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OPTIMIZATION AND SENSITIVITY ANALYSIS OF RAILWAY CONTAINER BLOCK

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Abstract:-*This paper optimize the dimensions of railway containers by taking into account the constraints related to space limitations. this paper is the extension of Previous paper by vaseem et. al. in this paper the sensitivity analysis is shown after the optimization. this is genralised research and can also be used by the transportation departement to calculate the optimum number of trucks in a space and thier proper allocation. the trucks like to follow last in first out policy to mininmize the inventory level within a given space. the research paper is coaded in Mat-Lab and C Language and thier results are compared with each other. the sensitivity analysis is shown in the later part of the research paper. the research paper can also be used for the traffic control on bumpy roads. the future of the research paper is limited to transportation only.*

Keywords: *container terminals, container yard, storage capacity, yard block, yard layout optimization, block size, re-handling moves, and terminal operations.*

1. LITERATURE REVIEW AND INTRODUCTION

Container terminal generally have two types of trucks, i.e. internal truck (IT) and external truck (ET). Internal trucks are basically used for transfer of containers from and to the storage blocks and trains. And, it runs only inside container terminal.External trucks are used for dropping the export container to storage block or trains and bring the containers from companies. These trucks run outside terminal. Frequency of IT is more than ET.

Container Terminal Operations

In today's scenario containers are most important equipment for intermodal transportation. Every container have their standard size and unit, which suits to trucks, trains and ships. In-depth container is the key connection between different types of transportation modes.

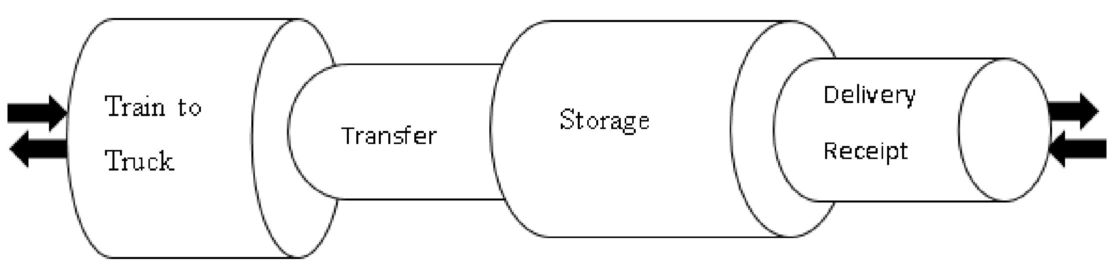

Fig.1 Chain of terminal operation

Storage and stacking operation: Once the containers moved from trains and reached to storage blocks, there is a need of some operation such as stacking, re-location. Basically containers are stored in two ways in storage yard, sometime containers are stored in chassis for buffer storage, if they are moved on same day. And, sometimes container are stored in storage blocks with the help of RTGC in vacant stacks and RTGC are also used for changing original position of containers.Delivery and receipt operation: At container terminal there are two types of storage block inbound storage block and outbound storage block. Finally, when time come for inbound container to deliver to the desired customer, it is operated by RTGC to put container from inbound storage block to external trucks. And, there is also operation related to receipt of container coming from customer for export, for this when external truck come to the outbound storage block, container receipt and stored in stack with RTGC and when time come to export, these containers are loaded on trains with help of RMGC and internal trucks.

1.1 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.

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 .

Jörg Wiese et al. (2010) [18] developed different model for planning yard layout which have transfer lanes, they developed linear programming model for rectangular yard layout and for non- rectangular yards they used the VND approach for solution, after doing the computational experiments they found that VND approach is more efficient for non-rectangular layout than linear approach.

Kap Hwan Kim et al. (2008) [19] developed the method for designing the optimal container yard, they basically considered two types of layout i.e. parallel and perpendicular and for determining the type of outline of the container yard they formulated the problem using the expected number of rehandle by crane and expected travel time by trucks inside the layout and for verification of formulation they have done numerical experiments.

1.2 **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.

1.3 Traffic congestion reduction

Yongbin Han et al. (2008) [24] developed a mix integer programming model to reduce traffic congestion problem, with help of low-high workload balancing technique, to achieve this the model determines minimum number of yard cranes needed to handle the imported containers coming to the container terminal and for verification of model number of numerical experiments are done. Joseph J. M. Evers and Stijn A. J. Koppers (1996) [25] developed a hierarchical model for controlling the traffic of automated vehicles, model developed is enhancing the performance of the information system used for controlling automated vehicles in container terminal.

Thomas F. Golob et al. (2000) [26] proposed policies to reduce traffic congestion from the container terminal and the policies are: (1) newly committed truck facilities, (2) enhanced operational efficiency, (3) modified traffic management, (4) improve truck urban major priority, (5) increased road capability and (6) congestion taxes and coordinated support for these to truck company characteristics. Gary Froyland et al. (2008) [27] proposed a three stage algorithm to accomplish the container exchange capability, also involves the scheduling of cranes, the management of related short-term inbound container stacking, and the provision of delivery positions for trucks and other container transportation, this paper also include the computational experiment to validate the algorithms.

1.4 Literature Review on Container Terminal Activities

Iris F.A. Vis et al. (2003) [28] described about container terminal operations such as arrival of ship, loading and unloading of ship, transfer of container from ship to stacks using internal transportation, stacking of containers in stacks using yard cranes and final operation i.e. delivery and receipt of containers, in these operations, this paper discuss the problems and solution using appropriate models, this paper mainly focus on handling of large number of containers in short period of time. Hans-Otto Günther et al. [29] also describe about container terminal operations, but they mainly focus on decision problems and logistic process, they suggest optimization techniques regarding real time decision problem and they also suggest way to solve problem related to logistics.

Tao Chen (1999) [30] described about policies for yard management, for this he listed the unnecessary moves and other factors which decrease the container terminal operational efficiency and the factors are bad quality of information sharing, storing capacity and height of container stacking out of which height of stacking influence more because of this yard cranes efficiency goes down. Kap Hwan Kim and Hoon Lee [31] reviewed about planning and real time controlling activities, planning activities basically includes decision making such as space requirement planning, loading and unloading sequence of containers and stowage planning etc. for the making of decision regarding planning and controlling they take the help of software i.e. terminal's operating system software (TOS).

Xinjia Jiang et al. (2013) [32] 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 high –low workload courtesy for solving the problem of traffic congestions at terminal and they used numerical examples for validation of concepts used. Katta G. Murty et al. (2005) [33] developed a decision support setup, which is basically a computational setup, purpose of this setup is reduce problem related to container terminal operations such as number of yard trucks to be allocated to a yard crane, berthing of vessels and they do the computational experiments on the basis of observed data obtained from Hong Kong container terminal.

Amir Hossein Gharehgozli et al. [34] described about the current developments in area of technologies, operation research, in the area of technologies they described new handling equipment such as automated lifting vehicle, double stacking yard crane, vehicle tracking inside container terminal and in the area of operation research they

2. FORMULATION OF MODEL

Operate on number of frequencies ranges such as: low range (100-150 kHz)-low data rate, cost, medium range (10-20 MHz)-medium data rate and high range (850-950 MHz)-high data rate, cost [36]. It has following component:

- **Tag** – It is a transponder that is made up of an integrated antenna and an electronic circuit. The information can be written and rewritten on a tag.
- **Reader –** It is a device that is used to interrogate an RFID tag. The reader has an antenna that emits radio waves; the tag responds back by sending its data.
- **Host Computer -** It reads /writes data from/to the tag through the reader. It stores and evaluates obtained data and links the transceiver to applications

RFID used in transportation, manufacturing, processing, logistics, and security and it is typically used in animal tagging, container tracking, road toll collection and postal tracking. It has advantage of working under adverse condition, reading is done without any human intervention, and reader can read more than one tag at a time and at speed.

If we use RFID at container terminals [35] (shown in figure 2) 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.

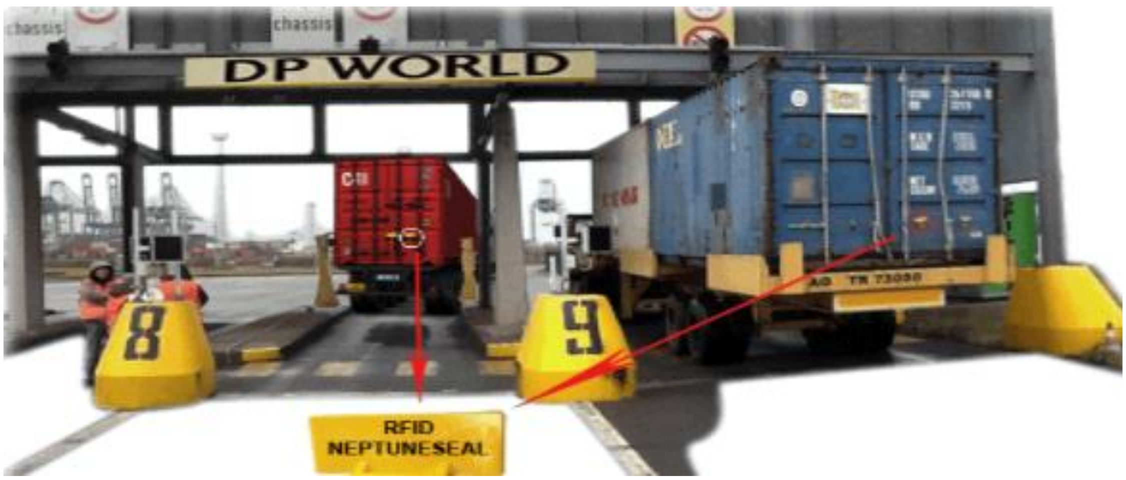

Fig. 2 RFID at container terminal [39]

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

Estimation of Expression for YC Cycle Time:

Evaluation of expression for cycle time
As discussed earlier in problem formulation to calculate the optimum value of block storage capacity, we have to find the expected value of time for the following operations-

- Receiving operation
- Loading operation
- Discharging operation
- Delivery operation

Where Receiving and Loading operation is used for outbound container block, Discharging, and Delivery operation for inbound container block.
To determine the expression of constraint in form of X and Y, we have to calculate the expected values in terms of X and Y. So, this section consist of number of expectance and formulas, but these formulas are depends upon the layout and configuration of the block.

Basic elements required for cycle time calculation

The parameters, which is required for estimation of cycle time are given below and the parameters of a bay and row of block are explained in the figure 3.2 and 3.3.

D_z^{xy} random variable of travel distance, for a movement of YC in which x, y, z are starting position, ending position and movement type respectively.

T_{zs}^{xy} random variable of handling time, for a movement of YC in which x, y, z and s are starting position, ending position, movement type and state of handling equipment (loaded or empty) respectively.

number of re-handles movement required by crane to pick up a random container from a bay with Y number of tier and Z number of rows, it is also a random variable.

d_z^{xy} D is replaced with d, in D_z^{xy}, when travel distance of a Yard Crane is constant instead of random variable.

YC basically perform three types of movements which are:

- Trolley movement
- Gantry movement
- Moving spreader up or down (i.e. lowering/Hoisting).

For performing any of the handling operations (i.e. loading, receiving, discharging, and delivery) YC performs number of movements. For example to receive a container YC perform number of movement in sequence which is shown in figure.A1.=

By property of expectance E[AB] = E[A]*E[B] if both A and B are independent from one another (Ross, 2010).

As discussed about loading operation, in case of discharging operation discharging of container occur consecutively until the no slot is available. Let u_{YZ} times the discharging operation is performed at same block bay, u_{YZ} is a constant value.

Cycle time for delivery operation includes the number of re-handling times and Kim (1997) provide a formula for estimating the expected number of re-handle per pickup (when all container retrieve from a block bay)

But in TKD container terminal the value of Z= 10, so the value of expression becomes,

So, expected re-handling time becomes

Derivation of expected values of various cycle time

As discussed above all the cycle time of operation depends upon number of handling movements, so to convert above expression in terms of X and Y we derive their expected values in terms of decision variable so that we can solve the problem by using optimization method.

For the sake of simplicity, we assume that

Let follows U(x,y) distribution (i.e. uniform distribution) (Ross, 2010) then,

= (x+y/2), in case of $x=g_c$ and $y= g_c+w_b$, where $w_b=(c_w+r_g)(Z-1)$ in our case Z=7, so the expression of is

Similarly for =(x+y/2), and $x=u_{max}$,$y=1.5+h_c$ where $u_{max}=1.5+ h_c(Y+1)$

If x and y are random position follows uniform distribution, then expected value of z=(x-y), which is distance between these two positions is expressed as

E[z]=(y-x)/3, where x= .5w_c and y= .5 w_c +(w_c+r_g)(X-1), so the expression of becomes

Based on Bozer and White (1984), the expected value of Tchebychev travel time is expressed as:

Mathematical Model for Optimal Travel Distance of Internal Truck:

As discussed earlier second part of this project is to optimize the container yard layout and for this, there is a need of understanding the container yard activities and operations. So that this section contains deep introduction about a container yard, problem formulation and their optimization.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] .

The model for optimizing the internal truck movement inside the container terminal yard layout are depends upon number of parameters. Notations for the parameters are given below:

TC_i - Total number of containers discharge from train (i)

T - Total number of trains standing at the terminal for unloading of containers

d_{ijk} - Distance between stack (k^{th}) of storage block (j^{th}) and standing train (i^{th})

V_{jk} - Number of vacancy of containers at stack (k^{th}) of storage block (j^{th}).

B - Total number of storage blocks in the yard of the terminal

S - Number of stacks in each block (assumed same in each block).

The value of T, B and S are known and fixed but to determine the value of TC_i and V_{jk} are one of the discussed problem at some of the container terminal yard. But at TKD container terminal value of these parameters are known to us because at TKD container terminal an advance technology i.e. GPS technology is used. Use of GPS technology is one more step towards automation of the terminal. Basically each gantry cranes are equipped with GPS technology which note the location of each container, number of containers discharge, number of container loaded and number of vacancies at each stack of the storage block. And, the value k are determined by the result obtained from first part of this project i.e. optimization of block size.

And, the decision variable in this model are number of containers transferred through internal truck because our objective is to optimize the movement of internal truck, which is basically depends upon total distance moved by the internal truck. And, total distance moved is increase as the distance associated with each container is increase and this depends on number of containers. So, to optimize the truck movement inside the container terminal requires optimum number of containers moved. The notation for decision variable is:

Y_{ijk} - Number of containers discharged from the train (i^{th}) and stored to stack (k^{th}) of block (j^{th}) of container terminal.

And, limits on Y_{ijk} are the constraints which are basically the value of decision variable is positive integer because the number of containers never become negative. And, other constraint for this model is basically supply and demand constraint. In supply constraint, the sum of values of decision variable over entire trains are equal to the number of vacancies of containers in stack (k) of storage block (j). Demand constraint of this model is basically the sum of values of decision variable over entire blocks and their entire stacks are equal to total number of containers discharge from train (i). These constraints are basically balanced the flow of containers.

And transportation model is applicable to TKD container terminal because the objective of this model is to minimize the total distance travelled by the internal truck inside container yard layout and decision variable are number of containers transferred to a specific location with same source point, so total distance travelled by truck between a source and a destination is sufficient to consider as objective.

Expression of problem formulation

Objective:

Minimize (distance travelled by internal truck):

Subjected to:

(1) (supply constraint)

For all j and k, where jϵ (1……B) and k ϵ (1……S)

(2) (demand constraint)

For all i, where iϵ (1……T)

…. (3) (non-negativity constraint)

For all i, j, and k.

Basically this model is generic in nature i.e. it can be used at any container terminal and for developing this model work of Chuqian Zhang et al. (2003) and Barnhart et al. (2006) have been referred, and modified as per TKD condition.

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:

It is basically named for solving simplex problem using C programming language [46] . This optimizer basically used as an optimization software for solving the problems related to linear programming, transportation problem, and assignment problem and sometime it is also used for quadratic problems. It involves some steps for optimizing the problems and these steps are:

- Creating model on the basis of problem formulation
- Creating data file by providing data
- Solving the created model
- Questioning result obtained

For creating the model for optimization of problem we used the CPLEX 12.6.1. It is a newest trial version. And, for creating the model we used the optimization programming language (OPL) and during creating model we convert the blocks in to number of stacks for ease of coding and created model's coding part is given below which include parameter definition, decision variable definition, objective function definition and constraints declaration.

3. RESULT AND ANALYSIS

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 = 620,
X (block length) = 39
Y (height of block) =4.

Outbound block
Block storage capacity = 850
X (block length) = 60
Y (height of block) =5.

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 = 16
X (block length) =2.5 and
Y (height of block) =1 (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 = 21

X (block length) =4

Y (height of block) =1.34.

Analysis
After getting the appropriate result from each model, there is a need of analyzing the result obtained from each model i.e. describing the significance of results in each model and this is done in following sections

Sensitivity Analysis of YC cycle time in optimal block size model
To check how value of objective function, which is total storage capacity of storage block is varied over the value of parameter, which is maximum cycle time available for YC to perform an operation on storage block we have done the sensitivity analysis.

Sensitivity Analysis of γ (outbound block)
Sensitivity analysis of γ is shown in table 1

Table 1: Result of analysis

Cycle time (min)	Storage capacity (no. of containers)
4	250
4.1	260
4.2	270
4.3	560
4.4	570
4.5	550
4.6	590
4.7	550
4.8	940

4.9	850
5	840
5.1	940
5.2	940
5.3	1170
5.4	1120
5.5	1120
5.6	1420
5.7	1120
5.8	1700
5.9	1400
6	1500

Sensitivity Analysis of β (inbound block)

Sensitivity analysis of β is shown in table 2

Table 2 : Result of Analysis

Cycle time (min)	Storage capacity (no. of containers)
6	560
6.1	860
6.2	560
6.3	560
6.4	660
6.5	560
6.6	560
6.7	560
6.8	560
6.9	688
7	609
7.1	651
7.2	693
7.3	735
7.4	756
7.5	798
7.6	840
7.7	840
7.8	840
7.9	940
8	840

Analysis of optimal block size model

Result obtained after each algorithm used in this model is not up to standards of TKD container terminal because of assumed value of constants used in the problem formulation of this model. But the significance of the result obtained from looping method is that if we storage containers in the blocks up to height three, length twenty nine and width seven, then size of block have become optimum so that truck waiting time and yard cycle time get reduce by significant amount and operations efficiency at TKD container terminal gets improve.

Analysis and validation of optimal truck travel distance model

As discussed earlier that the objective of this model is to minimize the total travel distance by internal truck during unloading of containers from trains to the stacks. To achieve this objective, we run the optimizer and get the result, which is up to standards of TKD container terminal.

The significance of getting the optimal truck travel distance equal to one hundred eight kilometer is that if we run internal truck in optimal way i.e. following the decision variable's path obtained from result, we get the optimal distance traveled by truck and reduce the traffic congestion at terminal up to some extent and also reduce transportation cost associated with container transfer within the terminal. And, all these findings tends to improvement in the operational efficiency of TKD container terminal.

For validation of result obtained from this model, we run the internal truck randomly with same value of parameters as in model we found the following result:

Total distance travelled by internal truck for unloading of containers = 130.145 Km

Validation shows that if we use the optimal way, then we can save lots of money which is used in transportation of containers within terminal with internal trucks.

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