Asia Pacific Industrial Engineering and Management System

A simulation study on re-marshaling operations in a block stacking storage system

Eun Joo Shin[a], Jiameng Shi[b],Youn Ju Woo[a], and Kap Hwan Kim[a*]

[a]*Department of Industrial Engineering, Pusan National University,Busan 609-735, Republic of Korea*

[b]*Department of Computer Engineering, Pusan National University,Busan 609-735, Republic of Korea*

Abstract

This paper addresses the operation of block stacking storage systems.In order to minimize the number of rehandles during the retrieval operation, the re-marshaling operations are performed. It is assumed that the storage area is segregated into several zones in which each stack has unit loads with a pre-specified range of remaining duration-of-stay (RDOS). This study develops a real time decision rule to determine storage locations ofunit loads in the yard during the storage process and the re-marshaling process. The ruleis used to minimize the total number of handing operations of unit loads while satisfying various constraints on stacking ina storage yard. This study suggests a method for finding an optimal number of stacks of each zone, the priorities among constraints in the decision rule, the priorities among filtering factors, and the value of the empty stack penalty. It is also attempted to optimize RDOSin each zone (stage) to minimize the total expected number of handles. It is shown that the rule is robust even when the arrival pattern and the retrieval times ofplates are uncertain. Numerical experiments by using practical data set are performed to test the validity of the approach in this study.

Keywords: steel plate storage; simulation; re-handling

1. Introduction

This study was motivated by a real example of a storage yard for steel plateswhich are to be supplied to ashipbuilding company. After the arrival at a storage place, some of steel plates are painted, and cut into smaller pieces. After being stored during a certain period, the steel plates are delivered to a shipbuilding company.For the storage of steel plates, the block stacking storage method is applied.

Insteel storage yards, the arrival and retrieval times of steel plates are scheduled considering the schedule of vessel arrivals and shipbuilding. When the shipbuilding schedules are constructed, the steel plates are ordered to a steel mill company, and those are shipped and stored at a steel storage yard. Cost of managing the storage yard occupies a large portion of the total logistics cost in the supply chain of steel plates. As the throughput of steel plates in the port terminal increases, a more storage space is needed but the storage yard space is usually limited. Therefore, the height of stackshas to become higher and thus, as a result, the number of re-handling becomes larger. This study addresses how to minimizethe number of re-handling during the retrieval process of plates by optimally managing the storage yard.

The handling process in the storage yard is as follows:after unloading the steel plates from a vessel, a worker checks the plate ID number with a PDA(Personal Digital Assistant) which shows thedetailed plate data. The worker considers the current storage space plan and the future retrieval time of the plate for deciding the storage location of the plate one by one manually.Becausethe decision on the storage location depends on the human operator, unnecessary re-handling operations

*Corresponding author. Tel.: +82 51 510 2419; fax: +82 51 512 7603.

E-mail address:kapkim@pusan.ac.kr (K.H. Kim)

may occur during the retrieval operation. To manage the storage system more efficiently, this study suggests a real time decision algorithm for the storage location to minimize the number of re-handling operations during the retrieval process.

There have been many studies on the re-handing operation, but most of them are related to container stacking issues. Watanabe (1991) analyzed the handling activities in container yards and suggested a methodto express the degree of the accessibility for various stacking methods for containers. Castilho and Daganzo (1993) and Kim (1997) also proposed a formula for estimating the number of relocations for the random retrieval of a container.Kim et al. (2000) addressed the problem of locating the arriving outbound containers by considering the weights of the containers.Kang et al. (2006) extended Kim et al. (2000) by relaxing the latter's assumption that the weight information of every arriving container is known with certainty.Kim and Hong (2006) suggested two methods for determining the locations of relocated blocks.Lee and Hsu (2007) and Lee and Chao (2009) discussed how to construct a plan for repositioning export containers within a yard so that no extra re-handles were needed during the loading operation.Lee and Lee (2010) addressed the relocation problem of inbound containers during the retrieval operation.Zhu et al. (2010) addressed also the relocation problem but they considered the export container yard.

For the case of the storage system of steel plates, Yang and Kim (2006) analyzed the storage location problem considering the arrival and the departure times of plates.Assuming more general types of plates and storage systems, Park and Kim (2010) attempted to estimate the number of re-handles for a given number of plates and a given type of a storage system.Kim et al. (2010) proposed the storage plan that requires the minimum number of shifts in the delivery stage. Their problem is a quite theoretical one. They assume that the relocated plates will be moved back and stacked in their original order immediately after the target plate is taken out. Tang et al. (2002) studied the slab stack shuffling problem in the slab yard. The problem is to choose appropriate slabs for a sequence of rolling items to minimizing the resulting shuffling workload. Tang and Ren (2010) suggested the improved strategies for slab stack shuffling problem, dynamic programming approach and segmented dynamic programming-based heuristic approach.

In this paper, various factors are considered for deciding the storage locations of steelplates. The storage locations of steel plates may be changed several times during the stay at the storage yard, which we call "re-marshaling operation."If there are at most two re-marshaling operations for a steel plate, then there must be three storage zones (stages) in the yard. Note that the re-marshaling operation is an intentional handling of plates for reducing the number of future handlings. But, there-handling is the relocation of a plate from a stack to another stack for retrieving a plate below.

This paper is organized as follows. In Section 2, we define the problem, provides assumptions in the formulation and input data used in the example. In Section 3, a real time decision algorithm for determining the storage location is proposed. Experiment results are presented in Section 4. Section 5 proposes the result of a case study. Section 6 summarizes this paper and gives conclusions.

2. Problem definition

When steelplates arrive atthe storage yard withthe information of eachplate's ID number, the arrival time, theexpected retrieval time, the next destination, the length, and theheight, the storage location of the plate is determined.Because steel plates are assumed to be retrievedaccording to retrieval schedules, steel plates need to be segregated according to the retrieval time. That is, steel plates having different retrieval times should be stacked separately. However becausethe stacking area is limited, steelplates with different retrieval schedules may have to be stacked in the same stack, which will cause the rehandling operations during the retrieval process.

The storage system in this study divides the storage yardinto 3 zones (stages) each of which is dedicated to steel plates with a pre-specified range of remaining duration of stay (RDOS) at the yard.For example,zone (stage) 1 has 4 stacks and can receive plates whose RDOSs are included within a pre-specified period of 28days;zone (stage) 2 has4 stacks and can receive plates whose RDOSs are included within a pre-specified period of 7days; stage 3 has 7 stacks for plates whose RDOSs correspond to specific days. In this case, the RDOS covered by stage 3is 7 days; that covered by stage 2is 28days; that covered by stage 1is 112days. The yard can receive steel plates whose maximum DOS is 147 days$(= (28 \times 4) + (7 \times 4) + (1 \times 7))$.

In Fig. 1,anexample of a storage process is described from discharging of plates from a vessel to the departure of plates from the storage yard. As thetime goes by, the plates in **stage 1** move to stacks in **stage 2** every 28 days, which is called"the 1st re-marshaling."Also the plates in **stage 2** move to one of the 7 stacks for **stage 3** every 7days, which is called"the 2nd re-marshaling operation." The plates in zone **(stage) 3** are retrieved every day.

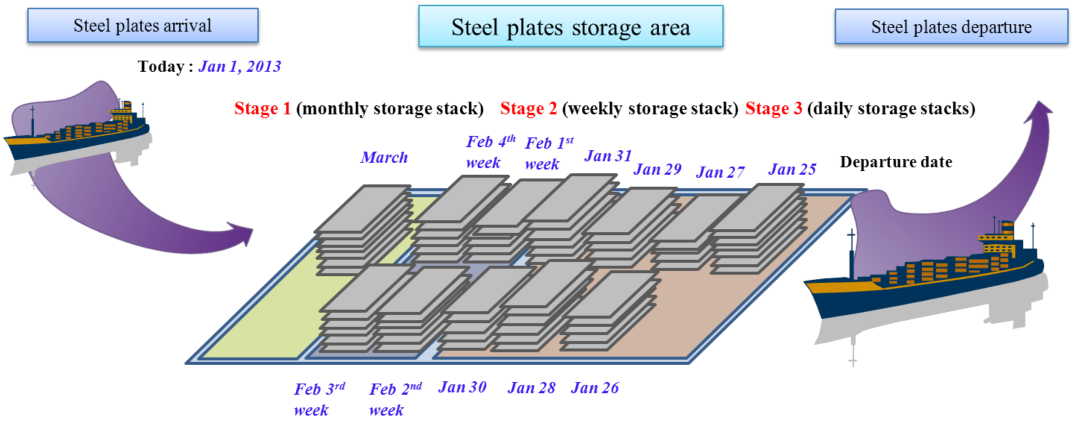

Fig. 1. Handling process of steel plates after the discharge from vessels at port steel terminals

For the definition of the problem, the following assumptions are introduced:

- The storage yard is divided into 3 zones and there are multiple stacks and covering periods in each stage. In Figure 1, the number of covering periods for stage 2 is 4 and the number of stacks of each covering period for stage 2 is one each. But, one covering period may require more than one stack. For example, the amount of plates to be retrieved during the 4th week of February may exceed one stack.

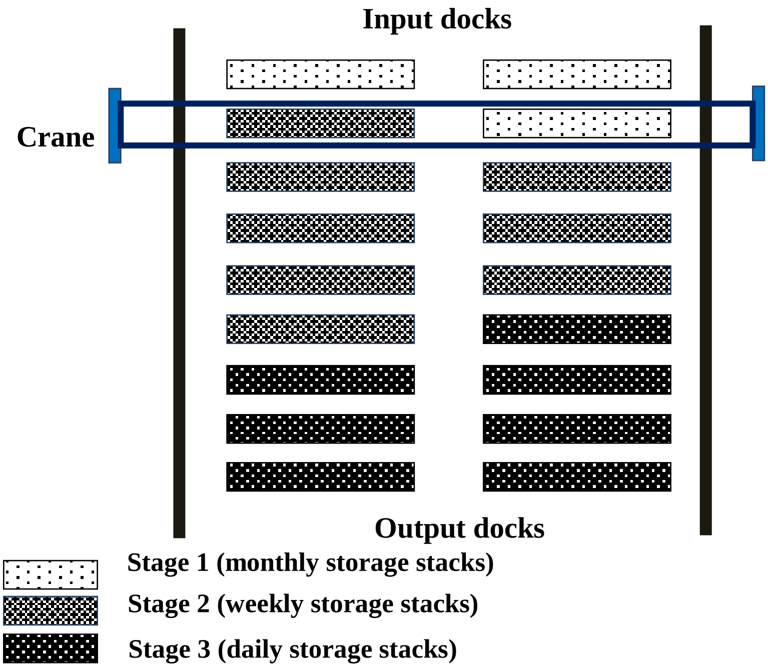

Fig. 2.Example of hierarchical re-marshaling operations.

- Arrival and depart events occurred once per day. This assumption can be relaxed with a minor modification to the discussions below. But, this assumption will be introduced for the simplification of the explanation.

2.1. Parameters for decision rules

Decision rules consists of constraints which decisions should satisfy, filtering factors for screening alternative stacks, and penalty function for evaluating alternatives. In addition, the number of stages, the length of a covering period at each stage, and the number of stacks of each covering period should be determined in advance. The followings explain these parameters in moredetail.

2.1.1. The length of a covering period and thenumber of stacks for each covering period

The length of a covering period and the number of stacks of each covering period should be determined in advance. See Table 1. For example, in stage 1 in Table 1, the length of a covering period is 90, while the number of stacks of a covering period is 4. The covering period in stage 1 impliesthat a stack in stage 1 stores plates whose RDOSs are included within the period of the length of 90 days. In stage 2, the length of a covering period is 30days and the number of stacks of a covering period is 2. It means thatthe RDOS of the plates stored in zone (stage 2) covers the period between 30 and 90 days after today. In stage 3,the length of a covering period is 1 and the number of stacks of a covering period is 32. Retrieval operation is done every day.

Table 1. Illustrative examples of parameters about zones

	Length of a covering period			Number of stacks of a covering period		
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
Case 1	90	30	1	4	32	32
Case 2	88	22	1	4	39	25

2.1.2.Constraints for restricting candidate unit loads to be stored at each stack

Constraints are imposed to candidate unit loads that can be stored at each stack. If a plate does not satisfy with the set of assigned constraints, the plate cannot be located at that stack. Constraints may include those on the length, the next destination, the stage, and so on. The parameters of constraints may be different from one stack to another.

2.1.3.Filtering factors

Filtering factors are used to find candidate stacks for storing a plate. Those stacks which pass the filtering factors can be candidate stacks for storing the plate. Filtering factors may be the conditions on the next destination, the length, and the covering period. If the next destination is one of the filtering factor, then the stacks which have only unit loads with the same next destination as that of the arriving unit load can be candidate stacks.

2.1.4.Penalties

Stack penalties are used to select the storage stackwhere the platewould be located.There are three kinds of penalties such as the evaluation penalty,theempty penalty,and the arrangement penalty.The plate is located atthe stack with the smallest penalty value.

The evaluation penalty is calculated by theevaluation formula. For the evaluation penalty, there are 5 kinds of factors to be considered such as the length of a plate, the next destination, the difference of RDOS between the arriving plate and plates already in the stack, the congestion ofthe stack, and the workload. The length factorof a plate is evaluated by thedifference between the length of a stack and a plate length. “Next destination” is compared between the next destination of the stack and that of the current plate. The difference in the covering period is evaluated by the changes in the covering period of a stack by locating the corresponding plate. The congestion of a stack is considered by the height of a stack. The workload is evaluated by the number of storage or retrieval orders issued for a stack at that time. All the factors have weightsandtheweight of each factor is determined by the yard manager.

Empty stack penalty indicates the value of an empty stack and it is determined by the managermanually. A larger empty penalty means ahigher value of an empty stack. It means that the empty stack has a high value and should not be wasted. If the demand forspace becomes large, theempty penalty should be set to be a large value. If penalties for all the otherstacks are larger than the empty penalty,then an empty stack is chosen to locate the plate.

When theempty penalty is smaller than that of any other stack but there is no empty stack, the yard manager decides whether the stack with the smallest penalty stack should be selectedor anempty stackshould be made by re-arranging (clearing) a stack with plates. If the smallest penalty is larger than the arrangement penalty, then the arrangement operation should be done for making empty stacks. The arrangement penalty is determined by the yard manager andthe arrangementpenalty is larger than the empty penalty. If the yard manager wants to re-arrange the yardmore frequently,then the value of thearrangement penalty should be set to be a smaller positive value.

3. Real time decision algorithm

To minimize the number of re-handling operations, a real time decision algorithm is proposed for findinga storage location for a plate. The algorithm determines the location of a plate when itarrives at the yard or re-marshaled, which can be described as follows:

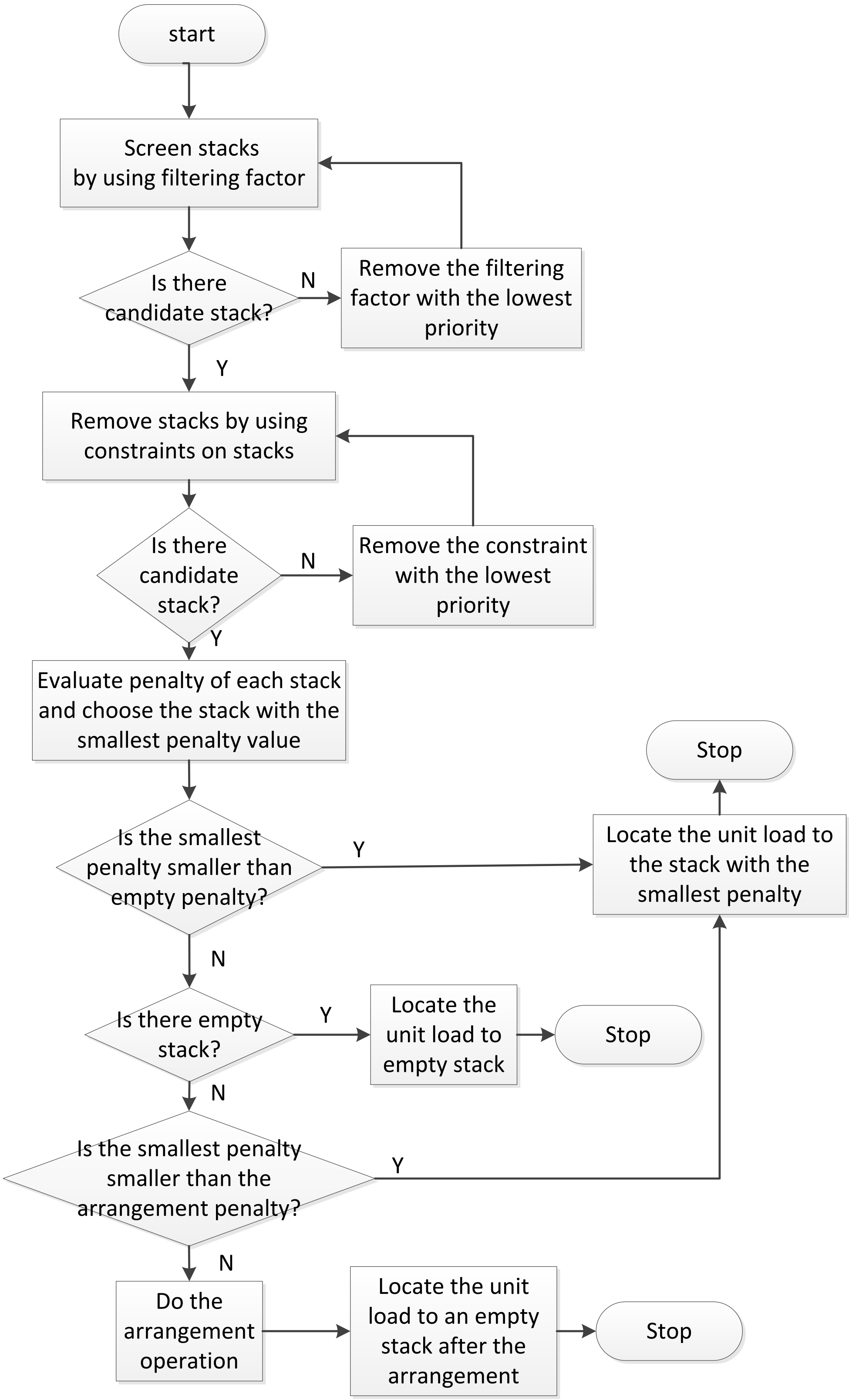

Fig. 3. A flow chart of the real time decision algorithm

Step 1. Find suitable stacks by using filtering factors. To find the stack, compare filtering factors of the plate with those ofeach stack. If there are stacks which havethesame values of the filtering factors as those of the plate, then add the candidate stacks to the candidate list.If there is no candidate stack, then remove the filtering factor with the lowest priority from the set of the filtering factors and then search candidate stacks again (relaxation). This relaxation procedure is repeated until at least one candidate stack is found.

Step 2. Remove candidate stacks from the candidate list, which do not satisfy constraints on stacks. If the candidate list becomes empty, then remove the constraint with the lowest priority from the set of the constraintsand then search candidate stacks again (relaxation). This relaxation procedure is repeated until at least one candidate stack is found.

Step 3.Evaluate penalty of each stack and choose a stack which has thesmallest stack penalty.

Step 4. Compare the smallest penalty among candidate stacks and theempty penalty. If the smallest penalty is smaller than the empty penalty, then locate the plate tothe stack with the smallest penalty. If the empty penalty is smaller than the smallest penalty and there is at least an empty stack, then locate the plate to an empty penalty stack. If there is no empty stack, then go to step 5.

Step 5. Compare the smallest stack penalty with the arrangement penalty. If the smallest penalty is smaller than the arrangement penalty, then locate the plate to the stack with the smallest penalty. Otherwise, find a stack to do thearrangement operation, which is the one whose total penalty for emptying the whole stack is smallest, and perform the arrangement.

4. Simulation experiments

A simulation program was developed to test the performance of the algorithm in this study. In the experiments, various design parameters were searched for improving the performance. They include the covering period of each stage, the number of stacks of ach covering period, and so on. For the evaluation, weights are assigned to evaluation factors. Also different priorities were given to filtering factors and constraints. For finding the best values of the parameters, simulation studies were conducted based on the analysis on the field data.

Three experiments were conducted to test the real time algorithm suggested in this paper. The field data is offered by ‘S’ company which is operating a steel plate yard at a port terminal in Korea. The real storage and retrieval data is composed of the steel plateID number, the arrival and retrieval times of each steel plate, the next destination (china, shipping company), the height, the length, and the amount of steel plates. The first experiment is conducted to find the optimal length of a covering period and the optimal number of stacks of a covering period for each stage. The second experiment wasperformed to find the optimal priorities of constraints and filtering factors, and the optimal weights on various evaluation penalties. The third experiment was done for the statistical analysis on the average number of re-handling in each stage. All the experimentsassumed the number of stagesis 3 and that the total number of available stacks is 68. The total maximum duration of stay of plates in the yardis 221days.

4.1. Experiment 1

In simulation, the storage area is divided into 3 zones (stages). To find the optimal length of a covering period and the optimal number of stacks of each covering period, 40 cases were chosen, which include cases with different numbers of stacks and covering periods. 40 cases are suggestedby a mathematical analysis in Kim and Shin (2013). The number of stacks and the length of a covering period of each stage werecalculated by various formulae and the 40 caseswith the smallest number of re-marshaling operations were selected.For a given storage space, the space exceeding the space required to accommodate the calculated number of stacks was distributed to each zone in proportion to the number of stacks allocated to each stage.

Table 2.Average no. of re-handling and re-marshalling operations per unit load

Case	Length of a covering period			No. of stacks			No. of re-handling and re-marshalling
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	
1	90	30	1	4	32	32	1.62
2	87	29	1	3	34	31	1.90
3	84	28	1	4	34	30	1.58

4	81	27	1	4	35	29	2.03
5	60	30	1	6	30	32	1.76
6	78	26	1	5	35	28	1.79
7	96	24	1	4	38	26	1.76
8	58	29	1	8	30	30	1.90
9	92	23	1	5	38	25	1.69
10	75	25	1	6	35	27	1.80
11	88	22	1	4	39	25	1.62
12	56	28	1	7	31	30	1.52
13	72	24	1	6	36	26	1.69
14	100	20	1	3	42	23	1.58
15	***84***	***21***	***1***	***5***	***39***	***24***	***1.46***
16	95	19	1	5	41	22	1.65
17	69	23	1	7	36	25	1.67
18	54	27	1	8	31	29	1.67
19	102	17	1	3	45	20	1.74
20	80	20	1	6	40	22	1.70
21	90	18	1	4	43	21	1.68
22	96	16	1	5	44	19	1.75
23	66	22	1	8	36	24	1.63
24	76	19	1	6	40	22	1.66
25	85	17	1	6	43	19	1.71
26	52	26	1	9	31	28	1.80
27	98	14	1	5	47	16	1.50
28	104	13	1	4	49	15	1.79
29	90	15	1	6	44	18	1.72
30	80	16	1	7	43	18	1.80
31	63	21	1	9	36	23	1.80
32	96	12	1	5	49	14	2.22
33	72	18	1	7	40	21	1.95
34	91	13	1	6	47	15	2.22
35	99	11	1	5	50	13	2.15
36	84	14	1	6	46	16	1.83
37	100	10	1	5	51	12	2.26
38	50	25	1	10	31	27	2.01
39	104	8	1	5	54	9	2.67
40	99	9	1	5	53	10	2.34

Case 15 gave the smallest number of re-handling and re-marshaling operations,in which the optimal length of a covering period is 84, 21, and 1 and the optimal number stacks of each covering period is 5, 39, and 24 for stages 1, 2, and 3, respectively. The expected number of re-handling and re-marshaling operation per unit load in the yard was 1.46.

4.2. Experiment 2

The various experiments have been conducted to find the best priorities of constraint andfiltering factors andthe best weights of penalty factors. The cases which were considered in the experiment are listed in Table 3. In this experiment, the empty penalty was set to be 0.2, andthe length of a covering period at stages 1, 2, and 3 was set to be 90, 30, and 1, respectively. The number ofstacks of a covering period was set to be 4, 32, and 32 for stages 1, 2, and 3, respectively.

Table 3. Cases with various priorities and weights

Cases	Priorities					
	Constraints			Filtering factors		
	Height	Next destination	Stage	Next destination	Retrieval time	Length
1	1	2	3	4	6	5
2	1	2	3	5	6	4
3	1	3	2	5	6	4
4	1	3	2	4	6	5
5	3	2	5	1	6	4
6	3	2	5	4	6	1
7	3	4	5	2	6	1
8	4	3	5	2	6	1
9	4	3	5	2	6	1
10	4	3	5	2	6	1

Cases	Weights				No. of re-handling and re-marshalling
	Evaluation factors				
	Length	Next destination	Retrieval time	Height	
1	1	2	8	5	**1.62**
2	1	2	8	5	1.76
3	1	2	8	5	1.67
4	1	2	8	5	1.74
5	1	2	8	5	1.75
6	1	2	8	5	1.82
7	1	2	8	5	1.87
8	8	1	2	5	2.58
9	1	5	2	8	3.12
10	1	8	5	2	2.31

Case 1 in Table 3 showed the smallest number of re-handling and re-marshaling operations which was 1.62. The best prioritiesamong constraints were 1, 2, and 3 and those for filtering factors 4, 6, and 5, respectively. Best weights of evaluation factors were 1, 2, 8, and 5, respectively. Note that a factor with a largerweight or priority has a larger importance in decision-making procedure.

4.3. Experiment 3

The number of re-handling and re-marshaling operations was analyzed. This experiment sets the empty stack value to be 0.2, the length of a covering period of each stage to be 90, 30, 1, the number of stacks for a covering period to be 4, 32, 32, respectively. The priorities were set to be(1, 2, 3)for (the height, the next destination, the stage) in constraints, (4, 6, 5) for (the next destination, the covering period, the length) in filtering factors. Weights of evaluation factors were(1, 2, 8, 5) for (the length, the next destination, the covering period, the height).

The total number of re-handling and re-marshaling operations was 90,193 during 10 months. The 1^{st} re-marshaling operation occurs when unit loads in stage (zone) 1 are moved to the 2^{nd} zone (stage) every 90 days. The 1^{st} re-handling operation occurs when the re-marshaling operation is conducted. During the re-marshaling process, if a unit load, which has to be moved from stage 1 to stage 2, is blocked by other unit loads, those blocking unit loads need to be relocated to other stacks to pick up the target unit load, which is called “the 1^{st} re-handling operation.”The 2^{nd} re-marshaling operation occurs when unit loads in stage 2 are moved to the 3^{rd} zone every 30 days. The 2^{nd} re-handling operationmay occur at this moment. Retrieval operation occurs when unit loads depart the storage system. Retrieval re-handling operation may occur during the retrieval process.

Table 4. Distribution of re-handling or re-marshalling operations

Event	No. of operations	Percentage
1st re-marshalling	795	0.9%
1st re-handling	990	1.1%
2nd re-marshalling	25277	28.0%
2nd re-handling	9427	10.5%
Retrievals	34061	37.8%
Retrieval re-handling*	19643	21.8%
Total	90193	100%

* Re-handling operations during the retrievals

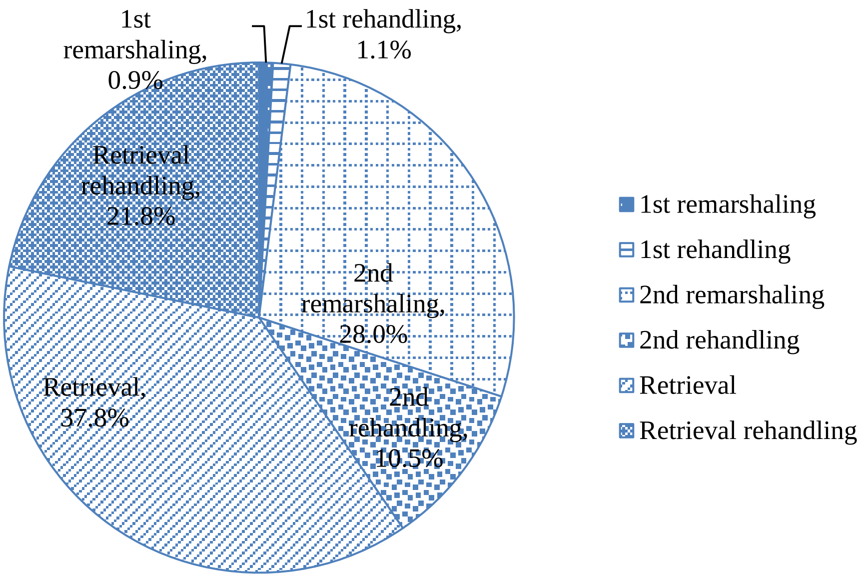

Fig. 4.Distribution of re-handling and re-marshaling operations

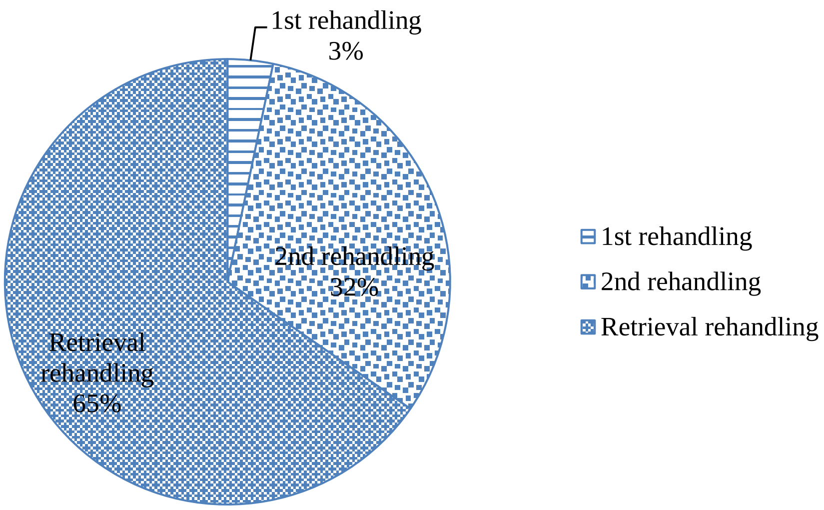

Fig. 5.Distribution of re-handling operations

Handling operations after the storage consisted of the 1st re-marshaling, the 2nd re-marshaling, retrievals, the 1st re-handling, the 2nd re-handling, and the retrieval re-handling which was re-handling operations during the retrievals. The 1st re-marshaling occupied 0.9% and the 1st re-handling occupied 1.1% which was larger than the re-marshaling operations. The 2nd re-marshaling accounted for 28% and it incurredre-handling operations occupying 10.5%. Retrieval operations occupied the largest portion which was 37.8% and 21.8% was theportion of the re-handling operations during the retrieval process (see Fig. 4).

Among re-handling operations, the 1st re-handling occupied 3%, while the 2nd re-handling accounted for 32%. The retrieval re-handling occupied the largest percentage, 65% (see Fig. 5). Because the largest proportion in re-handing operations is related to the retrieval process, it can be said that it is important to reduce the number of retrieval re-handling operations in order to reduce the handling cost.

5. Conclusions

A real time decision algorithm for determining the storage locations of steel plates is proposed. The algorithm can be used in ports, steel industry, ship building industry etc..The algorithm in this study can be applied to the storage systems for various products which are stored in blocking storage systemsThis study assumes that, to minimize the number of re-handling operations, thestorage area is divided into 3 zones. The scheduling method for re-marshaling operation is proposed, which includes the length of a covering period and the number of stacks of a covering period. The algorithm includes steps of finding candidate stacks by using filtering factors, constraints factors, and evaluations.

Experiments were conducted by changing the various input parameters in order to find the best combination of parameter values. The first experiment was to find the best length of a covering period and the best number of stacks for each covering period. The second was to find the best priorities of filtering factors and constraints. The third one was to analyze the distribution of the number of re-handling operations in each stage. In future studies, the impact of the number of storage stages (zones) on the performance of the system may be analyzedand uncertain retrieval schedules may be considered.

Acknowledgements

This work was supported bythe National Research Foundation of Korea (NRF) funded by the Korea government (MEST) (Project Number: 2013046740).

References

[1] Castilho B, Daganzo CF. Handling strategies for import containers at maritime terminals.*Transportation Research Part B*1993; *27*(2): 151-166

[2]KangJ, RyuKR, KimKH. Determination of storage locations for incoming containers of uncertain weights.*Ali, A. and Dapoigny (Eds.*): IEA/AIE 2006; LNAI 4031: 1159-1168

[3] KimKH.Evaluation of the number of rehandles in container yards.*Computers & Industrial Engineering*1997;32(4): 701-711.

[4] KimKH, Hong GP. A heuristic rule for relocating blocks. *Computers & Operations Research*2006;33(4): 940-954

[5] KimBI, Koo JI, SambhajiraoHP.A simplified steel plate stacking problem.*International Journal of Production Research*2011;49(17): 5133-5151.

[6] KimKH, Park YM, Ryu KR. Deriving decision rules to locate export containers in container yards.*European Journal of Operation Research* 2000; 124(1): 89-101.

[7] KimKH, ShinEJ.Hierarchical re-marshaling operations in block stacking storage systems considering duration-of-stay. In *Proceeding of the Intelligent Manufacturing & Logistics Systems* 2013

[8] Lee Y, Chao SL. A neighborhood search heuristic for pre-marshaling export containers.*European Journal of Operational Research*2009; 196: 468-475

[9] Lee Y,Hsu NY.An optimization model for the container pre-marshaling problem.*Computers & Operations Research*2007; 34: 3295-3313

[10] Park TK,Kim KH.Comparing handling and space costs for various types of stacking methods.*Computers & Industrial Engineering*2010; 58:501-508

[11] Tang L, Liu J, Rong A, Yang Z. Modelling and a genetic solution for the slab stack shuffling problem when implementing steel rolling schedules. *International Journal of Production Research*2002; 40(7): 1583-1595

[12] Tang L, Ren H. Modelling and a segmented dynamic programming-based heuristic approach for the slab stack shuffling problem. *Computers and Operations Research*2010; 37: 368-375

[13] Watanabe IR. Characteristics and analysis method of efficiencies of container terminal -An approach to the optimal loading/unloading method.*Container Age*1991(March);36-47.

[14] Yang JH, KimKH. A Grouped Storage Method for Minimizing Relocations in Block stacking systems.*Journal of Intelligent Manufacturing*2006 ; 17(5): 453-463

[15] Zhu M, Fan X, He Q. A heuristic approach for transportation planning optimization in container yard. In *Proceedings of the 2010 IEEE IEEM*2010; p. 1766-1770