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OPTIMIZATION OF RAILWAY TERMINAL BLOCK

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ABSTRACT: *The optimization of train containers layout plays an important role in the shop floor. There is a need to optimize the proper location and size of the containers yard. In this paper a technique is developed to optimize the size of the container block. When a trucks comes to pick up the block there should be an optimal distance travelled by the truck. In this paper a model is developed to minimize the distance travelled by the internal truck. The objective function is the distance travelled by the truck. The aim is to increase the efficiency of the terminal. A mathematical model is developed in this research paper to optimize the distance travelled by the truck. The model is solved in Mat-Lab and the optimization technique used in this research paper is Genetic algorithm. The model is also checked in the C language and the result is compared from both the programming language. This model is not generic and can be extended for other applications.*
The results of this study shows how an infidel factor such as block storage capacity, yard layout by taking into account the internal truck performance, etc. can improve the efficiency of container yard terminal.

Keywords: *Optimization, Container Yard Block,Yard layout optimization, block size, re-handling moves, terminal operations.*

INTRODUCTION

Container port serves the following functions:

- It receives the outbound containers from the shippers for loading into the ship/train and unloading inbound containers from vessel/train to be picked by the consignees.
- It provides as a temporary storage from containers between the changes in mode of transport [33].
- It acts as a place for packaging goods into the containers.
- It is also acts as mode of changing transport point because as discussed above containers come through ships to the port after that it transfers through either trains or trucks or ships to destinations.

Container transfer is basically main motto of a container port and these transfer of containers occurs at seaports and in the cities. Container terminal, which is located, near the sea is termed as marine container terminal or port and terminal, which is located in the cities is called as inland container depot. Therefore, ports are basically divided in two parts as given in the

- Marine or Sea port: It facilitates a link between water and land transport.
- Dry or Inland container depot (ICD): It provides a link between two land transports (rail-rail or road-rail).

Table 1: Characteristics of marine and dry ports

	Characteristics	Marine port	Dry port
1.	Volume of traffic	High	Low
2.	Capacity of vessels	Ship carry around 3000 TEU	Trains carry 90 TEU in single stack and 180 TEU in double stack.
3.	Link between	Water-land transport	Land-land transport
4.	Space allocation for loading/unloading	Berth allocation	Platform allocation
5.	Storage on vessel	Stowage allocation(based on weight of container)	Wagon allocation(based on weight of overall wagon in lower and upper deck)

1.1.3 Container Yard

Container yard is a space in the terminal where all the operation related to container terminal take place. Basically the structure of the container yard is rectangular, but some time the shape of the container yard is irregular.
Container yard basically have two types of storage block layout that is parallel and perpendicular layout. Parallel storage block layout is the layout in which storage block is align parallel to rail or quay side, in this layout yard cranes can travel from one block to another and container blocks are devoted to either inbound or outbound containers (no mixed blocks). Perpendicular storage block layout is the layout in which storage block is align perpendicular to rail or quay side, in this

layout yard cranes cannot travel from one block to another that they are fixed on one storage block. At TKD container terminal parallel yard layout is used and in general most of the Asian container terminals are using parallel yard layout.

Block of a container yard:

A block is basic unit of storage space at container terminal. A yard layout constitute number of blocks for storage. In Asian countries there is separate blocks for inbound and outbound containers, the number of inbound container blocks is always greater than number of outbound container blocks. Because in Asian countries import is higher than export.

A block constitute three parameters, i.e. number of bays (block length) (L), number of tier (H), and number of rows (W) as shown in figure 2. When these parameter's value increase then size of block is also increase.

The block storage capacity depends upon these parameters, higher the values of these parameters higher the block storage capacity.

Block storage capacity = L×H×W.

Container Handling Equipment

At container terminal there are number of operations associated with a container and these operations are performed using handling equipment such as:

Reach Stacker

A reach stacker is a type of handling equipment with a telescopic boom and top-lift accessory used for lifting and stacking containers. Figure 1.4 show's a reach-stacker that functions in the container terminal. It is basically used to stack containers and to load them into trucks, tractors or trains. Its storage capacity is approximately equal to 500 TEU per hectare. It can stack container up to three container height.

Figure 1: Rail mounted gantry crane [43]

Trucks:

So the container terminal operations are briefly described as follows:

Trainside operation: When a loaded train (train with containers) come at terminal then it stands on the rails provided for it. After that RMGC covered the train for unloading train, RMGC move on rails provided for its movements and RMGC take/put container from trains rack to truck. Same operation done for loading of containers to train. Transport operation: Containers which come to ICD through train are known as inbound container and containers which loaded to train from ICD and come from external customers are known as outbound containers. Once inbound container come to terminal it is taken off from train and send to storage yard through internal trucks. For relocating container from one block to another is also done by trucks.

LITERATURE REVIEW

Optimization of container handling system

Der-Horng Lee et al. (2009) [1] proposed a hybrid insertion heuristic algorithm for minimizing the total travel time by internal truck in container yard during container terminal operations. In this heuristic algorithm they used mix integer programming model. Seyed Mahdi Homayouni et al. (2014) [2] developed mixed integer programming model to solve the problem of integrated scheduling of yard cranes, trucks and platforms, they used method of comparison for verifying

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the result of simulate annealing algorithm and genetic algorithm, they found that result of genetic algorithm is more accurate than annealing algorithm.

Essmeil Ahmed et al. (2014) [3] developed strategy to improve the operational efficiency of container terminal, for doing this, they assign loading and unloading operation to a single yard truck to reduce their empty travel in the container yard, for verification of developed strategies and effectiveness, a simulation method is used and resulted in the productivity of container terminal gets increased by considerable amount. Kap Hwan Kim et al. (2002) [4] basically proposed a cost model for determining the optimal number of transfer cranes needed in the container yard, in cost model they include cost of setup, investment cost associated, etc. on the basis of cost model they developed two cases, one is deterministic and another for stochastic. Lee et al. (2010) [5] estimate the value of YC (yard crane) cycle time for performing yard operation by considering both types of layout and for both types of movement of YC (i.e., oblong and Tchebychev movement).

Optimal Storage Allocation

Kap Hwan Kim et al. (2002) [4] basically proposed a cost model for determining the optimal space requirement needed in the container yard, in cost model they include cost of setup, investment cost associated etc. and for verification of cost model they have done some numerical experiments showing the desire findings. Mohammad Bazzazi et al. (2009) [6] used the genetic algorithm tool to provide optimal storage allocation, they have considered the type of container because container type influence allocation of container in storage block, by doing this, they trying to minimize the retrieving/storing time and for verification of algorithm they used numerical examples.

Etsuko Nishimura et al. (2009) [7] used a heuristic algorithm, which used the lanragian relaxation concept to provide optimal storage to containers, they developed solution for mega- containership over feeder ship to optimize the operations related to containership, in this paper, for verification of model and algorithm computational experiment was used. Kap Hwan Kim et al. (2000) [8] developed the dynamic programming model to provide the storing location for export containers in storage yard, they basically consider the weight of container to optimize re-location, in this model they also developed the decision tree on the basis of result obtained from model and make the model real-time decisive in nature.

Bozer et al. (1984) [9] used concept of dedicated storage over the random storage of containers in the storage yard using the automated storing/retrieving system, in this paper they used statistical approach to verify that total travel time needed for dedicated storage is less than random storage of containers. Kang Tae Park et al. (2003) [10] developed a mix integer programming model for optimal allocation of containers in the storage yard, they used two heuristic algorithm for solving the problem, one of them is based on duration of stay of container in the yard and another base on gradient optimization, the computational result shows that first algorithm takes less time than second one.

I. Ayachi et al. (2010) [11] this paper used the genetic algorithm for solving the problem of optimal storage allocation to reduce halting time of ship at container terminal, it also considered the type of containers for applying solution techniques, they used some other algorithm i.e. last in first out for verification of solution come from genetic algorithm and found that genetic algorithm taking less halt time as compare to another algorithm. Zhang et al. (2003) [12] works for a Hong Kong container terminal, in this work they solve the problem of storage allocation of containers by dividing the problem in two stages, they used the rolling-horizon approach for solving problem. Formulation of problem is done using the mix integer programming and verification of the model is done by numerical analysis.

Optimization of container yard

Generally in all container terminal containers are stacked in such a way that utilization of the yard space are very high. In the yard there should be one more factor to increase the operational efficiency of the terminal i.e. to relocate the containers during accessing the desired container in such a way that number of movements of the other containers are minimum. Yusin Lee et al. (2007) [13] presents an optimization model base on integer programming to minimize the number of movements required to access the desired container from their current position. This model used the concept of multi-purpose network flow and some heuristic method to solve the problem even the extension of the problem. Xinjia Jiang et al. (2012) [14] work for storage yard managing problems, basically they used the consignment strategy for solving the problems of re-shuffling. They used the concept of space sharing to increase the storage space utilization and they also used the low- high workload consideration for solving the problem of traffic congestions at terminal.

Jo¨rg Wiese et al. (2013) [15] developed a model for optimal design of yard layout in which straddle carrier is used for doing the handling operation, for formulation of the model they consider number of parameters regarding layout of yard i.e. parallel or perpendicular layout and they found that each type of layout is best in some condition and for doing this, they calculate expected value of cycle time of straddle carrier. Akio Imai et al. (2006) [16] developed multiple objective programming model in which one of the objective is to minimize the number of rehandle required for loading or unloading of container from the container yard, they used the genetic algorithm to solve this model and verification of this model is demonstrated by number of numerical experiments.

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Byung Kwon Lee and Kap Hwan Kim (2010) [17], in this paper four models are developed to optimize the size of storage blocks and these four models are depend upon the condition of yard crane cycle time and the truck waiting time for both types of storage blocks (inbound and outbound) and both types storage block layout (parallel and perpendicular layout), and the verification of models are done by numerical experiments which showing the favorable result regarding block size with parallel layout. Ki Young Kim (2006) [20] developed the model for estimation of container movement time by automated yard crane by considering two types of block i.e. one in which transfer points are parallel to block and second, where transfer points are perpendicular to blocks .

Simulation

A.A. Shabayek and W.W. Yeung (2001) [21] developed a simulation model, which is based on the witness software, this model is used to determine the performance measure of container terminal operations, basically this paper is focused on Chung container terminal to predicting its performance of operating systems. Kap Hwan Kim et al. (2012) [22] developed a simulation model for determining the effectiveness of space planning techniques and quay crane scheduling, this model is basically developed on the basis of heuristic method used for space planning, for verification of simulation model number of simulations are done.

Gamal Abd El-Nasser A. Said et al. (2014) [23] developed a simulation model which can used to optimize container terminal operations by using simulation technique, the motto of this mode is to minimize vessel's turn-around time and enhance the performance of container terminal. The developed approach is applied on an actual data, which is taken from Alexandria container terminal at El-Dekheilla port, for verification of model number of computational experiments were done. The results present that the developed approach reduce the vessel's turnaround time at port where 51% reduction in vessel's service time (loading/unloading) at port is found.

MATHEMATICAL MODEL FORMULATION

If we use RFID at container terminals [35] (shown in figure 3) it is used to keep track of the locations of stackers and containers and it provide greater visibility of the operational data and it can be used to improve the control process.

Fig. 2 RFID at container terminal [39]

For checking that RFID can applicable at TKD container terminal and understanding the working, administrational work and observing the terminal we conduct a visit to TKD and we found that:

- There is already GPS system is working for tracking of containers and maintaining data regarding container position and their details about coming and going from and to

Mathematical Model for Optimal Storage Block

As discussed in introduction that block size basically depends upon three parameters, number of rows, number of tiers and number of bays. So to understand the entire structure of the container terminal we have to visit the TKD container terminal and also do the literature survey to understand the terminal operation and terminologies. If we increase these parameters the size of block increases and block storage capacity gets increase. Therefore, for optimizing the block size,

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we have to optimize the block storage capacity. By optimizing the block storage capacity the following benefits achieved:

- Smoothness of doing the container operation gets increase because it efficient the container terminal operation.
- Decrease the waiting time for trucks
- Increase the utilization of the container yard in efficient way.
- Number of container transfer gets increase because capacity of terminal gets increase by considerable amount.

But when we increase any of the parameters to more extent then it increases the cycle time of the YCs, which decrease the efficiency of operations i.e. YCs cycle time limits the block size to a limited value.

3.2.2 Problem Formulation

To optimize the block size, we have to optimize number of bays, number of tier, and number of rows and these are optimize when we optimize the block storage capacity. In TKD the focus of management is to mainly increase
For the problem formulation we model the operations as follows:

Expression of problem formulation

Problem formulation for optimizing the block storage capacity by considering the YC cycle as the constraint is as follows:

For Outbound block

Objective function:

$$\text{Maximize. Capacity} = 9\times X \times Y$$

Subjected to constraint:-

$$.4E[CT_{Lo}] + .45E[CT_{Re}] \ \leq \ \gamma \qquad \ldots\ldots (1)$$

$$1 \leq X \ \leq 100$$
$$1 \leq Y \ \leq 50$$

Where X, Y are decision variables

For Inbound block

Objective function:

$$\text{Max. Capacity} = 7\times X \times Y$$

Subjected to constraint:-

$$.43E[CT_{Un}] + .545E[CT_{De}] \ \leq \ \beta \qquad \ldots\ldots\ldots (2)$$

$$1 \leq X \ \leq 20$$
$$1 \leq Y \ \leq 40$$

of problem formulation becomes:

For Outbound block

Objective function:

$$\text{Max. Capacity} = 9\times \mathrm{X} \times \mathrm{Y}$$

Subjected to constraint:-

$$.45\times \left\{\left[\left(1+\frac{1}{C_{14}}\right)\times\left(\left(\frac{-C_9^3}{12\times C_{10}^2\times(X-1)^2}\right)\times\left(\frac{C_9^2}{3\times C_{10}\times(X-1)}\right)\times\left(\frac{C_{10}\times(X-1)}{3}\right)\right)\right] + 5C_8 + \quad C_6 + C_7 + \left[C_3\left(\frac{3C_{14}-1}{C_{14}}\right)\right] + 4\left[\left((1+C_{11})\times(C_4(Y+4)+C_5)\right)\right]\right\} \quad \leq \gamma \qquad \ldots\ldots\ldots (3)$$

$$1 \leq X \ \leq 34$$

$$2 \leq Y \ \leq 5$$

For Inbound block

Objective function:

$$\text{Max. Capacity} = 9\times \mathrm{X} \times \mathrm{Y}$$

Subjected to constraint:-

$$.45\times\left\{\left[\left(1+\frac{1}{C_{13}}\right)\times\left(\left(\frac{-C_9^3}{12\times C_{10}^2\times(X-1)^2}\right)\times\left(\frac{C_9^2}{3\times C_{10}\times(X-1)}\right)\times\left(\frac{C_{10}\times(X-1)}{3}\right)\right)\right]+\left(C_8\times\left(\frac{29Y+198}{112}\right)\right)+C_6+C_7+\left[C_3\times\left(34+C_{12}\left(\frac{C_{13}-1}{C_{13}}\right)\right)\right]+\left[\left(\frac{29Y+30}{56}\right)\left((1+C_{11})\times(C_4(Y+89)+C_5)\right)\right]+\left[\left(\frac{29Y-26}{112}\right)\times\left((1+C_{12})\times\left(C_2+C_1(X-1)\right)\right)\right]\right\}\leq\beta \quad \text{.........} \ (4)$$

$$1 \leq X \leq 499$$

$$1 \leq Y \leq 59$$

Where $C_1 = \frac{l_c+b_g}{V_{t1}}$, $C_2 = \frac{l_c}{V_{t1}}$, $C_3 = \frac{g_c+3(w_c+r_g)}{V_{t1}}$, $C_4 = \frac{h_c}{2V_{t1}}$, $C_5 = \frac{1.5}{V_{t1}}$, $C_6 = (t_{u1}^{nm} + t_{u0}^{mn})$, $C_7 = (t_{u0}^{nm} + t_{u1}^{mn})$, $C_8 = (t_p + t_r)$, $C_9 = \frac{g_c+6(w_c+r_g)}{V_{t0}}$, $C_{10} = \frac{l_c+b_g}{V_{g0}}$, $C_{11} = \frac{V_{u1}}{V_{u0}}$, $C_{12} = \frac{V_{t1}}{V_{t0}}$, $C_{13} = u_{YZ}$, $C_{14} = l_o$ are constants.

3.2.3 Optimization of problem

As it is observed from expression of problem that it has more than one power of decision variable, due to this it become non-linear mix integer program, for solving this nonlinear problem we use the two methods in M ATLAB (because it facilitate solution of all type of problem with easiest way of programming environment).

- *Looping Method*: In this method we use the nested for loop to select the combination and use a numeric array for storing the value of capacity. Else if statement is also used for sorting the value of capacity according to the constraint provided. After that for selecting the maximum value of capacity, we use a variable which give us max value of the capacity.

The algorithm of this method is as follows:

Step 1: Enter the value of constants
Step 2: Define the numeric array and RHS of constraint
Step 3: Check all the possible combination of X and Y
Step 4: Check for feasibility of constraint
Step 5: Obtain all feasible capacity
Step 6: Obtain optimal capacity

Fig 3.Train side operations [38]

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And after literature review, we come to the point that for optimization of container yard layout there is need to consider the number of issues concerned to the container yard layout. And those issues are following:

After analyzing the layout of container flow through internal truck, it is realized that supply end of layout act as source points and demand end are acts as destination point of a transportation model (because transportation problem in operation research deals with the goal of assigning sources to their desired destinations) [37] .

Optimization of problem

For the solution of the above problem we need the specific optimization tool, but before that we need the value of all the parameters, which is used in expression. The parameters whose values are needed for optimization are: distances between trains and particular block's particular stacks. The values of these parameters are assumed on the basis of observation done during visiting TKD container terminal.

Optimization Method

After analyzing the expression we found formulation is a mix integer linear problem and it can be solved by MATLAB and CPLEX optimizing tools. But number of variables and number of constraints are large, so it is difficult to solve the problem in less time with MATLAB tool. So for optimization of above problem we used CPLEX tool.
CPLEX Optimizer:

RESULT AND ANALYSIS

In this section we describe about finding of optimal block size model, as discussed in section 3.2 after trying several times for getting value of constants, but we do not get any chance to get the data. Finally, we have no value of constants, so for solving the optimal block size problem using the genetic and looping algorithms we need value of constants. Therefore, we assume the value of constants for giving the initial result, but for final result we need the actual value of these constants.

Using the Looping algorithm:
After running the algorithm in MATLAB, we found following values of capacity of block and their parameters for:

Inbound block
Block storage capacity = 767,
X (block length) = 27
Y (height of block) =7.

Outbound block
Block storage capacity = 120
X (block length) = 80
Y (height of block) =7.

Using genetic algorithm:
After providing the input to the inbuilt optimizer based on genetic algorithm, we found the following values.

For *outbound block:*
Block storage capacity = 24
X (block length) =3 and
Y (height of block) =2 (at assumed value of constant) as shown in figure 6. In the optimizing window of MATLAB (in Appendix B)

For *inbound block*:
Similarly for inbound block, we solve using genetic algorithm in MATLAB (at assumed value of constants).we found following values

Block storage capacity = 27

X (block length) =6

Y (height of block) =1.5.

Result of optimal internal truck travel distance model

In this section, we describe finding of optimal internal truck travel distance model. As discussed in section 3.3, this model's expression is linear and having number of variables and constraint, so we solved it using the CPLEX optimizer. After running the optimizer we found following result:

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For getting the result we take following value of parameters;

Number of train at terminal = 3

Number of blocks = 7

Number of stacks in each block = 12

Vacancy at each stacks=
[0,10,5,0,0,0,4,0,7,0,8,0,9,0,9,0,0,6,8,1,0,0,0,2,3,5,0,0,7,1,3,6,7,0,0,0,0,10,0,15,0,0,0,12,1,3,0,0,2,9]

Number of containers from trains = 80 (first train), 75 (second train)

Value of distances are given in data file of CPLEX optimizer and it is shown in Appendix D. after running the optimizer taking these value of parameters we found the result:

Optimal distance travel by internal truck = 110.195 Km

Sensitivity Analysis of γ (outbound block)

Table 2 Result of analysis

Cycle time (min)	Storage capacity (no. of containers)
4	280
4.1	280
4.2	280
4.3	560
4.4	560
4.5	560
4.6	560
4.7	560
4.8	840
4.9	840
5	840
5.1	840
5.2	840
5.3	1120
5.4	1120
5.5	1120
5.6	1120
5.7	1120
5.8	1400
5.9	1400
6	1400

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