An Empirical Research on Supply Chain Performance Evaluation of Material Handling Systems in Port Operation

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Abstract

Material handling system plays an important role in the efficient operation of port logistics. Scope of this research is container movement from quayside to yard side in port. The equipments involved in the container handling operation are Mobile Harbour Cranes, Reach Stacker Cranes (RSC), Hippo Trailers, and Rubber Tyre Granty (RTG) Cranes. The problems faced in the container handling operation at port are: poor utilization of RTG cranes. The reasons are: 75% RTG cranes have crossed their life span with very high cycle time, insufficient knowledge of the crane operators and non-availability of specific maintenance policy of the cranes. This research suggests some modifications in the present practice to solve the above difficulties through assessment of RTG utilization by work sampling method, determination of the yard capacity based upon different types of handling systems and finally suggesting proper maintenance policy to reduce the break down chances of RTG cranes.

Key words: Material handling, supply chain, container movement, cycle time, container capacity

1. Introduction

Material handling system plays an important role in the efficient operation of port logistics (Foster, 2008). Container utilities are growing very rapidly and it is expected that this growth will continue for the next decades (Kaynak and Hartley, 2008). A new generation of deep-sea container vessels, with a capacity of 8,000–10,000 "20-ft container equivalent units" (CEU) is in use. Even larger vessels are under development. These developments urge major ports to reconsider their equipment and logistics performance (Jian et al., 2009).

The equipments used for container handling operation are Mobile Harbor crane, Reach Sacker crane (RSC), Hippo Trailer, Rubber Tyred Gantry (RTG) crane, etc. Now a days importance has been given to stacking of containers at major international ports. According to Robinson and Malhotra (2005) the major challenge of the port is to store maximum number of containers within the available area. In DDS, four RTG cranes are deployed. The RTG cranes are making the final stacking of containers at the container parking yard. Along with these four RTG cranes, two Reach Stacker cranes are also making the final stake at the container storage yard of DDS (Khang and Arumugam, 2010). As compared to other major international ports, the annual container movement at DDS is quite less. The cause-effect diagram of the poor utilization of R.T.G. crane is presented in Figure 1.

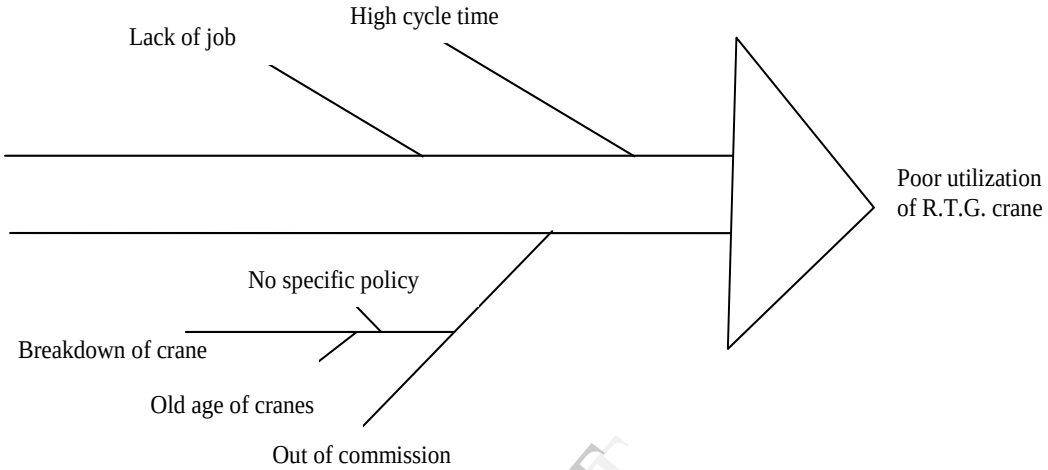

Figure 1: Causes of Breakdown of RTG crane

The objectives of this paper are following: (i) To assess the utilization of RTG crane, (ii) To calculate the yard capacity on the basis of different handling systems used at the container yard of DDS, (iii) To suggest alternative means to improve the performance and efficiency of container handling system at DDS. The scope of project work is in the area of operations at Dhamra Dock System (DDS) at Dhamara Port Trust.

2. Overview of Dhamara Port

Dhamara Port is the gateway to Eastern India for the rest of the world. This is the first Major Port in India and is the only riverine major port in India, situated 232km. Up-stream from the Sand heads. The Dhamara Port Trust manages two separate dock agglomerations - the Dhamara Dock System (DDS) and the Dhamara Fishery Complex (DFC). This paper is limited to the DDS.

2.1. Turn-round Time

In 2012-13 average turn-round time (TRT) of ships registered a mark of 6 to 7 days at Dhamara Dock System. Average TRT during 2011-12 was 7 days. So the general trend at DDS is along an improved gradient.

2.2. Equipment and Craft Profile

Two Mobile Harbour Cranes along with nine Reach Stackers have been installed at Dhamara Dock System on Own-Operate-Maintain basis, for improvement of productivity of containers. The details of the equipments at DDS are given below:

2.2.1. RTG Crane

- Rubber Tyred Gantry (RTG) cranes are mobile material handling devices that operate in shipyards and rail yards for the movement of containers.
- These mobile systems can load/unload containers, which may weigh up to 50 tons, at a rate of once every minute.
- Stacking capacity: RTG can stake containers up to 1 over 7 high, however most of them can stack 1 over 4 high
- Cycle time: 3 minute per move

2.2.2. Reach Stacker Crane

- It loads the containers on the trailer and discharge it from the trailer
- It operates in the container yard
- It is also used to stack the containers in the container yard
- The economic life of Reach stacker crane is 20 years
- It can stack the containers 1- 3 high.
- Cycle time of Reach stacker is 4min/move

3. Characteristics of RTG crane

Characteristics of RTG are mainly associated with its cycle time, mode of operation, and economic age life, stacking height of containers (Zhang et al., 2002). As per the description of Atkins (1993) RTG crane is utilizing minimum space and gives maximum output. RTG cranes provide more flexible operation than other cranes (Avery, 1999). RTG's are typically cheaper to install, more expansive to operate than RMG, which was found by Anonym (1996). The maximum Economic age life of RTG crane is 15 years from the date of its installation (Yang, 2001). RTGs can stack containers up to one over seven high, more than 45% of world units lift one over four. Kaohsiungin (2000) has recommended that the cycle time of RTG crane should be 3min/move, 71248 moves per year. The maintenance cost of diesel operated RTG units is much more than the maintenance cost of the electrically driven RTGs.

3.1. Utilization of RTG

Utilization of R.T.G. crane system has been widely adopted in most of the major international ports (Chu and Huang, 2002a). ABB developed the RTG system provides the following benefits.

i. Reduction of fuel consumption
ii. Reduction of environmental contamination
iii. Lower requirements for brake chippers

Use of RTG handling system at the container yard reduces the average distance traveled by trailers/trucks up to 38.78%. So, the utilization of container yards' ground slots is increased by 8.25%, container movement in the yard also increases by 4.37%. However, work sampling method may be applied to find out the delay allowances and percentage of RTG crane utilization. More number of observations should be taken to get a good desired accuracy level.

3.2. Container yard capacity of RTG handling system

Container handling capacity depends upon the types of handling system at the container terminal (Chu and Huang, 2005). Total ground slots of RTG handling system is more than the total ground slots of Reach stacker handling system (Kim et al., 2008). Frankel (1987) has proposed a method to calculate the area required for storage of containers. Dally (1983) has formulated a method to calculate the annual yard capacity and the annual yard capacity means to accommodate the number of containers as per given yard space. Itsuro (2001) has also formulated a method to compute annual yard capacity, which includes the transhipment ratio, mean profile height. Wang (2002) has proposed that the designed capacity of RTG handling system should be 500000 tons annually. A general form for determining the container terminal capacity is based on yard-sizes, the adopted handling system and crane dimensions.

3.3. Break down & Maintenance of RTG

Cheung et al. (2002) have mentioned the steps to be taken for the reduction of RTG crane break down chances. Those are preventive maintenance, corrective maintenance. In corrective maintenance two types of inspections are done depending upon the inspection frequency, namely, general and specialized inspections. Other methods are equipments over haul and maintenance planning. According to the overall period they are further divided into long range and short range plan. However, two main breakdown causes of RTG are: crane operator's error and equipment breakage.

3.4. Existing Container Terminal Facilities at Dhamara Dock System

The container handling process at DDS is described in Table 1 and 2 respectively.

Table 1: Sequence of processes for import of containers

Sl No.	Description	Process	Distance & Time
1	MHC lifts the container from the hook point of the vessel and off load it on the hippo trailer	Operation	Takes 1.5 minutes for each container
2	Then the Hippo Trailer takes the container parking yard about a distance of 150 m from the quay side	Transportation	150 meters distance covered
3	Container loaded Hippo Trailer arrives at the parking yard and waits for the arrival of Reach Stacker Crane (1-1.5 minute)	Delay	1-1.5 minute
4	Reach Stacker Crane lifts the container from the Hippo trailer and then load it on the storage yard within 2 minutes	Operation	2 minutes
5	After unloaded by the Reach Stacker Crane at the packaging yard, containers are lifted by the RTG for the final stacking (2 minutes)	Operation	2 minutes

Table 2: Sequence of processes for export purpose

Sl No.	Description	Process	Distance & Time
1	Containers which are moving for export are kept at the container storage yard in a stacked manner	Storage	1.5 minutes
2	The containers are lifted by the RTG crane/reach stacker from the stock of containers and off loaded on the Hippo trailer, taking 2 minutes	Operation	2 minutes
3	The Hippo trailer carries the container to the quay side about a distance of 150 meters from the storage yard, taking 2 minutes	Transportation	150 meters & 2 minutes
4	After the arrival of containers by the Hippo trailer at quay side within 1-2 minute, the MHC lifts the container from the Hippo trailer and off load it on the vessel	Delay	1-2 minutes
5	The MHC took 1.5 minutes for each container box for lifting and loading it in the vessel	Operation	1.5 minutes

4. Field Study and Data Analysis

The field study and the analysis of the data are used to solve the existing problems of DDS. Work sampling method has been used for the assessment of RTG crane utilization. The percentage of utilization of the RTG cranes was collected from the field study. Based on the collected data, the yard capacity is calculated

on the basis of type of handling system. Proper maintenance policy is suggested to reduce the breakdown of the RTG.

4.1 Work sampling method for the assessment of RTG crane utilization

It is a method for finding the percentage occurrence of a certain activity by statistical sampling. It is also known as random observation. The working and non-working of the machines is found by random observations. The causes related to the non-working of the machines are also found out. Steps for conducting random work-sampling are as follows:

Step-1: Define the problem.
Step-2: Take permission to conduct work-sampling study from the corresponding authority of the organization.
Step-3: Preliminary estimation of the percentage of occurrence of an activity.
Step-4: Determine the no. of observations to be taken, no. of days or shifts for the observations.
Step-5: Make the observations and record data.
Step-6: Calculate the accuracy.
Step-7: Analyze the data, draw conclusion.

4.2. Results obtained from random work sampling

i. Total number of observations taken = 2040
ii. Number of working observations = 902
iii. Number of non-working observations = 1138
iv. Utilization of RTG crane = 44.21%

To calculate the desired accuracy, first we have to calculate p as % of delay.

So, $p = 1138/2040 = .558$

$$Sp = 2\sqrt{\frac{p(1-p)}{N}} \quad \text{i.e. } 0.558S = 2\sqrt{\frac{.558(1-.558)}{2040}}$$

Hence, desired level of accuracy, $S = 0.035 = \pm 3.5\%$

The various causes of poor utilization of RTG Crane have been analyzed as depicted in Cause and Effect Diagram in Fig. 1.

4.3. Determination of container handling capacity at container terminal

Container handling capacity at container terminal is calculated based on the type of handling system used (Itsuro, 1991). In the container terminal of DDS, two types of handling systems are used. They are RTG handling system and Reach stacker handling system. The calculation of the container handling capacity at container terminal is given below:

4.3.1. Calculation of the area required for Container Yard

According to Hoffman (1985), the required area for container yard has been given below:

$$Cy = (c * A * T) \times (1 + F) / 360$$

Where, Cy = Area required for a container yard
C = Expected container volume (in TEU)
A = Area per container (in sq. m)
T = Average container dwell time in days
F = Peaking factor (about .0614) to ensure sufficient storage space at the peak period.
Hence in present case, container area =175.24 sq. m

4.3.2. Calculation of Storage Area

According to Frankel (1987), when standard deviation of dwell time and economic utilization is considered, area required for storage (CA) is obtained by using the following formula:

$$CA = [C \times A \times (T + 2t)] / [365 \times Z \times 10^4 \times (H + 2h) \times u]$$

Where, CA= area required for storage
C= Expected container volume
A= Projected area per container TEU
T= Average container dwell time (days)=3.5 days
t= Standard deviation (days) of dwell time=1 day
H= Average expected stack height = 3.5
h= Standard deviation of stack height = 1
z= Storage utilization=.18
u= total area utilization, affected by choice of equipment, width of lanes, span of gantries
In our case, storage area required=204 sq.m.

4.3.3. The annual yard capacity

According to Itsuro (2001), annual yard capacity over a given period is:

$$C = C_s \times H \times W \times K$$

In our case, $C = 5{,}462{,}261$ containers per year, assuming only RTG cranes are deployed to stack up to 4 containers.
The above equation gives $C = 4{,}05000.0$ containers per year, assuming only reach stacker cranes are deployed which stack up to 3 containers.

4.3.4. Total number of available ground slots

Dharmalingam (1987) has made slight modification to the above equation as follows:

$$C = C_t \times .6 \times K / T$$

Where, C_t = total number of available slots=1200
K= no. of days per year=365
T= mean container dwell time in CY=3.5 days
For calculation of dwell time, following equations are used,
As per Itsuro (2001), $D = [\mu D_t + (1-\mu) D_e + (1-\mu) D_i] / 2$
Where C = total number of TGS
μ = Trans-shipment container ratio
D_t = Average dwell time of trans-shipped containers
D_e = Average dwell time of containers for export
D_i = Average dwell time of containers for import
H_t = Stacking height of trans-shipped containers
H_i = Stacking height of import containers
H_e = Stacking height of export containers

4.4. Cycle time of handling equipments at the container yard of DDS

The cycle time of container handling equipments was collected for Jan, 2013 - June, 2013 for both RTG handling system as well as reach stacker handling system (Fig. 2). It was observed that the number of

containers handled by RTGs during the above period is almost same. However, there is slight variation in handling capacity by Reach Stackers.

1. R.T.G.-1-7min/move,
2. R.T.G.-2-7 min/move,
3. R.T.G.-3-7 min/move.
4. R.T.G.-4-3 min/move

1. Reach stacker-1-4min/move.
2.Reach stacker-2-4min/move.

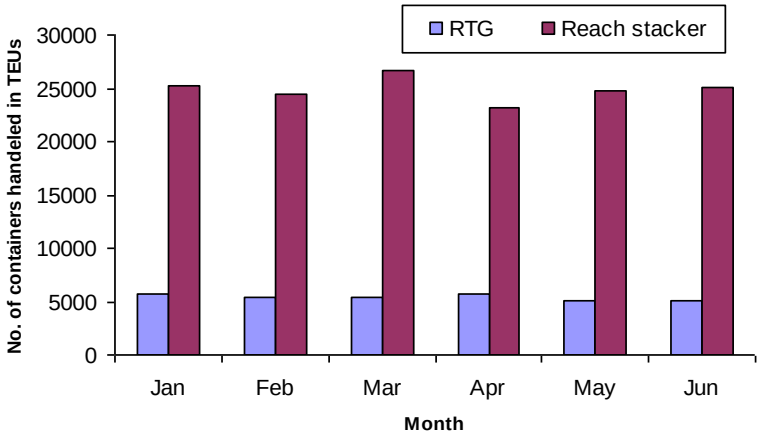

Figure 2: Container handling trend at Dhamara dock system

5. Results

The container handling capacity was calculated for both RTG handling system as well as reach stacker handling system. It was observed that the container handling capacity is more utilized in reach stackers as compared to RTG handling system. Therefore, RTG handling system should be employed in vigor at the container terminal of Dhamara dock system to obtain grater benefits. By efficient use of RTG handling system, 546227 numbers of containers can be handled. However, by using reach stacker handling system, 405000 numbers of containers can be handled in the existing available ground slots of 1200 container terminals.

6. Conclusions

As far as the calculation of container terminal capacity is concerned, more number of containers can be handled by RTG handling system than the reach stacker handling system. It is found that less number of containers is handled by the RTG cranes at the container terminal. According to the demand of Dhamara Dock System, around 350000 containers should be handled annually. At DDS, 4 RTG and 2 Reach stacker cranes are available. Of the 4 RTG cranes 3 RTG cranes are quite old and their cycle time is more in comparison to the other one. In the above situation, the container handling capacity by the RTG handling system is lesser than the Reach stacker handling system. Therefore, two numbers of newly developed RTG cranes having the annual handling capacity of 150000 containers in TEUs should be installed in place of the 3 old RTG cranes.

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