DETERMINING OPTIMUM NUMBER OF PRIME MOVERS FOR A CONTAINER TERMINALS

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Introduction

Services efficiency has to be enhanced in container ports due to demand increase in containerization (http://www.unctad.org). It could only be done by handling containers more efficiently within the port. A port's efficiency is often measured in terms of its throughput and typical ship turnaround time (i.e. time needed for loading and unloading a ship). To decide the optimum number of prime movers in order to reduce ship turnaround time is considered in this research since it would reflects ports' efficiency improvement (Vis & Koster, 2003). A mathematical model with objective function was developed with assumptions, to minimize the cycle time of the prime movers. To validate the developed equation, it is modeled and simulated with *Arena 10.0*software, with some real data that has collected from a port.

Mathematical Modeling

The mathematical model was developed to the layout of the container terminal shown in Figure 1. Mathematical equations have been developed for the vehicle operations of the container terminal. The time for a typical delivery cycle of a vehicle transport system consists of,

1. Loading at the pickup station
2. Travel time to the drop off station
3. Unloading at drop-off station
4. Empty travel time of the vehicle between distances

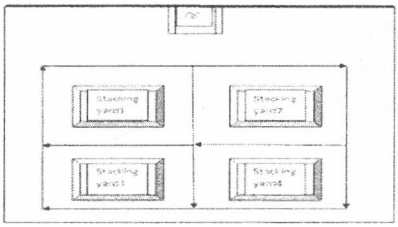

Fig. 1. Layout of the considered CT

Cycle time per delivery (T_{Cij})is given by

$$T_{Cij} = T_L + \frac{L_{dij}}{V_{loading}} + T_U + \frac{L_{eij}}{V_{empty}} \quad (1)$$

Total cycle time per delivery (T_C) is given by

$$T_C = \sum_{i=1}^{3} \sum_{j=1}^{4} n_i P_i C_{ij} \quad (2)$$

The total cycle time can be used to determine certain parameters of interest in the vehicle based system such as

1. Rate of deliveries per vehicle
2. Number of vehicles required to satisfy a specified total delivery requirement.

The hourly rate of deliveries per vehicle (R_d) is

$$R_d = \frac{60 \text{ minutes}}{T_{Cij}} \quad (3)$$

Any time losses during the hour should be taken in to account. Possible time losses are

1. Availability (reliability factor)
2. Traffic congestion
3. Efficiency of prime movers

Available time (AT) is

$$AT = 60\,AT_f E \quad (4)$$

Now The hourly rate of deliveries per vehicle (R_d) equation can be modified as follows

$$R_d = \frac{AT}{T_{cij}} \quad (5)$$

Optimal number of vehicles (n_c) can be estimated by dividing the total workload by available time per vehicle.

$$n_c = \frac{WL}{AT} \quad (6)$$

Workload (WL) is given by,

$$WL = R_f T_c \quad (7)$$

Therefore,

Optimal number of vehicles (n_c) is,

$$n_c = \frac{R_f}{R_d} \quad (8)$$

T_{Cij}- Cycle time of a prime mover with loads of ith QC to the jth station,

T_L - Time to load at a QC

L_{dij} - Distance between ith QC and jth station unloading point

$V_{loading}$ - Velocity of the prime mover once it is been loaded

T_U - Time to unload at a stacking crane

L_{sij}- Distance between jth station and ith QC

V_{empty}- Velocity of the prime mover once is been unloaded

n_i- Jobs handled by the ith QC

P_i- Percentage of total jobs handled for the jth station

C_{ij} - Cycle time per delivery

A - Availability factor

T_f- Traffic factor to indicate traffic congestion

n_c- Optimal number of vehicles needed for hour

R_f - Specified flow rate of total deliveries for a system (delivery/hour)

R_d- Hourly rate of deliveries per vehicle

E- Worker efficiency

Methodology

In this research simulating the problem is done using the student software version of *Arena 10.0*. *Arena* is discrete event simulation software where user can build experimental model using logic or process modules. Single QC operation to allocate containers for four stacking yards according to the developed mathematical model is considered for the experimental model.

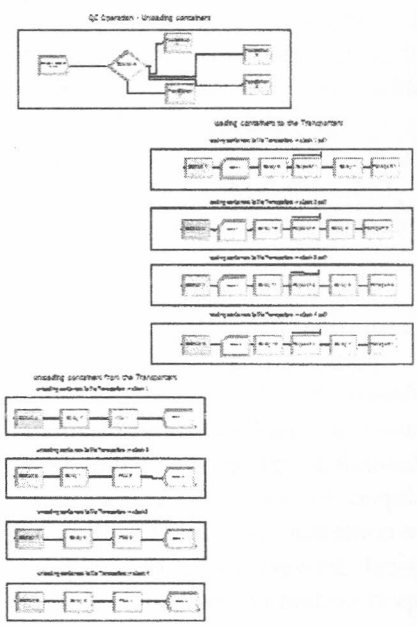

Fig. 2. *ARENA* model of the CT

As shown in Fig. 1, there are four cyclic paths where prime movers are circulated during the process of unloading. Container deliveries per day based on hourly manner, distances of four paths A, B, C and D, average velocity of prime movers, average T_f, average loading and unloading times for QC and stacking cranes are used for the model based on real values in a port.

Results

Twenty four hours operational period was simulated with number of containers loaded at the QC and number of containers unloaded at the 4 different stacking yards A,B,C and D at the end of each and each hour are tabulated.

Different simulations were carried out for different traffic factors and the results are given in Table 1. Next variations in the minimum number of vehicles needed in hourly based manner, depending on the traffic factor are graphed and the variations in the efficiencies are calculated.

Table1: Results of the simulation

Time	No. of containers shipped	Path A No. of Vehicles started	Path B No. of Vehicles started	Path C No. of Vehicles started	Path D No. of Vehicles started	Path A No. of Vehicles unload	Path B No. of Vehicles unload	Path C No. of Vehicles unload	Path D No. of Vehicles unload
1	30	7	7	7	7	4	0	0	3
2	38	8	14	5	6	7	7	3	5
3	43	13	8	7	9	7	7	1	7
4	44	10	17	10	6	14	10	1	9
5	45	8	18	12	8	9	15	6	7
6	48	15	22	12	11	10	16	10	5
7	39	19	20	5	9	13	20	9	12
8	38	10	13	15	12	8	18	11	8
9	45	7	15	13	8	11	6	7	12
10	46	16	10	7	7	9	15	14	9
11	39	13	15	9	8	8	13	13	7
12	37	9	14	10	4	14	12	9	8
13	34	9	7	14	4	9	14	4	5
14	48	12	18	17	10	9	13	0	3
15	47	10	24	16	6	13	7	11	6
16	36	11	11	9	11	9	16	12	4
17	44	21	14	10	17	9	24	18	9
18	44	10	17	15	4	24	11	18	16
19	38	11	11	9	5	8	14	9	10
20	37	8	12	10	6	9	17	9	6
21	38	10	11	13	8	12	11	12	4
22	40	9	19	14	10	9	12	10	10
23	46	12	17	13	6	10	11	13	7
24	39	13	14	11	6	11	19	13	7

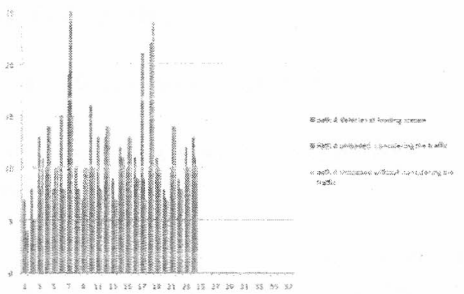

Fig. 3. Comparison of the effect of traffic on the jobs being served in path A

Discussion and Conclusion

The summarized results given in Fig. 2 shows that the optimum number of prime movers calculated for an hourly base and the minimum number needed at the QC in hourly manner. After calculating the efficiency it can be observed that it is above the 90 percent. But after considering the traffic congestion in the considered layout it can be observed that the efficiency decreases considerably.

References

http://www.unctad.org/templates/download.asp?doicd=1608&lang (last visited 12.08.2010)

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