An Optimization Strategy for Inter Terminal Transportation (ITT) of Containers: Case of Port of Colombo

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Abstract: Inter terminal container transportation (ITT) is a transferring process of containers between two more terminals. This research is related with inter terminal transport (ITT) operation of port of Colombo. The main objective of this research is to determine the optimum fleet size for ITT movements and secondly to identify possible cost savings of ITT in port of Colombo with the optimum fleet allocation to the existing operation. Inter terminal container transferring process was surveyed and the average truck turnaround time between each two terminals and the optimum fleet size was found under several assumptions. Further, by considering the current average number of ITT movements (or current maximum movements), the optimum fleet is determined. Allocating optimum fleet based on the volume of containers allow the minimization of the overall costs of ITT operation as the existing fleet requirement is well over the estimated fleet size.

Key words: Inter Terminal Transportation (ITT), Optimum Feet size, Container transfer time, and Container terminals

1. INTRODUCTION

Container shipping industry is identified as a prominent and rapidly growing cargo transporting mode in international trade. The governments around the world invest on making ports larger and deeper to keep up with the growth of containerized shipping mainly aided by increased ship size (Cullinane & Khanna, 2000). These ports contain multiple terminals which serve container vessels. Current trend is to use bigger ships by considering economies of scales and other technological factors. To use these bigger ships efficiently, the docking time at the port or else overall turnaround time must be as small as possible. This means that large amounts of containers must be loaded, unloaded, and transshipped in a short time span through efficient port operations.

To keep up higher productivity levels at ports, port operations which are connected and inter-dependence to each other, need to carry out smoothly. Inter terminal transportation (ITT) is one of such strategic operation at ports. ITT refers transferring containers between terminals when they need to be transshipped. That means some containers which discharge at a terminal need to be carried through a vessel which will berth at another terminal. Transferring those containers among terminals is referred as ITT. The ITT operation takes places via road, rail transportation or by using barges. Layout of terminals, connectivity among terminals, types and number of vehicles use for ITT, scheduling those vehicles can be identified as some of critical parameters and decisions that port planners have to make and ports should consist with, which are affected for smooth ITT operations. Overall objective of efficient and smooth ITT system is to transport containers between terminals on time while minimizing delays. As charges for delaying outgoings are usually high at ports, rivalry ports with high technical capabilities with automated equipment for their operation including ITT would get the competitive edge. Although the efficiency and the productivity levels of those ports' operations are high, the investment cost for that hi-tech equipment is also extremely high. Operations such as ITT could use as alternate along with the proper planning of existing resources to achieve higher productivity levels.

2. RESEARCH OBJECTIVES

The main objective of this research is to find out the optimum fleet of ITT trucks operating in a road network inside a port based on distance and travel time as a parameter. A simple model was developed to determine optimum fleet size under different criteria. The model demonstrates a systematic approach to have an efficient and reliable inter terminal container transfers. The main argument is the model provides a solution to the transfer (transport) operator to determine fleet size when the container transferring volumes among terminals are uncertain. If the optimum fleet size can be determined by considering number of transfers, it is advantageous for both terminal operator and container transfer operator and the shipping line. Determining the optimum fleet is also important for the fuel economy, to reduce traffic congestions and to reduce extra costs including cost of shut out containers. In this paper, optimum fleet size for a fleet of container transferring vehicles is determined and the same will be compared with the fleet size of the existing container transfer system of a selected port.

3. LITERATURE REVIEW

There are several scholarly works mainly on inter terminal transportation based on road freight transportation, traffic engineering, barges movements and container handling models. They mainly falls into simulation studies, modeling and measuring inter terminal transfer of containers by incorporating volume, and time and space. Ottjes, Duinkerken, Evers, and Dekker (1996) presented robotized inter terminal transport of containers system by demonstrating Port of Rotterdam. The study showed that automated vehicles as well as multi trailer systems can be used for inter terminal trucking. The main performance indicator used in the model is the percentage of containers which arrives at the ITT destination late. The study also showed that robotized ITT with single container carriers has advantages compared with manned ITT using the multi trailer system. This difference is attributable to the batch effects introduced by the MTS system and to the complexity of handling at the rail terminals. The automated guided vehicle system appears to give the lowest total system costs.

Vis and De Koster (2003) provided a classification of the decision problems that arise at container terminals. Solutions proposed in this study is similar to Ottjes et al. (1996), which had multi-trailer systems, automated guided vehicles and train systems including usage of them. To utilize big ships efficiently, larger amounts of containers need to be loaded, unloaded, and transshipped in a short time span, with a minimum use of expensive equipment. Problems encountered while continuing these operations are evaluated through this research. The study concludes that in ports with low labor costs, the system of manned vehicles is preferable. Further shorter trucks' service time is feasible but that this leads to an increase of traffic conflicts in the internal transport network.

Janic (2007) developed a model for calculating comparable combined internal and external costs of intermodal and road freight transport networks. Internal costs consist of the operational-private costs borne by the transport and intermodal terminal operators, and the time costs of goods tied in transit. The internal cost of each component embraces the cost of ownership, insurance, repair and maintenance, labor, energy, taxes, and tolls/fees paid for using the network. But internal costs directly associated with the particulars of a consignment, such as depreciation, maintenance, repair, and insurance costs, are not included because they are assumed to be borne by shippers or recipients. The external costs include the costs of the impacts of both networks on society and the environment such as local and global air pollution, congestion, noise pollution, and traffic accidents. In analysis of the full costs of a given intermodal and equivalent road transport network requires an understanding of the network size, of the intensity of operations, of the technology in use, and of the internal and external costs of individual components of the system. For the intermodal transport network, the average full costs decrease at a decreasing rate as the quantity of loads rises indicating economies of scale. The study shows that minimizing internal costs, that is the transport operation related costs lead to higher return for the operator.

Tierney, Voß, and Stahlbock (2014) presented a model for ITT while proving it using dataset from Maasvlakte 1 & 2 area of the Port of Rotterdam and Port of Hamburg. This model showed through graphs such as base graph, time - space graph while considering on terminal nodes, intersection nodes and long-term nodes to build up formulas. This model assists ports in analyzing the impact of new infrastructure, the placement of terminals, and ITT vehicle investments while the model is general enough to model several important real-world aspects such as traffic congestion, penalizing late container delivery, multiple ITT transportation modes, and port infrastructure modifications. This model of ITT incorporates optimization of vehicle routes and container flows to provide ports and terminals with the best performance a configuration of vehicles and infrastructure can deliver. The model represents a particularly difficult class of time-space models, in which interacting vehicle flows, a multi-commodity flow, and congestion constraints all interact. The correct choice of the layout of terminals and the transportation connections between them, as well as vehicle type and the number of vehicles, represent expensive and critical decisions that ports must make. The goal of an efficient ITT system is to minimize the delay of containers moving between terminals, so as to reduce the delayed departure of containers. Traffic congestion is a key issue facing many ITT systems, as they often utilize roadways open to general traffic. Modeling the basic effects of congestion is an important component of this model.

Analytical models that are used in this nature of research most often are mathematical programming models, branch and bound models, queuing models, network models and assignment problems while using simulation models also. However, their applicability is limited given the dynamic nature of the terminal handling industry and process. This paper presents a more simplified operational model with certain operational gains mainly specific to time and distance based costs.

4. THE CASE: ITT OPERATION IN PORT OF COLOMBO

ITT operation in Port of Colombo is undertaken through a third part company namely Colombo Logistics (Pvt) Ltd. ITT operation between three container terminals namely Jaya Container Terminal (JCT), South Asia Gateway Terminal (SAGT) and Colombo International Container Terminal (CICT) is carried out. The firm usually allocates around 80 prime movers for ITT by considering the priorities and the requirements of each terminal. Overall coordination and managing process of ITT is done by Colombo Inter Terminal Office (CITO). Trucks are running between terminals almost whole the hours in a day to fulfill ITT operations. Shipping agents who determine the routes and schedules of containers pay for the terminals to fulfill ITT operations. Each terminal have separate yard spaces to stack ITT containers and the terminal operators are responsible to pay for Colombo Logistics (Pvt) Ltd after fulfilling those operations. Table 1 presents inter terminal container transferring cost per day according to estimated average container transfer amount per day.

Table 1: Inter terminal container transferring volumes and cost

Between	Average transfer amount per day	1 TEU transferring cost LKR	Total LKR. per day
JCT to SAGT	350	Rs. 1,258.00	Rs. 440,354.70
SAGT to JCT	295		Rs. 370,945.91
JCT to CICT	652	Rs. 1,535.00	Rs. 1,001,153.70
CICT to JCT	736		Rs. 1,130,293.91
SAGT to CICT	713	Rs. 1,140.00	Rs. 812,642.02
CICT to SAGT	337		Rs. 383,882.61
Total	**3083**		**Rs. 4,139,272.84**

Sources : SLPA documents on ITT expenditure and documents of Colombo Logistics Pvt

Figure 1 and Figure 2 below show ITT expenditure in LKR millions per day from JCT to SAGT and CICT for a period (2015/Oct/16-31, 2015/Nov/16-30). Expenditure LKR amount is changing over time with respect to the number of transfers.

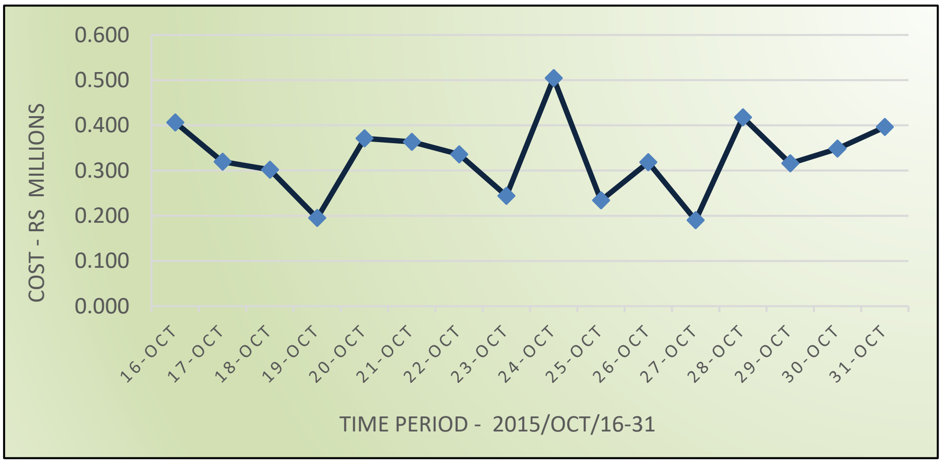


Figure 1 : JCT - SAGT: Expenditure for ITT *(2015/Oct/16-31)*

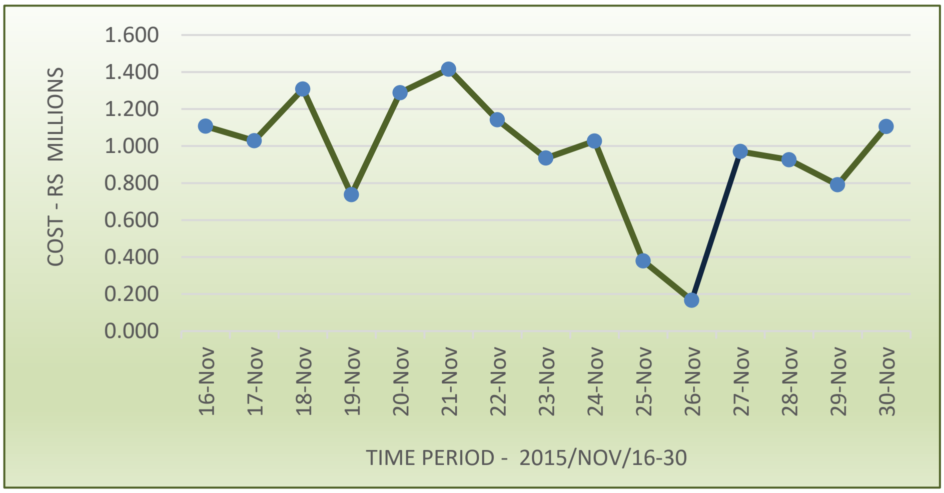


Figure 2 : JCT - CICT: Expenditure for ITT (2015/Nov/16-30)

Before discharging containers from a vessel, yard planning process is carried out to determine the stacking position of containers at the yard. ITT containers are also transferred through terminal tractors as usual and are stacked separate ITT stacking location at the yard (X,Y lanes) until they are transferred for the other relate terminal through trucks of Colombo logistics. At JCT, there are two separate gates as ITT in and out. There are officers at each gate from SLPA, Colombo logistics, security office in order to control ITT transfers. There is also a separate officer in the equipment control unit to monitor and control ITT flowing by coordinating operations at the yard as well as already prepared plans. There is another officer from Colombo logistics to coordinate ITT container picking order at the yard premises. In SAGT and CICT, there are no separate gates for ITT. Instead of that sensor detecting technologies are used at the gates which is somewhat efficient than manual method at JCT.

The ITT containers that need to be transferred immediately are called as hot connections which are prioritized in the ITT operations. The containers which have sufficient time to transfer for the other terminal are called as normal connections. Whole the ITT containers should be transferred before the cut-off time. Otherwise containers become shut out and shipping lines are required to declare such containers to the next available on-carrier which incur extra costs. Thus, inter terminal transportation can be identified as one of a key operation which need to organize well especially after expansions happens in port of Colombo.

Table 2: Estimated ITT volumes in 2015

Container transfers between	Estimated ITT Volume in 2015
JCT to SAGT	103,353
SAGT to JCT	86,987
JCT to CICT	192,839
CICT to JCT	217,223
SAGT to CICT	210,289
CICT to SAGT	99,338
Total	910,028

Source: Documents of Colombo Logistics Pvt

Table 2 denotes estimated ITT volume in 2015. By those tables each container types handled belong to each container terminal can be compared with ITT volumes.

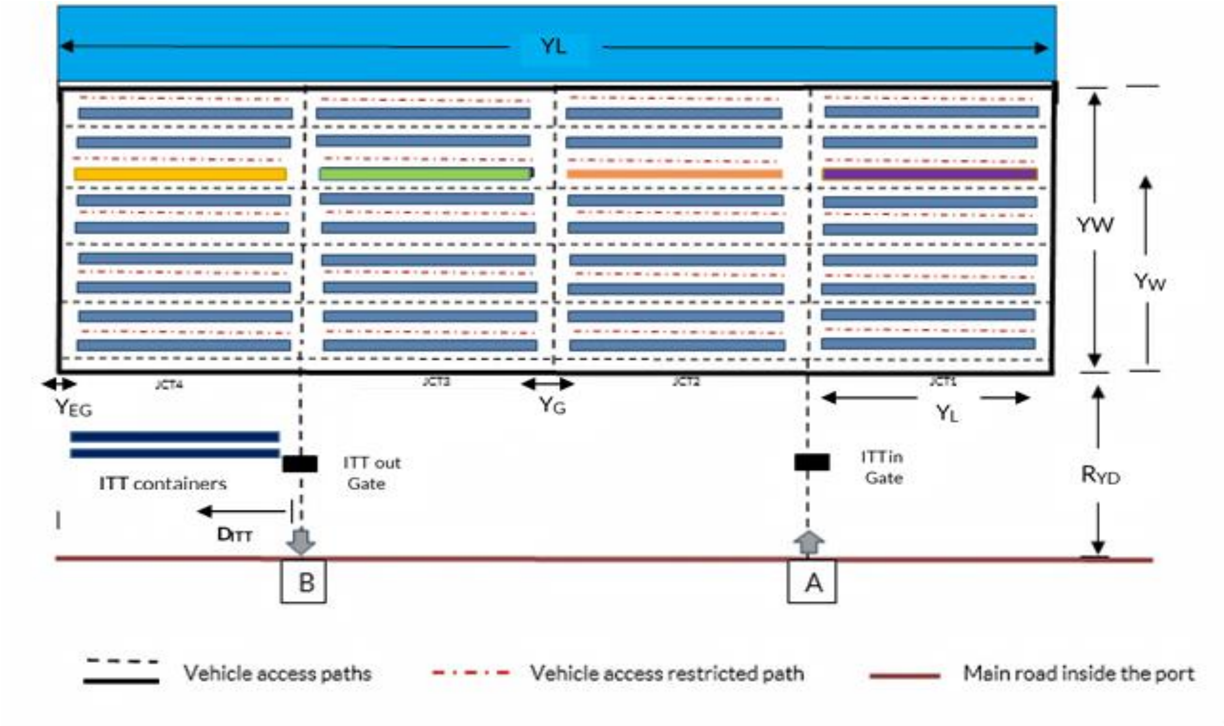
5. RESEARCH PROBLEM IDENTIFICATION

Inter terminal transportation proportion with respect to other vehicle flows prevails at a higher level within the route network in the Colombo port premises. Currently this service at the port of Colombo is carried out almost all hours in the day to transfer related containers among the four terminals. Transferring container volumes among terminals are varying overtime. Because shipping agents plan container routes with their experience to meet the customer requirement. As an example, pre-planned container to load to a vessel which berth in a particular terminal may change by a prompt decision to load for another vessel which berth in another terminal. If that container was already stacked in the previous terminal, that container has to be transferred to the new terminal. Like-wise there are so many incidents that directly affect for uncertainty of ITT transferring volumes. Some containers cannot be transferred on time due to uncertainty and escalation of transferring volumes which are called as ‘shutout containers’. Those containers should be retained in the origin terminal until plan for another vessel, which burden a huge recovery cost for terminals and shipping agents. Another fact is that ITT trucks on the road network inside the Port of Colombo affect the other vehicle flows including import and export container trucks. Thus, number of ITT trucks usage for each time is depending on several factors. This all means that the uncertainty of transferring container volumes among terminals, high shutout containers and traffic impact of ITT trucks on other vehicle flows is the problem based for this research paper.

6. RESEARCH METHODOLOGY

The methodology used in the research involves a distance based ITT container truck movement plan in yard and the total distance between two terminals. The hypothetical container yard layout was used to determine the required distances that ITT truck virtually move. Distances within the terminal are shown in Figure 3.

Figure 3: ITT container truck moving distance in yard.



Formula for transferring distance of an ITT container inside the yard;

$$D = \sum_{i=1}^{n} R_{YDi} + 2Y_W + \sum Y_{Li} + \sum Y_{Gi} + \sum Y_{EGi} + 2D_{ITT} \qquad (1)$$

$$Y_W < YW, \qquad Y_L < YL, \; Y_{Gi} < Y_L$$

R_{YD} = Distance between main road and yard,

YW = Yard width (Y_{w} - variable),

YL = Yard length. (Y_L - variable),

Y_G = Yard gap length,

Y_{EG} = Yard edge gap length.

D_{ITT} = Length of ITT yard.

Further the distance between the terminals participating in ITT operation can be obtained using google maps.

Transportation related transfer time between each two terminals.

Based on the average distances between each terminal, average speeds of a fully loaded container truck can be estimated. This estimation identifies circular ITT process as two linear processes.

$$Transfer\ time: Distance\ /\ Time\ =\ Speed \quad (2)$$

Estimating truck turnaround time

The following equation was used to calculate average transfer time.

$$\begin{aligned} &Average\ total\ transfer\ time \\ &\quad = Truck\ moving\ time\ +\ container\ handling\ time\ (loading\ +\ unloading) \\ &\quad +\ Waiting\ times\ (at\ gates, until\ transfer\ crane\ approach, congestion) \quad (3) \end{aligned}$$

Estimating fleet sizes

Based on the truck turnaround time data, ITT container transferring volume analysis, fleet size calculation was carried out using the following equation.

$$\begin{aligned} &Total\ Number\ of\ full\ trips \\ &\quad = Max\ (Number\ of\ trips\ by\ a\ 40'Size\ truck;\ forward\ trip\ , return\ trip) \\ &Fleet\ size\ (40'\ size\ container\ trucks) \\ &\quad = (Total\ Number\ of\ trips\ /\ Time\ constraint) *\ Truck\ turn\ around\ time \quad (4) \end{aligned}$$

Analyzing other affecting facts for fleet sizes

The research envisaged that there are also other factors such as road traffic condition affecting the transfer rate. A factor can be adopted based on the traffic theory based parameters that include Passenger Car Unit (PCU) calculation, traffic capacity study in the road network of the port and maximum service flow calculation. The equations used are shown below.

$f_{HV} = 1 / (1+P_T(E_T -1)+P_M(E_M -1))$ - *level grades*

Maximum Service Flow (MSFi) = $7600 * (V/C)_i * f_d * f_w * f_{HV}$

This equation determines the service level of a road.

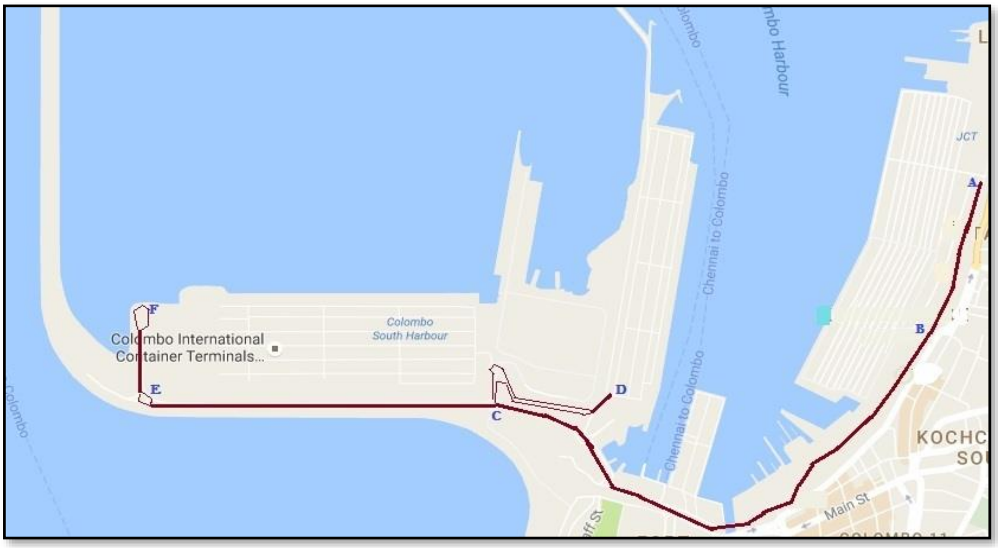
Other factors

Other factors that have potential impact include the number of vessel divert from other terminals to a terminal and the volume of ITT containers stored in the yards which are to be transferred.

6.1 Data Collection

The paper used data collected from Port of Colombo to empirically test the developed model with regard to achieve optimal vehicle fleet for ITT transfer. Primary data on ITT were collected from traffic surveys conducted at respective container terminals. The distances among terminals were obtained from google road map of Port of Colombo (Figure 4).

Figure 4: JCT - SAGT - CICT ITT Transport Layout: Distances between terminals



Distances:

A-B = 850m,

B-C = 2300m,

C-D = 850m,

C-E = 1400m,

E-F = 500m.

The data collection locations and the respective data and the data use are presented below.

a. Colombo Logistic company data - ITT container volume, among the terminals in Port of Colombo from 27th Sep 2015 - 23th March 2016. The purpose of analysis is to determine average, minimum, and maximum transfers to use for fleet size calculations.

b. ITT balances (JCT) - Number of ITT containers available at JCT yard at a particular time periods which will be transported to SAGT and CICT terminals. These data are categorized as loading vessel wise and data available from 2016/01/30 - 2016/02/11. The purpose of this analysis is to identify yard utilization of ITT containers (analysis of factors affecting for ITT).

c. Secondary data were collected through various industry reports and articles. The data collected include;

- Total number of vessels diverted to CICT & SAGT from JCT - 2015
- Expenditure of ITT - 2015/10, 2015/11
- Container throughput of port of Colombo - 2015,
- Other secondary data (eg:- yard widths/lengths, road distances)
  The purpose of analysis is to identify external factors affecting for ITT, derive statistics related with ITT and for calculations.

d. Vehicle counting survey was conducted to gather ITT container trucks and other vehicle movement in number on the road network inside of the port. The purpose of the analysis is to identify inter-relationship and the effect of ITT trucks to rest of the vehicles flows and vice versa.
The model is also based on pre-determined assumption. They are;

- Whole the Trucks that use for ITT are longer trucks that can transfer two 20' containers or one 40' (45') container at once.
- Circular ITT process has been identified as few linear processes.

- Two 20’ containers that carry through a single truck unload at nearer points at the yard.
- A single (particular) truck move in between two terminals only (for considering time period).
- Considering ITT among JCT, SAGT and CICT only.(without UCT)
- Considering Zero idle time and on time ITT trucks available situation. (No ITT truck queues or lacks)
- Whole the time available (eg :- 12 hours for day period) use for the operations.

7. DATA ANALYSIS AND RESULTS

7.1 Transfer time between Terminals - JCT and SAGT

Based on the road distances between the two terminals – JCT and SAGT, using equation (2), the transfer time between each terminal were estimated. The distances and the estimated time are presented in Table 3.

Table 3: Transfer time between terminals (excluding transfer time within the yard)

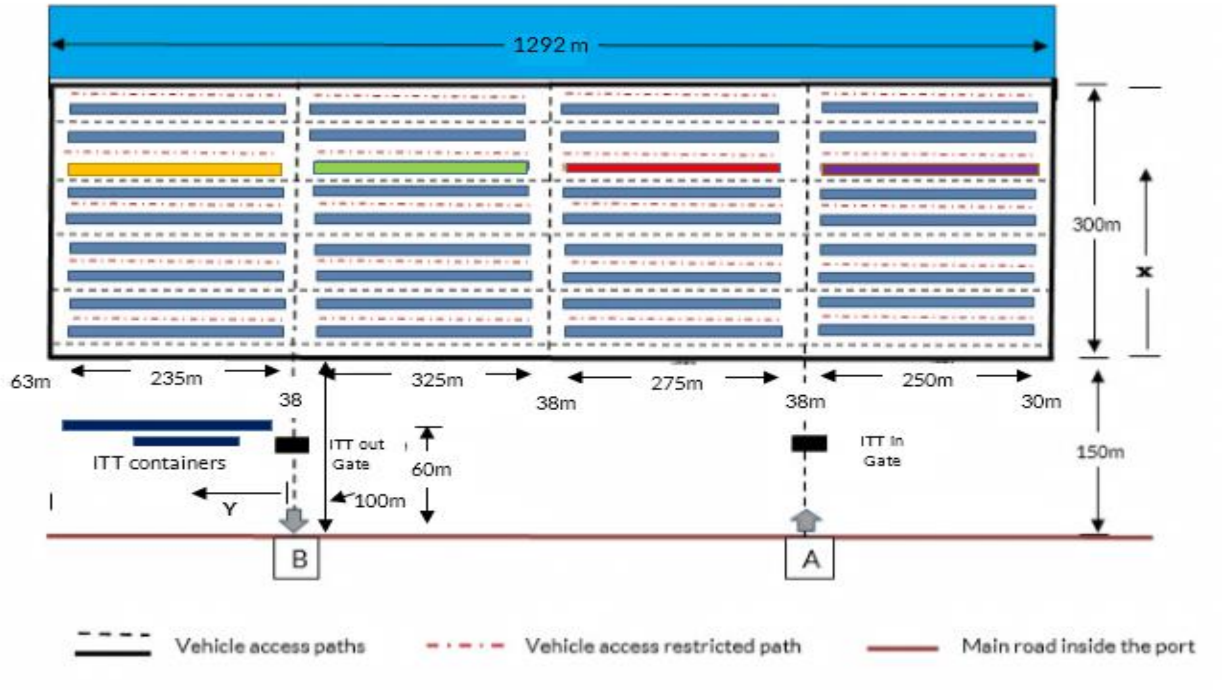
Terminal pair	Distance (m)	Transfer Time*(minutes)
JCT out gate to SAGT	3150	10.5
SAGT to JCT in gate	4000	13.33
CICT to SAGT (SAGT to CICT)	2250	7.5
JCT out gate to CICT	3700	12.33
CICT to JCT in gate	4550	15.17

**The observed speed of a full loaded container truck* = $12.192m / 1.75s = 6.967\ ms^{-1} = 25kmh^{-1}$ *and the estimated average speed of a full loaded container truck* = $5\ ms^{-1}$

7.2 Transfer time within terminals

Inside terminal yard, transferring distances of ITT container and therefore the transfer time are different as receiving containers’ planned positions in the yard are different. For instance, in Figure 5, if a particular container’s planned location is purple color bay of JCT1 yard, the container truck which access from ITT in gate should be moved towards purple color bay from the right side of the JCT1 yard. After unloading happens, that truck should move towards ITT container stacking yard location. Then after loading happens, it should move towards related terminal via ITT out gate. If the receiving container’s unloading point is yellow color bay in the JCT4 yard, transferring distance of the truck inside the yard is different from the previous incident’s distance. X and Y are the main distance based variables for ITT container trucks that move in JCT yard. Value X is less than 300m and value Y is less 265m.

Figure 53 : ITT container truck moving distance in JCT yard



Transferring distances inside the yard from point A to ITT container picking position (if planned position of the container is the purple color bay) based on equation (1) is

$(d_1) = 150 + 19 + 250 + 5 + X + 5 + 250 + 19 + X + 19 + 275 + 38 + 325 + 19 + Y + 40$

$$= 2X + Y + 1414$$

If planned position is the red color bay;

$(d_2) = 150 + X + 19 + 275 + 19 + X + 19 + 325 + 19 + Y + 40$

$$= 2X + Y + 866$$

If planned position is the green color bay;

$(d_3) = 150 + 19 + 275 + 19 + X + 19 + 325 + 19 + X + Y + 40$

$$= 2X + Y + 866$$

If planned position is the yellow color bay;

$(d_4) = 150 + 19 + 275 + 38 + 325 + 19 + X + 19 + 235 + 5 + X + 5 + 235 + Y + 40$

$$= 2X + Y + 1365$$

Then the average distance (da) can be obtained by taking the average distance of all possible locations.

Average distance $(da) \;=\; (d_1 + d_2 + d_3 + d_4) / 4$

$$(da) = (8X + 4Y + 4511) / 4 = 2X + Y + 1127.75 \ meters$$

Transferring distances from ITT container picking position to the point B:

$$d_0 = Y + 60 \ meters$$

$$X > 2, \quad X < 270, \quad Y < 265, \quad 19 < Y$$

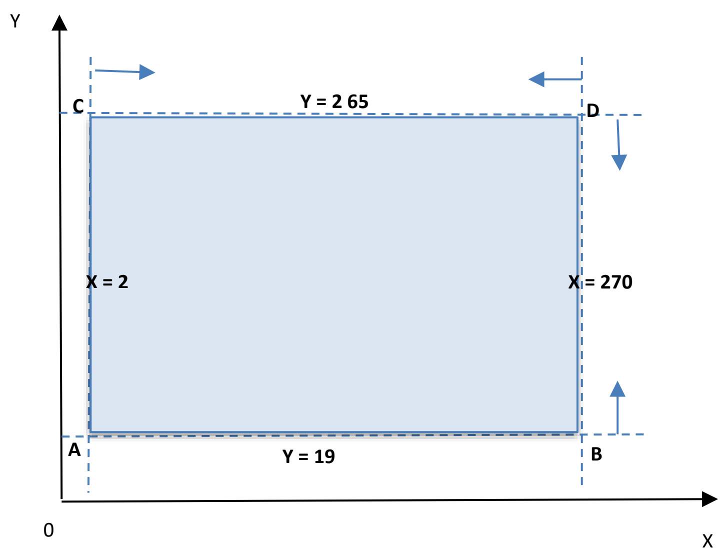
Note: The number of ITT containers that unload in each four yards in JCT within a unit time period varies. However, Colombo Logistics Company charges a fix rate even though transferring distance and transferring time inside the yard is varied. Considering on average distance can be generalized in that manner. However, the variance with the average distance value will be considered as a parameter under ITT container, full transferring time formula. The distances finding in JCT yard are obtained from Google map, published documents and reports and estimates (the length of each yards according to container stacking length). Maximum and minimum transferring distances inside the yard from point A to ITT container picking position (Figure 6 shows the objective function).

$\boldsymbol{f}_{(x,y)} = 2X + Y + 1127.75$, constraints :- $X > 2, X < 270, Y < 265, 19 < Y$

$$Max\ Z = 2X + Y + 1127.75$$

$$Subjected\ to: \ X > 2, \ X < 270, \ Y < 265, 19 < Y$$

Figure 6: Chart of objective function.



$A = (2, 19)$

$B = (270, 19)$

$C = (2, 265)$

$D = (270, 265)$

From point A to ITT container picking position can be estimated as;

$$Maximum\ distance\ =\ 2(270)\ +\ 265\ +\ 1127.75\ =\ 1932.75m$$

$$Minimum\ distance\ =\ 2(2)+\ 19\ +\ 1127.75\ =\ 1150.75m$$

Note: - ITT containers are transferred that belong to the ships that berth in adjacent days. JCT yard's container stacking has been arranged as service wise. Container stacking lanes in the land side are allocated for import and feeder line containers. Then potential transferring distance proportion of ITT containers is near to the maximum value.

Estimated average distance from point A to ITT container picking position;

$$da = (1932.75 * 5\ +\ 1150.75 * 1)\ /\ 6\ =\ 1800m$$

Estimated speed of a full loaded container truck inside the yard= 3 ms^{-1} $(10.8kmh^{-1})$

Estimated possible transferring time from point A to ITT container picking position;

$$1800m\ /\ 3\ ms^{-1} =\ 10\ min$$

Transferring distances from ITT container picking position to point $B\ =\ Y\ +\ 60$

$$19\ <\ Y\ <\ 265 \qquad rating\ (2:1)$$

$$(265 * 2\ +\ 19 * 1)\ /\ 3\ \approx\ 180$$

Estimated distance from ITT container picking position to point B is

$$180\ +\ 60\ =\ 240\ m$$

Estimated transferring time from ITT container picking position to point B is

$$240m\ /\ 3\ ms^{-1}\ =\ 1.34\ min$$

7.3 SAGT yard related calculations.

Assume point "w" - middle point of ITT stacks as the ITT container loading point. Transferring distances (as shown by Figure 9) inside the yard from access gate to ITT container picking position (after unloading the receiving container):

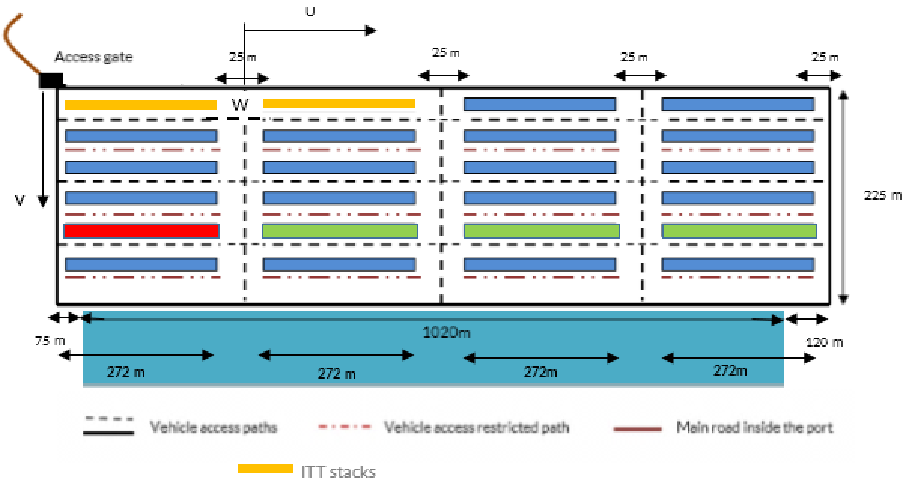
If unloading position any of a green color bay $(d_1)\ =\ 25\ +\ 272\ +\ 12.5\ +\ V\ +\ U\ +\ V\ +\ U$

$$=\ 2U\ +\ 2V\ +\ 309.5$$

If unloading position red color bay $(d_2) =\ 25 +\ V\ + 272 + 12.5 +\ V$

$$=\ 2V\ +\ 309.5$$

Figure 7: ITT container truck moving distance in SAGT yard.



Average distance = $(3(2U + 2V + 309.5) + 2V + 309.5) / 4 = (6U + 8V + 1238) / 4$

$$= 1.5U + 2V + 309.5$$

$$U < 885, \quad 2 < V < 200$$

$$Maximum\ distance = 1.5 * 885 + 2 * 200 + 309.5 = 2037m$$

$$Minimum\ distance = 2 * 2 + 309.5 = 313.5m$$

Note :- Bays of the opposite of the berth near to the access gate are used to stack ITT containers that need to be transferred for other terminals and import containers. The estimated average distance from access gate to ITT container picking position is;

$$rating\ (6:4) : - (2037 * 6 + 313.5 * 4) / 10 = 1347.6$$

The estimated speed of a full loaded container truck inside the yard is $3\ ms^{-1}$ $(10.8kmh^{-1})$. Based on equation (2); Estimated possible transferring time from access gate to ITT container picking position is ($1347.6m$ / $3\ ms^{-1}$ =) $7.49\ min$.

Transferring distances from ITT container picking position to access gate = $25 + 272.5 + 12.5 = 309.5m$. Estimated transferring time from ITT container picking position to access gate is therefore ($309.5m$ / $3\ ms^{-1}$ =) $1.72\ min$.

7.4 JCT to SAGT: total truck turnaround time calculation

ITT container transferring takes place in a circular process between JCT and SAGT and can be identified as two linear processes as follows.

a) Container picking from ITT container stacking point of JCT up to approaching the truck towards ITT container picking point of SAGT.
b) Container picking from ITT container stacking point of SAGT up to approaching the truck towards ITT container picking point of JCT.

These two approaches and related calculations are presented below as Process 1 and 2.

Process 1:

Estimated transferring time from ITT container picking position of JCT to point B (up to the main road)

$$240m\ /\ 3\ ms^{-1}\ =\ 1.34\ min$$

Estimated transferring time from JCT out gate to SAGT main gate

$$3150m\ /\ 5\ ms^{-1}\ =\ 452.13s\ =\ 10.5\ min$$

Estimated possible transferring time from access gate of SAGT to ITT container picking position (after unloading the carrying container)

$$1347.6m\ /\ 3\ ms^{-1}\ =\ 7.49\ min$$

Average truck movement related total transferring time:- $19.35\ min$

Average total transferring time = Truck moving time gate + container handling time (loading + unloading) + Waiting times (at gates, until transfer crane approach, congestion)

$$=\ 19.35\ min\ +\ 2\ min\ +\ 3\ min$$

$$=\ 24.35\ min$$

Process 2:

Estimated transferring time from ITT container picking position of SAGT to main gate

$$309.5m\ /\ 3\ ms^{-1}\ =\ 1.72\ min$$

Estimated transferring time from SAGT to JCT in gate

$$4000\text{m} / 5\ \text{ms}^{-1}\ =\ 574.135s\ =\ 13.33\ min$$

Estimated possible transferring time from JCT in gate to ITT container picking position (after unloading the carrying container)

$$1800m\ /\ 3\ ms^{-1}\ =\ 10\ min$$

Average truck movement related total transferring time:- $25\ min$

Average total transferring time = Truck moving time gate + container handling time (loading + unloading) + Waiting times (at gates, until transfer crane approach, congestion)

$$=\ 25\ min\ +\ 2\ min\ +\ 3\ min$$

$$=\ 30\ min$$

In summation, the truck turnaround time between JCT and SAGT is ($30min$+$24.35min$) $54.35\ min$. Following the same calculation procedures, the transfer time between CICT and SAGT and JCT and CICT can also be calculated. The calculated truck turnaround time (transfer time) between each terminal are presented in Table 4.

Table 4: Truck turnaround time between all terminal pairs

Terminal pair	Truck Turnaround time (m)
JCT ←→ SAGT	54.35
CICT ←→ SAGT	48.27
JCT ←→ CICT	62.9

7.5 Fleet size calculations

Next step is the fleet size calculation pertinent to each terminal pair based on the container volume to be transferred between each terminal pair. There were several assumptions were laid to calculate the optimum fleet size. They are;

- Whole the Trucks that use for ITT are longer trucks that can transfer two 20' containers or one 40' container at once.
- Circular ITT process has been identified as few linear processes.
- Two 20' containers that carry through a single truck unload at nearer points at the yard.
- A single (particular) truck move in between two terminals only (for considering time period).
- Considered ITT among JCT, SAGT and CICT only.
- Considered Zero idle time and on time ITT trucks available situation. (No ITT container queues or lacks).

Table 5 and 6 presents number of trips by a 40' size truck day and night respectively (With respect to average number of Container transfers from 27th Sep 2015 – to 23th March between each terminal pair, the number of trips by a 40' size truck is obtained by the following equation.;

Table 2: Number of trips by a 40' truck (Day)

Day	Between	TEUs	Number of trips by a 40' Size truck
	JCT to SAGT	194	97
	SAGT to JCT	132	66
	JCT to CICT	322	161
	CICT to JCT	399	200
	SAGT to CICT	332	166
	CICT to SAGT	145	73

Table 6: Number of trips by a 40' truck (Night)

Night	Between	TEUs	Number of trips by a 40' Size truck
	JCT to SAGT	156	78
	SAGT to JCT	163	82
	JCT to CICT	330	165
	CICT to JCT	337	169
	SAGT to CICT	380	190
	CICT to SAGT	192	96

$$Number\ of\ trips\ by\ a\ 40'size\ truck\ =\ roundup\ ((TEU\ amount)\ /\ 2))$$

Based on Equation 4, fleet size was estimate for each terminal pair. The results are shown in Table 7 for day, night and total for the day respectively.

Table 7: Fleet size required for day operation

		Day, 12 hours		Night, 12 hours		Total, 24 hours	
Transfers among	**Truck Turnaround time**	**Avg. TEUs**	**Fleet size (40'' size container trucks)**	**Avg. TEUs**	**Fleet size (40'' size container trucks)**	**Avg. TEUs**	**Fleet size (40'' size container trucks)**
JCT to SAGT	54.35	194	8	156	7	350	7
SAGT to JCT		132		163		295	
JCT to CICT	62.9	322	18	330	15	652	17
CICT to JCT		399		337		736	
SAGT to CICT	48.27	332	12	380	13	713	12
CICT to SAGT		145		192		337	
Avg Total		1525	38	1558	35	3083	36
Max Total		1945	51	2066	64	4011	56
Min Total		852	30	743	23	1595	27

After calculating average TEU amounts for day, night and total wise; the number of trips for a 40' size truck was calculated. Then numbers of trips between each two terminals were calculated considering the maximum number of trips by a 40' Size truck. Then fleet size was calculated by using total number of full trips, time constraint and truck turnaround time. Also the maximum and minimum fleet numbers were calculated by using container transferring volume data of truck Service Company.

Table 8: Simulated movement of TEUs and truck against the actual movements

Transfers among	**Truck Turnaround time**	**Estimated TEU movements**			**Actual operations on selected dates**			
		Avg TEUs Day	**Avg TEUs Night**	**Avg TEUs total**	**2/21/2016 Day**	**1/31/2016 Night**	**12/13/2015 Night**	**12/13/2015 Night**
JCT to SAGT	54.35	194	156	350	176	396	188	322
SAGT to JCT		132	163	295	198	64	279	106
JCT to CICT	62.9	322	330	652	356	223	298	167
CICT to JCT		399	337	736	338	554	331	682
SAGT to CICT	48.27	332	380	713	439	378	594	601
CICT to SAGT		145	192	337	185	70	46	188
Total		1525	1558	3083	1692	1685	1736	2066
Optimum Fleet size (40')		**38**	**35**	**36**	**46**	**62**	**54**	**75**
Trucks for existing system (40')					*90*	*82*	*81*	*76*
Excess Trucks for existing system (40') - Optimum Fleet size (40')					**44**	**20**	**27**	**1**

Above Table 8 presents the optimum fleet of 40' size container trucks with respect to 10 hour time constraint assuming the actual scenario. Average values (TEUs) related with transfer amount comparison of whole period of the research. Trucks deployed by Colombo Logistics (Pvt) Ltd are converted as 40' size truck amounts. Those trucks amount cannot be considered as full time operating throughout 10 hours. That means within 10 hours every trucks have been deployed at least once a time. However, it can be seen that there is a significance difference between trucks deploying of existing system and optimum fleet size derived from the model, that the existing fleet is higher than the optimum fleet. Therefore, it is important to deploy optimum fleet of truck in order to reduce extra costs incur due to assigning a truck and, in aggregate, the other effects of high number of trucks movement within the port.

8. CONCLUSION AND RECOMMENDATIONS

Trucks deploying after determining the exact fleet size based on the demand level for each time period (day) is important. If there are more trucks than the requirement, it may affect the traffic condition in the main route network within the port and generate high level of negative externalities and high cost of operation. Furthermore trucks may be waiting near ITT container loading points while the number of trips for each single truck may be lower, which indirectly affect to reduce truck divers' income. On the contrary on time operation would be interrupted, if there are lesser trucks than the requirement for inter terminal transferring operation. Thus, there may be remaining containers which cannot be transferred on time to vessels. Then shipping agents of those containers have to re-plan those containers for another vessel which containing a processes with extra costs. Therefore, deploying optimum fleet of trucks for ITT operation is important for all stakeholders participating in it, port authority, shipping agent, shipping company, terminal operator and the cargo owner. Based on the data obtained from Colombo Logistics Pvt Ltd on ITT operation, which simply deploys trucks for ITT operation by their experience, this paper derived an optimal number of trucks required for daily operation. Drawback of existing truck allocation system can be reduced while maintaining a smooth ITT operation if a mathematical model is used. Analysis results showed that the existing fleet allocation is random and it has led to excess capacity of trucks in ITT operation. Findings of this paper are important as mathematical model is able to determine fleet size for ITT operation in Port of Colombo. However, this research has some limitations. The mathematical model is based on certain assumptions and thus the model is not dynamic. Even thought by developing the mathematical model towards the practical scenario, more reasonable and practical optimum solution (fleet size) can be derived.

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