for taking into proper account all information of the status.

Interesting problems related to the organisation of the stocking area have been considered in Kim et al. (2000), Preston and Kozan (2001) and Taleb-Ibrahimi et al. (1993), Chen (1999).

3. Resolution approach for the evaluation of different yard storage strategies

Our aim is to determine the best strategy to follow for the yard storage management.

In order to evaluate the impact of the yard organisation on container stowing operations, we consider two kind of analysis based on the proposed model.

First, we analyse the problem in order to minimise the total stop time of a containership in the terminal, without considering those constraints that are related to the picking operations in the yard. In this case, we can suppose that the terminal applies the “pre-marshalling strategy” (*PM*), preparing the pre-marshalling area in accordance to the list of containers as it is suggested by the optimal solution of the MBPP. We hence do not include now the cost, or time, related to the need of moving containers in a temporary area; therefore, we solve MBPP having as objective function the minimisation of the total stowage time T, that is given by summarising the time for loading each container in its assigned location of the containership, by the following objective function:

$$T = \sum_{l} \sum_{c} t_{lc} x_{lc} \qquad (1)$$

where t_{lc} is the time required for stowing container c into location l, $\forall c \in C$, $\forall l \in L$, while x_{lc} is a binary variable such that $x_{lc} = 1$ if container c is stowed in location l and $x_{lc} = 0$ otherwise.

As a second analysis, we evaluate the influence of picking operations on the total stop time of the ship in the terminal with the hypothesis that the terminal yard management applies a “sort and store strategy” (*SS*). In particular, we consider the case in which a ship receives containers for their loading according to a given sequence and look for stowage plans for minimising the number of unproductive moves, or “shifts”, that is the number of containers that is necessary to move for loading/unloading other containers previously stowed. In order to implement the sort and store strategy in MBPP, we consider arrival sequences of containers from the yard as constraints and minimise a new objective function value, denoted by τ, expressing the stowage time T, as before, plus a penalty P that includes the possible re-stowing time due to the need of moving an already stowed container for being able to load on board another one without violating any stowing constraint. The modified objective function is the following:

$$\tau = \sum_{l}\sum_{c} t_{lc}x_{lc} + \sum_{l}\sum_{c} t_{lc}y_{lc} \qquad (2)$$

where t_{lc} is as before and y_{lc} is a binary variable such that y_{lc} = 1 if for putting container c into location l it is required to move from it an already stowed container, and y_{lc} = 0 otherwise, $\forall c \in C$, $\forall l \in L$.
We solve the MBPP with respect to different sequences of containers reflecting two different hypothesis of staking in the yard. In particular, the storage of export containers is planned according to the following sequences of information status:
S_1: shipping line – loading vessel – weight;
S_2: shipping line – loading vessel – destination – weight.
Summarising, there are different decisions to take: first of all we can choose between the above strategies and then, referring to the sort and store one, it is necessary to define the best sequential information for the storage planning; we represent this scenario by using the decision tree reported in Fig.1.

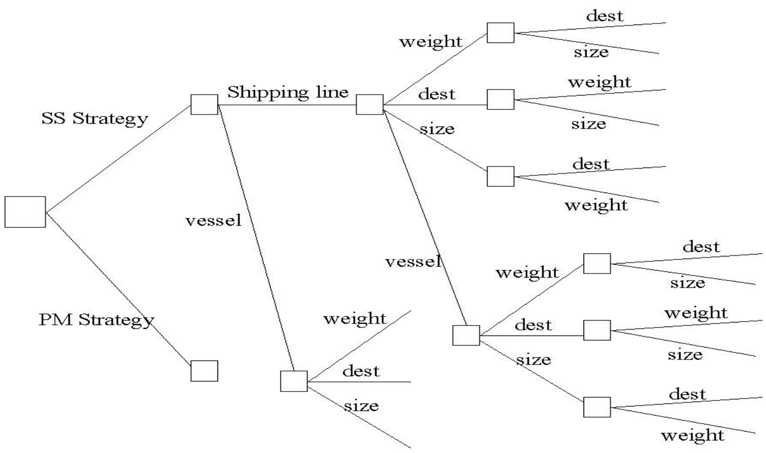

Fig.1

For our analysis we solved the MBPP by using the heuristic approach based on a 0-1 linear programming model proposed in Ambrosino, Sciomachen and Tanfani (2002).
Briefly, when the PM strategy is chosen, we solve the MBPP once, respect to the objective function (1), while when the SS strategy is chosen, we solve a modified version of the MBPP n times, according to the lot arrival, respect to the objective function (2). In particular, we modify the model in accordance to the different hypothesis of staking in the yard and the characteristic of the containers reaching the quay.
We evaluate these alternative yard storage strategies with real size stowage plans for a containership that is a "client" of the maritime terminal in Genoa (Italy) we are involved with.
Preliminary results show that the stowage plans optimisation not only enables to have good solutions in a very short computational time, but also guarantees better terminal performance indices than those that are today obtained, when an effective synchronisation between loading and picking operations is provided.
Moreover, it is important to note that the effectiveness of yard operations is related to the possibility of regulating the arrival of the export containers, while for loading operations it is relevant the assigned space, that is to say the storage capacity for each ship and the number of yard cranes devoted to it.

The best storage strategy is strongly affected by land constraints like space available for the yard or quay operations that influences the cost of these operations and the productivity of the terminal. Analysing different scenarios it is possible to understand where some actions are to be taken for increasing the terminal global productivity.

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