http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (21): 5967-5974, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.5967.5974

Study on Bay-filling Problem in Stowage Planning of Export Containers

[1]Zhao Ning, [1]Shen Yifan, [1]Chai Jiaqi, [2,3]Mi Chao and [1,2]Mi Weijian
[1]Logistics Engineering College, Shanghai Maritime University, China
[2]Container Supply Chain Tech. Engineering Research Center, Shanghai Maritime University, China
[3]School of Economics and Management, Shanghai Maritime University, China

Abstract: Owing to the fact that the container terminals occupy an increasinglydecisive position in today's maritimeindustry, the container stowage planning which is one of the important procedures during container-loading operations, gradually attracts the attention of port operators. In this study, we discuss the vessel stowage planning problem for export containers, in which the bay-filling problem is specifically analyzed on the basis of Preliminary Stowage Plan (PSP). Bay-filling is acrucial step in loading operations at a container terminal. By seriously conducting on-site research and careful practices in the stowage process of export containers, a decision-making problem of bay-filling is proposed. Herein, a multi-objective integer programming model is formulated based on various rules in the stowage operations. Then for solution, an algorithm framework is developed in AIMMS and calculated by CPLEX. In this way, a decision support system is then established which helps to control the partitioning of yard operations and yard crane reassignment. Moreover, a wide variety of numerical tests are carried out and their results show the effectiveness and feasibility of the proposed model. The application of the proposed system ensures a practical value for improving stowage efficiency and quality.

Key words: Stowage planning, partitioning of yard operations, yard crane reassignment, decision support system

INTRODUCTION

Port operators as well as shipping companies pay much attention to vessel stowage and associated loading or unloading operations which may directly affect handling efficiency and related fees in container terminals. The quality of stowage plans is a significant factor that determines ship's dwelling time in the port. The dwelling time of a ship includes the time for berthing, unloading, loading and departure and therefore smooth and orderly ship turnaround is essential for the economic performance of liner shipping companies.

For many container terminals, the operational process contains yard crane scheduling, quay crane scheduling, storage space allocation both at the quay side and yard side, berth allocation and so forth. Amongst, the stowage planning ensures great importance during the container loading operations. The problem addressed in this studyexactly refers to the position assignment for containers in a containership. It is a kind of container loadingproblem which means a detailed loading plan for pre-stowing containers of a specific vessel. In the late period of the last century, the vessel stowage was performed by the chief-officer of a vessel. By contrast, the terminal today may decide the stowage plan in a more intelligent and reasonable manner with regard to the given instructions and principles.

The study is concerned with vessel stowage problem.It is a NP-Complete problem which is widely recognized in the previous literatures.

Winter (1999) introduced stowage planning in connection with loading plans, taking the workload balance of quay cranes into consideration. These researches were intensively focused on ship stability. However, from our perspective, there is no need for port operators to think about stability in the stowage planning. Since it has been defined in the pre-stowing plans from shipping liners, some conditions have been confirmed and so it is not essential owing to the fact that containers from the same group can be stowed into a single vertical stack in the vessel. Containers in the same stack will be unloaded at the same destination. Excessive concerns about stability may exert great working pressure and unnecessary calculations on port operators. Wilson and Roach (1999, 2001, 2000) presented a theoretical model, in whichvarious technical restrictions were considered in order to realize the implementation of a commercial decision supportsystem. Their approach was based on

Corresponding Author: MI Chao, Container Supply Chain Tech. Engineering Research Center, Shanghai Maritime University, Shanghai, China Tel: 0086-21-38282670

decomposingthe planning process into two phases. In thefirst phase, called the strategic process, they made a rough stowage plan, based on classifying the containers with the same characteristics interms of size, destination and etc. The calculations were performedby a branch and bound procedure. Inthe second phase, called the tactical process, individualcontainers were assigned to specific locations by using a tabu search heuristic, thus resulting in a detailed stowage plan. Haghani and Kaisar (2001) developed a heuristic algorithm for vessel stowage planning with minimization of container handling cost which is related to unloading rehandles. Kim *et al.* (2004) addressed a loadplanning problem in with an objective of proper arrangement of container stacks on board in light of the smooth quay crane operation and the other one of proper container retrieval sequence from container stacksin the storage yard in view of an orderly transtainer operation, in which a beam-search algorithm was developed. Ambrosino *et al.* (2004) addressed a stowage-planning problem withthe objective to minimize the total stowage timewhere more practical constraints were taken into account such as different types of containers (inlength) and weight limit accepted for securingship structure. They assigned some ship holdsto containers with the same destination in order to avoid unproductive unloading rehandles. Imai *et al.* (2006) tackled the problem to obtaina non-inferior solution for stowage problem. The problem was defined as a multi-objective integerprogramming, for which a set ofnon-inferior solutions was generated by using the weighting method. Sciomachen and Tanfani (2007) employed a 3D-BPP approach to optimize stowage plansand terminal productivity. They evaluatedthe performance of stowage plans so as to minimize the total loading time and ensure an effective use of quay cranes. However, in the process of on-site stowage planning, the evaluation of yard cranes and other factors are also decisive and they cannot be ignored.

More recently, Lee and Lee (2010) presented aheuristic way for the optimization of a workplan which was aimed to retrieve all the containers from a given yard according to a given order. The optimization goal was to minimize the number of container movements as well as the cranes' working time. A binaryintegerprogram was generated to reducethelengthofthe movement sequence and the sequence was iterated toshorten operational time. These researches mainly discussed container reshuffles in the storage yard. Ren *et al.* (2011) addressed a special kind of container loading problem with shipment priority to solve practical problems. A tree search method was presented based on a greedy heuristic. A method of space splitting and merging is also embedded in the algorithm to facilitate efficient use of the container space. Junqueira *et al.* (2012) presented mixed integer linear programming models for the container loading problem and the vertical and horizontal stability of the cargo and the load bearing strength of the cargo (including fragility) were considered. Delgado *et al.* (2012) introduced an accurate definition called CSPBDL of stowing a set of containers in a bay section. Two CP and IP models were developed to solve the CSPBDL optimally. Woo and Kim (2011) addressed a method for determining the size of storage space for outbound containers. Various rules were proposed for determining the optimal reservation sizes. Kang *et al.* (2012) considered a three-dimensional bin-packing problem in which objects of various volumes are packed into a single bin to maximize the number of packed objects. A hybrid genetic algorithm was used to solve the bin-packing problem with the formulated packing strategy. Salido *et al.* (2012) presented a decision support system to manage container stacking problem, berth allocation problem and quay crane assignment problem. Lim *et al.* (2013) considered a single container loading problem with practical constraints. An integrated heuristic solution approach was proposed that combined a GRASP wall-building algorithm with linear integer programming models. Zhang *et al.* (2012) presented an efficient heuristic block-loading algorithm based on multi-layer search for the three-dimensional container loading problem. He and Huang (2011) proposed a Fit Degree Algorithm (FDA) for solving a classical 3D rectangular packing problem. Experiments showed that FDA outperformed other algorithms. Chen and Lu (2012) addressed the storage location assignment problem for outbound containers. The problem was decomposed into two stages. The problem in the first stage was solved by a mixed integer programming model while a hybrid sequence stacking algorithm was applied to solve the problem in the second stage.

All in all, no research work has been conducted on bay-filling problem in stowage planning and emphasis on its significance which is the scope of this study. On account of this, the related assignment principles are taken into consideration, namely the study on stowage bay-filling problem of export containers in container terminals.

The rest of study is organized as follows. Section 2 defines the problem we address in this study. In section 3, a detailed illustration to the proposed model is given which is oriented to quay crane scheduling. Thereafter, solution procedure and computational results are presented in Section 4. Conclusions are discussed in Section 5.

PROBLEM DEFINITION

The preparation scenario for the actual stowage plan includes two major aspects. The first phase is to collect all documents about container loading and then carefully check related information, in this sector, containers listed on manifest with customs clearance will be eventually stowed and therefore information on manifest and CLP (Container Load Plan) should be examined to avoid human errors. And moreover, port operators are required to make arrangements considering the position of export containers in storage yard to reduce container reshuffling, thus ensuring a reasonable loading sequence and handling efficiency. The second phase is to formulate pre-stowing plans which secure important reference for loading operations along the quayside. Such plans are divided into two parts (Overview of the whole containership and cross-sectional view of each vessel bay). Note that special containers are stowed into specific location and their priority is higher than that of GP containers.

Two elements are taken into account in vessel stowage. The first one is related to the safety of containerships, in which ship stability and draft are guaranteed when the ship's loading capacity is fully utilized. The second one is concerned with transportation economy, including the sequence of discharging ports, the number of container reshuffles and the convenience of handling processes.

The stowage problem addressed in this study refers to the container assignment for containerships. In addition to the fact that ship's stowage plan has to consider the assignment of containers to a three-dimensional storage space, such related factors as ship stability, drafts, dwelling time and container types are supposed to be considered and the vessel stowage must be formulated in accordance with restrictions imposed in retrieving containers from stacks in storage yard. Note that each container can only be loaded into a cell in a ship's hold or on the upper deck. In order to ensure a feasible and orderly terminal operation, vessel stowage must satisfy handling techniques and operational modes required by port operators.

Stowage planning is an uppermost procedure when the outbound containers are planned to be loaded onto their target vessel. The planning is intended to assigneach container with a specific location on the vessel where the stacking areahas been specified by a preliminary stowage plan from the liner shipping company. But in special cases, the containers are not placedaccording to the plan and the chief officer has the right to refuseto sign a document for the ship's departure and the terminal will suffer from the severe penalty.As a result, the actual loading sequence must be made in order thateach containeris stowed into the right position.

The stowage planning of containers is closely related to the loading efficiency of a vessel.Once the stacking position in a containership is determined, some container reshuffles are inevitableand the yard cranes are required to move for an extra distance to perform the tasks. Furthermore, an improper stowage plan may lead to the potential inefficiency of quay cranes. Some of the Yard Cranes (YCs) may interfere with each other without proper control. And even worse, the number of workingYCs may be insufficient. Consequently, a sound stowage planning is definitely important.

The process of stowage planning is generally composed of five steps, as shown in Fig. 1. Firstly, pre-stowing export containers of a vessel are classified according to pre-stowing information provided by shipping companies, such as discharging ports, container sizes and shapes. This is aimed to separate a complicated stowage process into several sections to simplify the problem and reduce container reshuffling. Secondly, for each container group, multiple vessel bays are determined to provide a certain number of adjacent cells to hold containers from a container group. The relationship between container groups and vessel bays is formulated up till now. Thirdly, the concept of bay-filling is put forward and it will be discussed in detail in the following paragraph. Fourthly, with regard to the bay-filling result, the slot of a vessel bay is regarded as the smallest unit in this procedure and a group of containers from yard bays

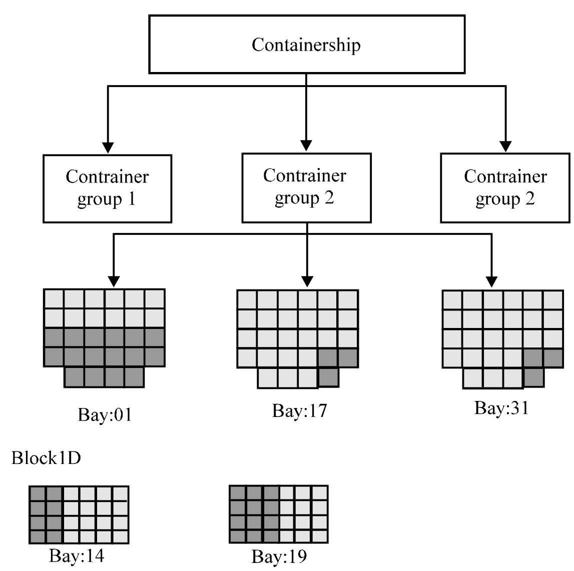

Fig. 1: Process of stowage planning

are stowed into a single slot. Eventually, the plan of retrieving sequence and the stowing outcome of each vessel cell are generated.

Figure 1 shows a typical example of the stowage operation. The vessel contains three container groups and containers from Group 2 will be classified into three vessel bays, Bay 01, 13 and 25, respectively. Totally there are eight containers in bay 01, seven containers in bay 13 and five containers in bay 25. And two yard bays in block 1D are assigned to release containers (eight containers in bay 14 and twelve containers in bay 58) through bay-filling operation.

During the entire stowage planning, bay-filling serves as an important link that performs the partitioning of cells in a vessel bay and the search of eligible containers in yard bays to match these cell group (Fig. 2).

It can be interpreted as a phase during which containers from slots in yard bays are assigned to be retrieved and stowed into cell groups of a vessel bay according to container distribution in storage yard and pre-stowing plans provided by maritime companies.

Bay-filling must keep to the following rules:

- Multiple bays of a certain block are firstly pieced together and then gathered by bay slots. If the number of containers from several yard bays exceeds the volume limit of a vessel bay, yard bays may be divided in order to avoid unproductive movement of yard cranes and to some extent save time and energy
- Due to the fact that each quay crane is associated with a given number of yard cranes, all these yard cranes should be deployed to carry out handling operations. Multiple blocks are pieced together and containers from these blocks are stowed into a certain vessel bay, thus improving operational efficiency

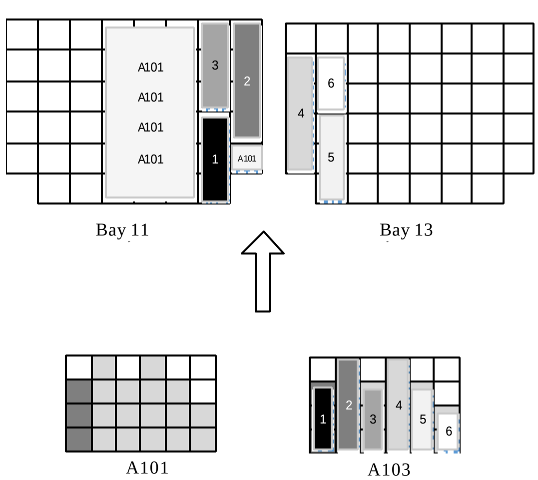

Fig. 2: Illustration of bay-filling

- Slots of yard bays are pieced together. Note that containers retrieved from slots in a yard bay can only be assigned to a vessel bay which is aimed to reduce container rehandles

MODEL

Notations: The parameters are listed as follows:

- B: The set of vessel bays (indexed by b)
- S: The set of slots of certain bay in a block (indexed by s)
- Q: The set of blocks in storage yard (indexed by w)
- W: The set of yard bays (indexed by w)
- A_b: Cells of vessel bay b
- N_su: Occupied cells in slot s
- L_b: Number of yard cranes needed for vessel bay b, namely partitioning of yard operations
- R_{SW}: Indicates the relationship between s and w. It is 1 if s belongs to w, 0 otherwise
- T_{wq}: Indicates the relationship between q and w. It is 1 if w belongs to q, 0 otherwise

The decision variables are listed as follows:

- X_{sb}: Indicates whether containers in slot s are loaded into vessel bay b
- D_{qb}: Indicates whether containers in vessel bay b are retrieved from block q, it is 1 if containers in vessel bay b are retrieved from block q, 0 otherwise
- M_{wb}: Indicates whether containers in vessel bay b are retrieved from yard bay w, it is 1 if containers in vessel bay b are retrieved from yard bay w, 0 otherwise

Constraints

Constraints 1

Container volume of vessel bays: In the process of vessel stowage, the volume of each vessel bay should be measured and the number of loaded containers cannot exceed the capacity limit of each bay (Fig. 3). The constraint is defined as follow:

$$\sum_s X_{sb} * N_s \le A_b \quad (1)$$

The left term of the constraint is a zero-one matrix where the parameter X_{sb}*N is summed with regard to slot s. And the right term refers to the allowed number (capacity limit) of stowing containers in the vessel bay b.

Constraints 2:

Partitioning of yard operations: Partitioning of yard operations means the number of yard cranes that are correlated with each vessel bay and its corresponding quay crane, namely the number of blocks (Fig. 4).

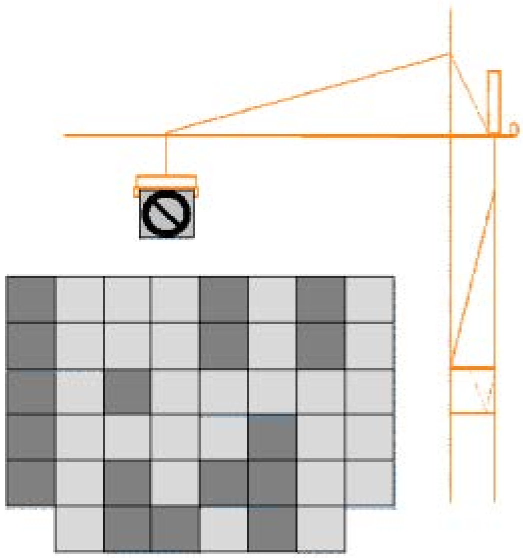

Fig. 3: Constraint 1

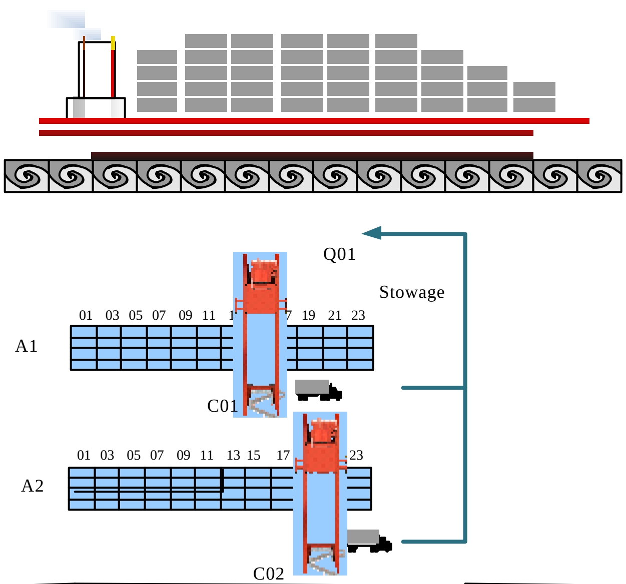

Fig. 4: Constraint 2

During the bay-filling operation, partitioning limit for each vessel bay must be taken into account which can be described as follow:

$$\sum_{q}\left[\text{If}\left(\sum_{sw} X_{sb} * R_{sw} * T_{wq}\right) > 0,1,0\right] \leq L_b \qquad (2)$$

For the left term:

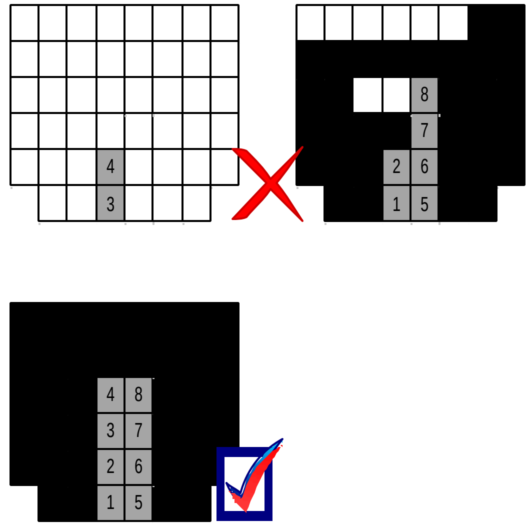

Fig. 5: Constraint 3

$$\sum_{sw} X_{sb} * R_{sw} * T_{wq}$$

refers to the number of yard bays retrieved from block q that are assigned to vessel bay b.The summation is then computed in terms of block q which means the number of yard operations. And the right term defines the maximum partitioning of yard operations.

Constraints 3

Forced assignment: During bay-filling process, a slot in yard bay can only be moved towards a vessel bay. If two or more vessel bays are planned to hold a slot, the clash may occur (Fig. 5). It is defined by the following equation:

$$\sum_{b} X_{sb} = 1 \qquad (3)$$

For the left term, the parameter X_{sb} is a zero-one two-dimensional matrix and the number of vessel bays is calculated with regard to slot s. And the right term is forced to be 1 which satisfies the assignment of a yard bay with a vessel bay.

Objective

Objective 1

Partitioning of yard operations: In the bay-filling process, the partitioning of yard operations should be maximized which is expressed as follow:

$$\text{Obj1} = \sum_{qb} [\text{If}(\sum_{sw} X_{sb} * R_{sw} * T_{wq}) > 0,1,0] \qquad (4)$$

Objective 2

Remarshaling of yard cranes: The minimum occupancy of yard bays refers to the intensiveness of bay operations and so the frequency of yard crane movement is minimized to avoid unnecessary reshuffle which can be defined in the following equation:

$$\text{Obj2} = \sum_{wb} [\text{If} \sum_{s} (X_{sb} * R_{sw}) > 0,1,0] \tag{5}$$

To optimize the bay-filling operation, the above two sub-objectives should be integrated, namely maximizing the partitioning of yard operations and minimizing yard crane reassignment respectively. Note that there exists no priority between two targets. The objective function is to enhance and optimize the overall resource utilization which is shown as follow:

$$T\_obj = \text{Obj1} - \text{Obj2} \tag{6}$$

Linear transformation: We can find that the objective expressions (Eq. 4-6) are non-linear equations. This increases the complexity of the proposed problem and its computational efficiency and accuracy is far lower than that of the linear objective function. Hence, the concept of linear transformation is herein applied and two auxiliary decision variables are introduced to construct auxiliary constraints.

For the first objective, an auxiliary decision variable is added which is defined as D_{qb}. And the constraint can be expressed as follow:

$$[\sum_{sw} (X_{sb} * R_{sw} * T_{wq})]/1000 \le D_{qb} \tag{7}$$

The left term of the constraint is a two-dimensional matrix with regard to q and w. Due to the fact that the amount of bay slots in a block must be far smaller than 1000, the number divided by 1000 can generate the matrix elements between 0 and 1. Accordingly, the first objective function can be revised as follow which is a maximization problem:

$$\text{Obj1} = \sum_{qb} D_{qb} \tag{8}$$

For the second objective, an auxiliary decision variable is also applied which is defined as M_{wb}. The constraint can be shown as follow:

$$[\sum_{s} (X_{sb} * R_{sw})] \div 1000 \le M_{wb} \tag{9}$$

The left term of the constraint is a two-dimensional matrix with regard to b and w. Due to the fact that the amount of bays in w must be less than 1000, the number divided by 1000 can lead to the matrix elements between 0 and 1. Thus, this objective can be expressed as follow which is a minimization problem:

$$\text{Obj2} = \sum_{wb} M_{wb} \tag{10}$$

From all mentioned above, the entire mathematical model can be summarized as follows.

Objective function:

$$\begin{aligned} \max\ T\_obj = & \sum_{qb} \left[\text{If} \left(\sum_{sm} X_{sb} * R_{sw} * T_{wq} \right) > 0,1,0 \right] \\ & - \sum_{wb} \left[\text{If} \left(\sum_{s} X_{sb} * R_{sw} \right) > 0,1,0 \right] \end{aligned} \tag{11}$$

Subject to:

$$\sum_{s} X_{sb} * N_s \le A_b \ \forall b \tag{12}$$

$$\sum_{q} \left[\text{If} \left(\sum_{sw} X_{sb} * R_{sw} * T_{wq} \right) > 0,1,0 \right] \le L_b \ \forall b \tag{13}$$

$$\sum_{b} X_{sb} = 1 \ \forall s \tag{14}$$

$$[\sum_{sw} (X_{sb} * R_{sw} * T_{wq})]/1000 \le D_{qb} \ \forall q, b \tag{15}$$

$$[\sum_{s} (X_{sb} * R_{sw})]/1000 \le M_{wb} \ \forall w, b \tag{16}$$

where, the partitioning of yard operations is calculated and maximized in the first term of the objective function 11 while the second term in Eq. 11 measures movement frequency of yard cranes and tries to minimize it. The weights of two terms can be adjusted according to the relative importance of two sub-objectives. The objective function is formulated to optimize bay-filling operations and enhance resource utilization. Constraint 12 defines the maximum number of containers stowed into a vessel bay. Constraint 13 ensures that the partitioning of yard operations for each vessel bay will not exceed the allowable level. By constraint 14, a slot in yard bay can only be assigned to one vessel bay. As for constraints 15 and 16, the concept of auxiliary variables is introduced to transform a nonlinear programming problem into a linear one. In constraint 15, an auxiliary decision variable D_{bq} is proposed to enable the first term of objective function 11 to be a linear sub-objective. The left side of the expression is calculated to obtain matrix elements between 0 and 1. The meaning of the auxiliary decision variable M_{wb} is the same with D_{qb}.

NUMERICAL EXPERIMENTS

In this section, the proposed stowage bay-filling is evaluated using practical data generated from a typicalcontainer terminal in Ningbo, Zhejiang Province. The solution method is coded in AIMMS and run on a personal computer with duo CPU @ 1.8 GHz and 1 GB RAM. And the mathematical programming model is solved using CPLEX 10.0, a commercial software package.

To verify the effectiveness and reliability of the single-objective programming model, multiple experiments are carried out with different parameter settings, namely the number of slots in yard bays. We retrieve the solution from CPLEX and the numerical results of the performance on computational efficiency for 25cases are summarized in Table 1.

Table 1: Comparison of computational efficiency

Test No.	Vessel bays	Slots of yard bays	Variable No.	Solution time(ms)	CPU memory
1	2	30	60	30	1.1
2	2	36	72	30	1.1
3	2	42	84	80	1.2
4	2	54	108	90	1.4
5	3	42	126	90	1.6
6	3	54	162	140	1.8
7	4	48	192	170	2.0
8	4	54	216	200	2.4
9	4	66	264	270	3.0
10	4	70	280	300	3.6
11	5	68	340	330	4.1
12	5	75	375	350	4.5
13	5	82	410	375	4.9
14	6	78	468	410	5.5
15	6	85	510	445	6.0
16	6	90	540	470	6.4
17	7	85	595	490	6.7
18	7	90	630	505	7.0
19	8	90	720	520	7.2
20	8	94	752	533	7.4
21	8	100	800	545	7.5
22	9	95	855	558	7.9
23	9	100	900	570	8.1
24	9	105	945	580	8.1
25	9	110	990	585	8.2

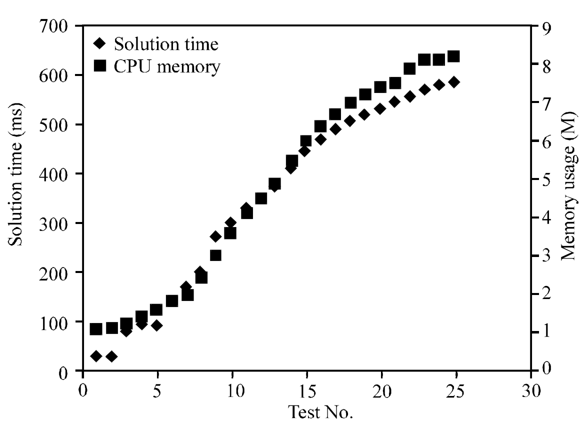

Fig. 6: An illustration showing comparison of solution time and CPU memory

It can be observed from Table 1 and Fig. 6 that the computing time and the memory usage of the proposed decision support system is rather short despite large amounts of computed variables. It is of great use to improve the effectiveness of bay-filling operation.

CONCLUSION

In this study, we discussthe stowage planning problem for containerships, in which several key principles are considered and analyzed. We present a decision support model for bay-filling in the stowage process of export containers. Analysis of bay-filling is conducted to obtain related information about vessel bays and containers in stacking blocks. The proposed problem is optimized by the maximization of partitioning of yard operations and the minimization of reshuffling frequency of yard cranes so as to improve stowage efficiency in container terminals. Computational tests are performed with 25 instances randomly generated and solved by CPLEX. The results show the practicality and effectiveness of the decision model which helps to carry out bay-filling operation. The proposed model can also be useful to motivate future research in order to solve related container loading problems.

ACKNOWLEDGMENTS

This study sponsored by National Natural Science Foundation (71201099), Shanghai Municipal Education Commission Project (14ZZ140), National 863 plans projects (2009AA043001) and Shanghai Maritime University Foundation Project (20120104). We also thank anonymous referees and the editor-in-chief for their ideas and suggestions.

REFERENCES

Ambrosino, D., A. Sciomachen and E. Tanfani, 2004. Stowing a containership: The master bay plan problem. Trans. Res. Part A: Policy Pract., 38: 81-99.

Chen, L. and Z.Q. Lu, 2012. The storage location assignment problem for outbound containers in a maritime terminal. Inter. J. Prod. Econo., 135: 73-80.

Delgado, A., R.M. Jensen, K. Janstrup, T.H. Rose and K.H. Andersen, 2012. A Constraint programming model for fast optimal stowage of container vessel bays. Eur. J. Oper. Res., 220: 251-261.

Haghani, A. and E.I. Kaisar, 2001. A model for designing container loading plans for containerships. Proceedings of the 80th Transportation Research Board Annual Meeting, January 7-11, 2001, Washington, DC, USA.

He, K. and W. Huang, 2011. An efficient placement heuristic for three-dimensional rectangular packing. Comput. Operations Res., 38: 227-233.

Imai, A., K. Sasaki, E. Nishimura and S. Papadimitriou, 2006. Multi-objective simultaneous stowage and load planning for a container shipwith container rehandle in yard stacks. Eur. J. Operational Res., 171: 373-389.

Junqueira, L., R. Morabito and D.S. Yamashita, 2012. Three-dimensional container loading models with cargo stability and load bearing constraints. Comput. Oper. Res., 39: 74-85.

Kang, K., I. Moon and H.F. Wang, 2012. A hybrid genetic algorithm with a new packing strategyfor thethree-dimensional bin packing problem. Applied Math. Comput., 219: 1287-1299.

Kim, K.H., J.S. Kang and R.R. Ryu, 2004. A beam searchalgorithm for the load sequencing of outbound containers inport container terminals. OR Spectrum, 26: 93-116.

Lee, Y. and Y.J. Lee, 2010. A heuristic for retrieving containers from a yard. Comput. Oper. Res., 37: 1139-1147.

Lim, A., H. Ma, C.Y. Qiu and W.B. Zhu, 2013. The single container loading problem with axle weight constraints. Inter. J. Prod. Econo., 144: 358-369.

Ren, J., Y. Tian and T. Sawaragi, 2011. A tree search method for the container loading problem with shipment priority. Eur. J. Oper. Res., 214: 526-535.

Salido, M.A., M. Rodriguez-Molins and F. Barber, 2012. A decision support system for managing combinatorial problems in container terminals. Knowledge-Based Syst., 29: 63-74.

Sciomachen, A. and E. Tanfani, 2007. A 3D-BPP approach for optimising stowage plansand terminal productivity. Eur. J. Operational Res., 183: 1433-1446.

Wilson, I.D. and P.A. Roach, 1999. Principles of combinatorial optimization applied to container-ship stowage planning. J. Heuristics, 5: 403-418.

Wilson, I.D. and P.A. Roach, 2000. Container stowage planning: A methodology for generating computerised solutions. J. Operational Res. Soc., 51: 1248-1255.

Wilson, I.D., P.A. Roach and J.A. Ware, 2001. Container stowage pre-planning: Using search to generate solutions, a case study. Knowledge-Based Syst., 14: 137-145.

Winter, T., 1999. Online and real-time dispatching problems. Ph.D. Thesis, Technical University of Braunschweig, Germany.

Woo, Y.J. and K.H. Kim, 2011. Estimating the space requirement for outbound container inventories in port container terminals. Inter. J. Prod. Econo., 133: 293-301.

Zhang, D., Y. Peng and S.C.H. Leung, 2012. A heuristic block-loading algorithm based on multi-layer search for the container loading problem. Comput. Operations Res., 39: 2267-2276.