Graduate Student Research Day 2011
Florida Atlantic University

COLLEGE OF ENGINEERING AND COMPUTER SCIENCE

An Algorithm for the Integrated Scheduling Problem of a Container Handling System Within a Container Terminal

Yueqiong Zhao and Evangelos Kaisar

Department of Civil, Environmental, and Geomatics Engineering, College of Engineering and Computer Science, Florida Atlantic University, Boca Raton, FL

Currently, there has been an exponential increase in container volume shipment within intermodal transportation systems. Container terminals as part of the global ports represent important hubs within the systems. Thus, the need to improve the operational efficiency is the most important issue for container terminals from an economic standpoint. In order to increase the efficiency of operations, the development of optimization models and mathematic algorithms is critical in finding an optimal solution. The objective of this study is to evaluate the optimum solution to find the proper number of Yard Trailers (YTs) with the minimal cost for the container terminals. This study uses the Dynamic YTs operation's method as a background for modeling. A mathematical model with various constraints related to the integrated operations among the different types of handling equipment is formulated. This model takes into consideration both serving time of different types of cranes, and cost reduction strategies by decreasing use of YTs with the specific objective of minimum total cost including utilization of YTs and vessel berthing time. A heuristic algorithm combined with Monte Carlo method and Brute-force search are employed. The Monte Carlo method is proposed to generate vast random numbers to replicate simulation. The Brute-force search is used for identifying all potential cases specific to the conditions of this study. Some preliminary numerical test results suggest that this method is good for use in conjunction with simulation of container terminal operations.

Modeling and Simulation on the Yard Trailers Deployment in the Maritime Container Terminal

Yueqiong Zhao, Evangelos I. Kaisar, Department of Civil, Environmental & Geomatics Engineering, Florida Atlantic University

Abstract

In recent years, there has been an exponential increase in container volume shipment within intermodal transportation systems. Container terminals as part of the global port system represent important hubs within this intermodal transportation system. Thus, the need to improve the operational efficiency is the most important issue for container terminals from an economic standpoint.

The objective of this study is to evaluate the solutions to find the proper number of Yard Trailers (YTs) with the minimal cost for the container terminals. This study simulates the YTs' operations under the dynamic YTs operations' method and takes into consideration both serving time of quay cranes and yard cranes, and cost reduction strategies by decreasing use of YTs with the specific objective of minimum total cost including utilization of YTs and vessel in the berth. In addition, The Monte Carlo method is proposed to generate vast random numbers to replicate simulation for real cases. The Brute-force search is used for identifying all potential cases specific to the conditions of this study.

Some preliminary numerical test results suggest that this method is good for use in conjunction with simulation of container terminal operation. The expected outcome of this research is a solution to obtain the best feasible number of YTs for transporting containers with a minimum cost; thus, improving the operational efficiency in a container terminal.

Objective

①Evaluate the best feasible solution to find the proper number of Yard Trailers (YTs) with the minimal cost for the container terminals

②Develop a mathematical model with various constraints related to the integrated operations among the different types of handling equipment to look for the solutions to improve the operational efficiency

Background and Problem Statement

①The performance of container terminal is very important to the intermodal freight transportation, and the container operations can be grouped in to three parts:

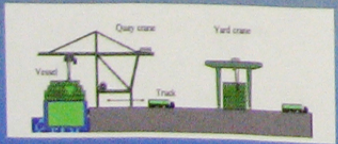
- Container Assignment
- Resource allocation: Quay Cranes ; Yard facilities
- Logistics and Transportation

②There has been an exponential increase in container volume shipment within intermodal transportation systems

③ From an economic standpoint, the need to improve the operational efficiency is the most important issue for container terminals

④The full use of all loading and unloading equipment is necessary in order to increase revenue

⑤Yard Trailers (YTs) are important to improve efficiency and reduce cost for unloading and loading operations



Methodology

①Develop a mathematical model

- The dynamic YTs operation's method (inter-ship method) is used as a background for modeling
- The first principle is the mooring time of the unloading vessel (as short as possible)
- The second principle is to find an appropriate total # of trailers that can minimize the total cost (vessel mooring costs and vehicle costs)

②Develop an algorithm to replicate the simulation and look for the best feasible solution

③The model's performance is tested with a MatLab simulation

Assumptions

① Cost Functions

$$MC(k)=\sum_{i=1}^{I} MC_i \max_{il} t_{il} \qquad VC(k)=\sum_{i=1}^{k}\sum_{l=1}^{L} VC_i * t_{il}$$

② YTs Analysis

$$d_{il}=d_1+d_2+d_3+|x_a-x_1^{(i)}|+|y_a-y_1^{(i)}|+|x_1^{(i)}-x_2^{(i)}|+|y_1^{(i)}-y_2^{(i)}|+|x_2^{(i)}-x_b|+|y_1^{(i)}-y_b|$$

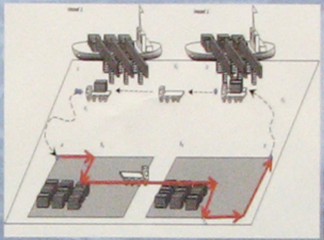
$$t_{il}=\frac{d_{il}}{v}+Yut_{ij}+Ylt_{ij}+Qlt_{ij} \qquad k_{il}=t_{il}/Qut_{ij}, \forall l\in L, i\in I \qquad 0\le k\le \max t_{il}/Qut_{ij}, \forall l\in L, i\in I$$

③ Objective Function

$$Z=MC(k)+VC(k) \qquad \min_{k\ge 1} Z$$

④ Constraints

$$0\le x_a\le m_1$$
$$0\le x_b\le m_2$$
$$0\le y_a\le n_1$$
$$0\le y_b\le n_2$$
$$N^-=N^+$$
$$o_c-o_{c+1}\ge 0, \ \forall c, c+1\in C$$



Variables

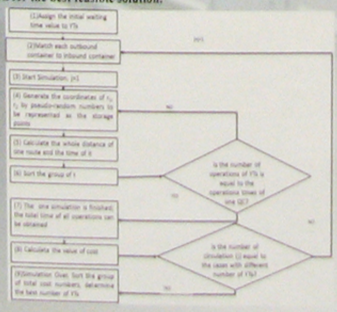
- Z=the total cost
- MC(k)=the cost of mooring in the berth of the unloading vessel ($)
- VC(k)=the cost of YTs in use ($)
- d_{il}=the distance of the l[th] circle of the i[th] YT
- t_{il}=the time of the l[th] circle of the i[th] YT
- k_{il}=the number of YTs in use during the l[th] circle of the i[th] YT
- P_a=the random position in the yard for storage, P_a={ (x_a, y_a) | (x_a, y_a) ∈S_1∧ (x_a, y_a) is empty}
- P_b= the random position in the yard for loading to the loading vessel, P_b={ (x_b, y_b) | (x_b, y_b) ∈S_2∧ (x_b, y_b) has the loading container}
- O_c,O_{c+1}= the value of the loading container c and c+1
- k=the proper number of YT in use

Parameters:

- Yut_{ij}=the unit time of the operation of the YC for unloading (min* per container)
- Ylt_{ij}=the unit time of the operation of the YC for loading (min*per container)
- Qut_{ij}=the unit time of the operations of the QC for loading (min*per container)
- Qlt_{ij}=the unit time of the operations of the QC for loading (min*per container)
- v=the velocity of the YTs (min/meter)
- MC_u=the unit cost of mooring in the berth ($/min)
- VC_u=the unit cost of the YT in use ($/min*car)
- N^-=the number of unloading containers from the unloading vessel
- N^+=the number of loading containers from the loading vessel

Solution Algorithm

Monte Carlo Method will be employed to replicate the simulation; Brute-force Search will be used to look for the best feasible solution.



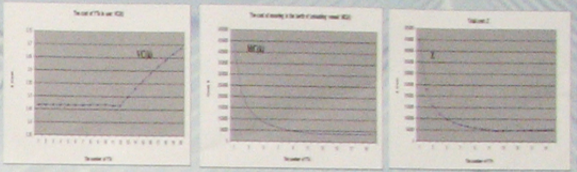
Numerical Test Results

Input Data

[illegible]

The mean value after 10000 simulation runs

[illegible]

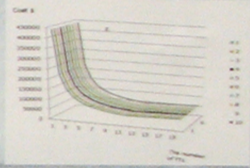


Sensitivity Analysis

①Container Configuration

Choose 10 simulation results randomly:

- Before best feasible number of YTs is reached, there are very small differences in cost between 10 simulations
- After this point, cost is the same



② Change the ratio of the unit cost of the unloading vessel in the berth and the unit cost of the YTs

MC_u =[5,30] VC_u =[0.2,1]

③Change the ratio of the unloading volume and the number of QCs

The work load of a QC=[200,600]; The QC are assigned for each vessel=[2,6]

④Change the ratio of the unit time of the QC for unloading and loading

Qut_{ij}/Qlt_{ij} (min)	The number of YTs	MC(k)	VC(k)	Z
1.5-3	12	35940	2908.4	47565.6
2-3	12	36545.2	2955.26	[illegible]
1.5-3	16	27064.5	2916	39928.5
1.5-2.5	16	26955	2916	[illegible]

VC_u-MC_u	The number of YTs	MC(k)	VC(k)	Z
0.7-23	12	27661	14211.5	68507
0.3-15	12	18038.4	4376.20	35540.20
0.6-15	12	18039.8	8753.41	53053.44
1-5	12	6013.05	14587.67	64062.72
0.5-9	13	17970	9453.60	55784.40

Inbound containers/ QC for unloading	The number of YTs	MC(k)	VC(k)	Z	[illegible]
7182	12	[illegible]	[illegible]	[illegible]	[illegible]
9763	12	[illegible]	[illegible]	[illegible]	[illegible]
12044	12	[illegible]	[illegible]	[illegible]	[illegible]
13424	12	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]
24405	12	[illegible]	[illegible]	[illegible]	[illegible]
19563	13	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]
29965	12	[illegible]	[illegible]	[illegible]	[illegible]
24604	12	[illegible]	[illegible]	[illegible]	[illegible]

Results Summary

- The configuration of the containers has negligible affect on the cost
- Changing the unit cost (with in a valid range) has no affect the optimal number of YTs
- Changing the load on QCs (with in a valid range) has no affect the optimal number of YTs
- Changing the unit operation time of the QC for unloading (with in a valid range) has a marginal impact on the optimal number of YTs
- The unit costs will dominate the relationship and the trend of the two cost functions

Conclusion

①Contributions

- A mathematical model is developed to formulate the YTs' deployment
- An algorithm is developed to replicate the simulation to search for the best feasible number of YTs

②Limitations

- Data Collection
- Model Development

③Future Research

- Optimization of yard storage policy and integrating unloading and loading operations schedules could be considered