Collaborative optimization of container allocation and yard crane deployment based on truck appointment system

Huiyun Yang\textsuperscript{1,2}, Li Wang\textsuperscript{1}, Qi Xu\textsuperscript{1} and Zhihong Jin\textsuperscript{1,3}
\textsuperscript{1} College of Transportation Engineering, Dalian Maritime University, Dalian 116023, China
\textsuperscript{2} Dalian Port Co., Ltd., Dalian 116601, China
\textsuperscript{3} E-mail: jinzhihong@dlmu.edu.cn

Abstract. Due to the increase of container transport volume and the limitation of yard resources, yard congestions in container terminal have become increasingly serious. Therefore, it is necessary to optimize the problem of container allocation and yard crane deployment for import containers. With the extensive application of truck appointment system, yard resources allocation could be performed based on the appointment application submitted by shippers or trucking companies. Taking the information of truck appointment system and arrival period of vessels into account, a two-stage programming model is proposed. The container allocation problem is solved to balance the workload among different blocks in first stage, while the second stage aims to minimize the total shifting distance of yard cranes. Then, solver CPLEX is used to provide optimal solution for numerical experiments. It is concluded from experiments that the proposed mode is efficient in reducing the yard congestion by balancing the workload among blocks and decreasing the shifting distance of yard cranes, thus improving both the operational efficiency of yard and the accuracy of resources allocation.

1. Introduction

The terminal yard is mainly used for stacking import and export containers. The operational efficiency of yard greatly determines the performance of the container terminal. Concentrated container allocation or frequent yard crane shifts can cause severe traffic congestion in the yard which is not conducive to high-efficiency operation of yard. Therefore, it is one of the most effective methods to reduce yard congestion by optimizing container allocation and yard crane deployment.

Yard resources are divided into space resources and equipment resources. To solve the space resource allocation problem, Mao J et al. [1] built an optimization model with the objective of workload balance among blocks and minimized transport distance of inner trucks, and Sharif O et al. [2] adopted an ant-based algorithm for import and export containers allocation in the bi-directional traffic network. Abbas A et al. [3] studied the specific stacking position of containers. A fuzzy knowledge-based model was used to deal with the uncertainty of the departure time of containers. Jiang X J et al. [4] formulated an optimization model to determine the number of containers allocated to each sub-block and yard cranes required in each block, aiming to minimize the cost of yard crane scheduling during the whole planning period.

However, yard operation optimizations are related to other two significant research topics, that is the optimizations of landside operation and quayside operation. In terms of quayside operations, Karam A et al. [5] solved the problem of quay crane assignment, specific quay crane assignment and internal truck assignment simultaneously to minimize service and operation costs for vessels. Jin J G
et al. [6] tackled two optimization problems simultaneously in the container terminal. One problem is to determine preferred berthing positions for vessels, and the other problem is to allocate storage space for containers. In addition, collaborative and outsourcing strategies for yard trucks were also extensive studied. Karam A et al. [7] proposed that terminal could transfer trucks from uncongested adjacent terminals or rent additional trucks from third-party providers simultaneously to provide better service and save total costs.

Unlike the determinate arrival and departure information of vessels, landside operations optimizations are uncertain. This is because the delivery and pickup information for containers is depends on shippers. Dhingra V et al. [8] adopted Markov-modulated Poisson Process to characterize time-varying arrivals of trucks in the semi-open queuing networks. The matrix-geometric method was verified to be effective in resource planning and regulating the number of trucks. To avoid the effect of randomness of landside operations on yard operations, Zhen L [9] divided sub-blocks into exclusive mode and sharing mode when optimizing yard space allocation problem, thus reducing resources allocation costs. Under uncertain maritime market, Tan C M [10] presented a flexible yard template strategy instead of fixed yard template strategy for yard management, and then an integrated optimization model was formulated. However, the truck appointment system has been widely used in many terminals, which provides deterministic arrival information of trucks and is beneficial to yard resources allocation. Azab A E et al. [11] put forward a dynamic and collaborative truck appointment management system. A discrete event simulation model followed by a MIP model were proposed to solve the optimal arrival time of trucks.

In summary, there are a small number of literatures considering the arrival information of trucks when yard resources allocation. However, owing to the extensive application of truck appointment system, it is convenient for yard operators to obtain the delivery and pickup information from trucking companies. In this context, the optimizations on container allocation and yard crane deployment are more accurate. Therefore, taking both vessels and truck appointment information into account, this paper formulates a two-stage optimization model, thus making rational storage plans for containers and assigning yard cranes for blocks.

2. Problem description

Truck appointment refers to the operation that shippers or trucking companies submit pickup or delivery applications to the terminal via truck appointment system. Shippers or trucking companies need to submit information such as the delivery date, truck number and port of destination for making a delivery appointment. In the same way, before picking up containers from yard, the pickup date, the number of containers and the truck number need be submitted in the system. Then the truck appointment system will receive the appointment information and transmit the information to yard operation system.

Since container vessels travel on a fixed timetable, dispatchers can foreknow the arrival and departure information. In the traditional mode, the shippers or trucking companies were not allowed to pick up import containers until the container has been unloaded into the blocks. Under the circumstance, the import containers are allocated just according to the information about container vessels. However, the application of truck appointment system makes it possible for shippers to submit pickup appointments before the vessels arriving berth. Therefore resource allocation for import containers could be carried out based on both appointment information and vessels arrival information. In this proposed mode, truck appointment system will be fully utilized and better performed. The two modes of resource allocation for import containers is shown in figure 1, the solid lines represent the process of proposed mode while the dotted lines represent traditional mode.
Figure 1. The process of resources allocation.

Container allocation and yard crane deployment are the resource allocation of planning level and based on the consequence of strategic level. The resource allocation at strategic level calculates the size of each block and identifies the corresponding relations between blocks and berths according to some specific rules. In this paper, the optimization of resource allocation at planning level includes two main tasks, i.e. container allocation and yard crane deployment. “Container allocation” means to allocate appropriate storage blocks for import containers arriving at different time periods. “Yard crane deployment” means to distribute a reasonable number of yard cranes for each block, ensuring that the missions in every block are completed.

Truck appointment system supports the function of multiple trucks booking multiple containers, so each shipper usually only submits one application in the system. The series of import containers, with same shipper, arrival time and departure time, will be regarded as one import job in this paper. Every import job consists of two discontinuous sections, discharging containers from berth to block and picking up containers from block to shipper. It is illustrated in figure 2 that the layout of the container terminal and the process of import jobs. In the figure, the solid lines indicate the process of picking up containers while the dotted lines represent discharging containers.

Figure 2. Layout of the container terminal.

The rolling-plan mode means that only the first day of the plan will be implemented and the second day will be the first day of the next planning period. This mode is used to optimize resource allocation in this paper. That is, the appointment information in the plan period is updated dynamically. It requires that shippers or trucking companies need to submit appointment application in the system one day in advance and there is enough time for dispatchers to scheduling. What’s more, every job has a
specific designated berth and there are corresponding relations between blocks and berths. Therefore, whether the block is reserved for a specific job is also known.

3. Mathematical model

Truck appointment information is used to provide detailed parameter for the collaborative optimization of container allocation and yard crane deployment, such as the number of containers, the arrival period, the departure period and the relationship between jobs and blocks. Based on making full use of information of both the appointment system and vessels, a two-stage programming model is established in this paper. Container allocation is solved to balance the workload among blocks in the first stage. To minimize the total shifting distance of yard cranes, the second stage aims to distribute yard cranes for each block, thus achieving the purpose of avoiding the traffic congestion caused by frequent shifting of yard cranes.

3.1. Assumptions

1) The containers of one job are allowed to be stacked in different blocks, but they must be completed in the same time period;
2) Yard crane can only operate in one block within a period, but is able to shift between different blocks at the interval of two periods;
3) Based on the arrival information of vessels and capacity of quay crane, it is possible to obtain the arrival period of import containers;
4) If the yard crane is idle in the next period, then it needs to rest in the current working block.

3.2. Notations

Sets and parameters

- $T$: Set of time periods
- $K$: Set of yard cranes
- $B$: Set of blocks
- $J_i$: Set of import jobs
- $J_p$: Set of jobs that only need pickup
- $Q$: Storage capacity of each yard block
- $NK$: The number of yard cranes enabled in the yard
- $NB$: The number of blocks enabled in the yard
- $cap$: The capacity of yard crane in one period, all yard cranes have the same capacity
- $n_j$: The number of containers included in job $j$, $j \in J_i$
- $\alpha_{jb}$: Whether the block $b$ is the reserved space for job $j$, $\alpha_{jb} = \{0,1\}$, $j \in J_i$
- $\beta_{jt}$: Whether job $j$ arrives at period $t$, $\beta_{jt} = \{0,1\}$, $j \in J_i$
- $\gamma_{jt}$: Whether job $j$ departs at period $t$, $\gamma_{jt} = \{0,1\}$, $j \in J_i$
- $Z_{jtb}$: The number of containers of job $j$ that stacked in block $b$ before the planning period and planned to be picked up in period $t$, $j \in J_i$
- $M$: An infinite number
- $L_{bb'}$: The distance between block $b$ and block $b'$, expressed in distance units

Decision variables

- $R_{jb}$: Whether the containers of job $j$ are unloaded to block $b$, $j \in J_i$
- $U_{jb}$: The number of containers of job $j$ that are unloaded to block $b$, $j \in J_i$
- $X_{ktb}$: Whether yard crane $k$ is busy at block $b$ in period $t$
S_{kb} : Whether yard crane \( k \) is idle at block \( b \) in period \( t \)

**Derived variables**

\( P_{tb} \): The number of containers that are loaded from block \( b \) in period \( t \)

\( D_{tb} \): The number of containers that are unloaded to block \( b \) in period \( t \)

\( C_{tb} \): The number of containers that are stacked in block \( b \) in period \( t \)

\( A_{tb} \): Whether yard crane \( k \) shifts from block \( b \) to block \( b \) after period \( t \)

### 3.3. Mathematical Formulations

A two-stage mathematical model is established in this chapter to allocate containers and yard cranes for import jobs.

**Objective function of first stage**

\[
\text{min} \sum_{t} \sum_{b} \left( D_{tb} + P_{tb} \right) - \frac{\sum_{k} \left( D_{tb} + P_{tb} \right)}{NB} \tag{1}
\]

**Constraints**

\[
R_{jb} \leq a_{jb} \quad \forall j \in J_1, b \in B \tag{2}
\]

\[
\sum_{b} U_{j\beta} R_{jb} = n_{j} \quad \forall j \in J_1 \tag{3}
\]

\[
D_{tb} = \sum_{j \in J_1} U_{j\beta} \beta_{jt} \quad \forall t \in T, b \in B \tag{4}
\]

\[
P_{tb} = \sum_{j \in J_1} U_{j\beta} \beta_{jt} + \sum_{j \in J_2} Z_{jtk} \quad \forall t \in T, b \in B \tag{5}
\]

\[
C_{t+1,jb} = C_{tb} + D_{tb} - P_{tb} \quad \forall t \in T, b \in B \tag{6}
\]

\[
C_{tb} \leq Q \quad \forall t \in T, b \in B \tag{7}
\]

\[
R_{j\beta} \in \{0,1\}, U_{j\beta} \in N \quad \forall j \in J_1, b \in B \tag{8}
\]

The objective function (1) is to minimize the imbalance workload among blocks during the whole planning period. The first part represents the workload of block \( b \) in period \( t \) and the second part represents the average workload of all blocks in period \( t \). The absolute value of the gap between the two parts is the imbalanced workload of block \( b \) in period \( t \). Equation (2) represents the constraint of decision variable. That is, for every job, the containers must be unloaded in the job’s reserved blocks. Equation (3) indicates that for each job, the total number of containers stacked in different blocks should be equal to the number of containers included in the job. Equation (4) is the calculation formula for the unloading amount of containers in every block and time period, while equation (5) is for the loading amount of containers. When calculating the loading amount, two kinds of jobs should be considered. Equation (6) is the recursion formula of the stacking quantity of containers in each block at two adjacent periods. Equation (7) represents that the stacking quantity of containers in each block shall not exceed the capacity limit at any time period. Equation (8) is the non-negation and binary constraint of decision variables.

It needs to be added that solver CPLEX is only suitable for solving linear programming problems. Equation (3) contains a multiplication of two decision variables, which makes it non-linear. So, equation (3) should be replaced by the following equation (9) which represents the total number of containers in job \( j \), then equation (10) is added to limit the value of \( R_{j\beta} \). Equation (10) represents that \( U_{j\beta} \) is greater or equal to 1 if \( R_{j\beta} \) is 1, and \( U_{j\beta} \) must be 0 if \( R_{j\beta} \) is 0.

\[
\sum_{b} U_{j\beta} = n_{j} \quad \forall j \in J_1 \tag{9}
\]
\( R_{jb} \leq U_{jb} \leq M \times R_{jb} \quad \forall j \in J_1, b \)  

**Objective function of second stage**

\[
\min \sum \sum \sum A_{t,b} L_{b} \quad (11)
\]

**Constraints**

\[
\sum_{k} X_{t,b} = \left( \frac{D_{t,b} + P_{t,b}}{\text{cap}} \right) \quad \forall t \in T, b \in B
\]

\[
\sum_{b} X_{t,b} \leq 1 \quad \forall t \in T, k \in K
\]

\[
\sum_{b} X_{t,b} \leq NK \quad \forall t \in T
\]

\[
\sum_{b} X_{t,b} + \sum_{b} S_{t,b} = 1 \quad \forall t \in T, k \in K
\]

\[
X_{t,b} + S_{t,b} \leq 1 \quad \forall t \in T, k \in K, b \in B
\]

\[
A_{t,b} = \begin{cases} 1, & X_{t,b} + S_{t,b} + X_{k(t+1)b} = 2 \quad \forall t \in T, k \in K, b \in B \\ 0, & \text{else} \end{cases}
\]

\[
X_{t,b}, S_{t,b} \in \{0,1\}
\]

The objective function (11) is to obtain the minimum shifting distance of yard cranes. Equation (12) is to ensure that yard cranes have to complete the workload of every block but not excess. Equation (13) indicates that yard crane only works in one block at one time period. Equation (14) indicates that the number of operating yard cranes at every period should not exceed the number of yard cranes available in the yard. Equation (15) shows that every yard crane can only be in either busy or idle at one time period. Equation (16) represents that any yard crane may be busy, idle or not in the given block for any time period. Equation (17) is intended to explain that the yard crane need to rest at the current block if idled in the next period. Equation (18) is the recurrence relation between derived variable and decision variables. Lastly, equation (19) is the binary constraints of decision variables.

4. **Numerical experiments**

4.1. **Numerical data**

Two berths and ten blocks in a specific terminal are used as numerical data in this paper, and the actual storage capacity of each block is 300 containers. According to the correspondence between berths and blocks, the berth 1 corresponds to the block 1-5, and No.2 corresponds to the block 6-10. The import containers must be unloaded into the corresponding blocks. There are 12 yard cranes available in the yard, and the capacity of each yard crane is 160 containers per period. Due to the rolling-plan mode, the resources allocation plan of the first day is made in this paper and the planning period is divided into 6 periods of 4 hours each.

There are 16 import jobs from two vessels and 4 jobs that only need pickup in this experiment. We assume that the vessel 1 arrives at berth 1 in period 1 and the vessel 2 arrives at berth 2 in period 2. According to the information given by truck appointment system, the arrival time of trucks for import trucks follow negative exponential distribution, marked as \( \beta \sim \text{Exp}(0.4) \). The number of containers for import jobs follows uniform distribution, marked as \( n \sim U(20,200) \). Table 1 shows the detail information of import jobs, and the table 2 shows the information of jobs that only need pickup. Then the input parameters such as the number of containers, arrival time, and departure time are available.
### Table 1. The detail information of import jobs.

| Job | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|-----|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|
| Berth | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 1 |
| Departure time | 3 | 2 | 3 | 2 | 4 | 5 | 4 | 5 | 5 | 4 | 5 | 6 | 6 | 6 | 6 |
| Number | 147 | 155 | 69 | 142 | 137 | 49 | 41 | 109 | 192 | 81 | 125 | 60 | 155 | 65 | 111 | 145 |

### Table 2. The detail information of jobs that only need pickup.

| Job | 17 | 18 | 19 | 20 |
|-----|----|----|----|----|
| Berth | 2 | 9 | 7 | 4 |
| Departure time | 3 | 2 | 1 | 2 |
| Number | 44 | 80 | 157 | 96 |

### 4.2. Results and analysis

The above linear programming model was solved by CPLEX. An experiment was done to explain the solution process of model. In the first stage, the value of decision variable $U_{jb}$ is shown in table 3 and the objective function value is 1775.6. The quantity assigned to each block was not only related to the job itself but also related to other jobs in the same block and period.

### Table 3. The value of decision variable $U_{jb}$.

| Job | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 |
|-----|----|----|----|----|----|----|----|----|----|-----|
| J2 | / | 16 | 139 | / | / | J1 | 69 | / | 26 | 26 | 26 |
| J4 | 3 | / | / | / | 139 | J3 | / | 69 | / | / | / |
| J7 | / | 22 | / | 19 | / | J5 | 26 | 26 | 26 | 26 | 33 |
| J10 | 25 | / | 25 | 6 | 25 | J6 | / | / | / | 49 | / |
| J11 | / | / | 64 | 61 | / | J8 | 90 | 3 | / | 16 | / |
| J12 | 60 | / | / | / | / | J9 | / | 62 | 65 | / | 65 |
| J15 | / | 47 | / | / | 64 | J13 | / | 37 | 37 | 37 | 44 |
| J16 | 14 | 23 | 36 | 36 | 36 | J14 | 35 | / | / | / | / |

Then, the value of derived variable $D_{ib}$ and $P_{ib}$ were used as the input parameters for the second stage. Figure 3 shows the operation status of each yard crane during each period. In the figure, the squares indicate periods and the number in the square represents the block where the yard crane worked. The square with grey background indicates the yard crane is busy while white background is idle. For example, yard crane 1 stays in block 4 during the entire planning period, but it is idle in period 3. As shown in the figure, after period 1, yard crane 7 shifts from block 5 to block 9 and yard crane 12 shifts from block 3 to block 6. Therefore, the shifting distance is 5 distance units.

---

**Figure 3.** The status of yard cranes.
The validity of the model was verified by the imbalance of workload among blocks and the distance of yard cranes shift. In traditional mode, without the support of truck appointment system, the imbalance of workload is 3551.6 and the shifting distance is 6 units. By comparison with traditional mode, the imbalance of proposed mode dropped by 50% and the shifting distance dropped by 16.7%. And to avoid the randomness of the test data, ten experiments were done. All results showed that making full use of truck appointment system is helpful to reduce yard congestion. Therefore, the collaborative optimization of container allocation and yard crane deployment based on truck appointment system is significant.

4.3. Sensitivity analysis

To verify the effect of three main factors (i.e. arrival interval of vessels, arrival interval of trucks and the number of containers) on the experimental results, three scenarios are selected in this chapter to sensitivity analyses. In every scenario, only one factor has a change in the parameters of distribution function, while others remain unchanged. When the factor is constant, its value is referred to the numerical data of 4.1. The parameter $\alpha_b$ and $Z_{itb}$ are also unchanged during the experiments. Table 4-6 lists the results of experiments.

| Scenario | Parameter | Proposed mode | Traditional mode | Gap (%) |
|----------|-----------|---------------|-----------------|---------|
|          | Imbalance of workload | Shifting distance | Imbalance of workload | Shifting distance |
| 1        | {1,1}     | 933           | Excess          | 2218.6  | 57.9   |
|          | {1,2}     | 1775.6        | 5               | 3551.6  | 6      | 50.0   | 16.7   |
|          | {2,1}     | 2688          | 3               | 3728.8  | 4      | 27.9   | 25.0   |
|          | {2,2}     | 910.4         | Excess          | 2101.6  | Excess | 56.7   | /      |

In the scenario 1, the objective function is optimal when the both two vessels arrive at period 1 or 2. However, vessels are not allowed to arrive at the same period considering the workload of quay cranes and internal trucks. The excess means that although the imbalance of workload among blocks is reduced, the workload of loading and unloading at the same period is too large to be completed by existing yard crane. However, the experimental results show that the arrival period of vessels affects container allocation and yard crane deployment. Since import containers usually arrives at yard in large quantities, it is effective to avoid the overwork in a specific period if the containers are picked up in different time periods. Therefore, the timetable of vessels should be reasonably formulated, thus conducive to the optimization of objective function values.

| Scenario | Parameter | Proposed mode | Traditional mode | Gap (%) |
|----------|-----------|---------------|-----------------|---------|
|          | Imbalance of workload | Shifting distance | Imbalance of workload | Shifting distance |
| 2        | 0.3       | 1739.6        | 4               | 3294.2  | 5      | 47.2   | 20.0   |
|          | 0.4       | 1775.6        | 5               | 3551.6  | 6      | 50.0   | 16.7   |
|          | 0.5       | 2072.2        | 6               | 3369.6  | 6      | 38.5   | 0.0    |
|          | 0.6       | 1818.6        | 4               | 2756.6  | 5      | 34.0   | 20.0   |

We have concluded from scenario 2 that larger arrive interval of trucks are not conducive to the imbalance of workload. But compared with 0.5, the objective function is more optimal when arrival interval is 0.6. This is because many containers are not picked up within the planning period when the time interval increases to a certain value. Therefore, controlling the arrival interval of trucks by setting...
a reasonable booking share for truck appointment system is helpful to optimize yard resource allocation.

Table 6. The sensitivity analysis of scenario 3.

| Scenario | Parameter | Proposed mode | | | Traditional mode | | | Gap (%) | | |
|----------|-----------|---------------|---|---|----------------|---|---|-----------|---|---|
| 3        | (20,200)  | 1775.6        | 5 | 3551.6 | 6 | 50.0 | 16.7 | | | |
|          | (20,150)  | 1567.8        | 3 | 2697.6 | 4 | 41.9 | 25.0 | | | |
|          | (50,200)  | 1999.2        | 6 | 3982.2 | 6 | 49.8 | 0.0 | | | |
|          | (50,150)  | 1839.2        | 5 | 3470.8 | 5 | 47.0 | 0.0 | | | |

It is proved in scenario 3 that the number of containers was another major factor affecting the results. When the number of containers for each job is between 20 and 150, the imbalance of workload and shifting distance are optimal. In general, the objective function is optimal when the number of containers is small and the gap in the number of containers among jobs is small. This is because that the workload among jobs were little difference by themselves.

In conclusion, reasonable arrival interval of vessels, arrival interval of trucks and the number of containers of import jobs are helpful to better resource allocation. In addition, the objective function values of proposed mode are all better than the traditional mode. The above sensitivity analyses provide important guidance for the yard to make a scientific management strategy.

5. Conclusions
Making full use of truck appointment system could provide more accurate information for resource allocation. In this paper, we aimed at the minimum imbalance of workload among blocks and shifting distance of yard cranes. A two-stage optimization model for containers allocation and yard crane deployment was established. We adopted solver CPLEX to get optimal solution and made reasonable storage plans for import containers. It turns out that considering appointment information is able to avoid yard congestion caused by trucks and shifting yard cranes effectively, thus improving the efficiency of yard operations. In addition, sensitivity analyses were performed on the arrival interval of vessels, arrival interval of trucks and the number of containers of import jobs. Thus, it provides a reference for the storage management.

Acknowledgements
This work is founded by the National Natural Science Foundation of China (71302044, 71431001, 71572023, 71302085 and 71602130), Special fund for basic scientific research of Central High School (3132018113, 3132016301).

References
[1] Mao J, Li N and Jin Z H 2014 Optimization of the allocation of space resources in a container terminal based on mixed stacking pattern Journal of Dalian Maritime University 40 117-122
[2] Sharif O and Huynh N 2013 Storage space allocation at marine container terminals using ant-based control Expert Systems with Applications 40 2323-30
[3] Abbas A, Al-Bazi A and Palade V A 2018 Constrained fuzzy knowledge-based system for the management of container yard operations International Journal of Fuzzy Systems 20 1205-23
[4] Jiang X J and Jin J G 2017 A branch-and-price method for integrated yard crane deployment and container allocation in transshipment yards Transportation Research Part B 98 62-75
[5] Karam A and Eltawil A B 2016 A Lagrangian relaxation approach for the integrated quay crane and internal truck assignment in container terminals International Journal of Logistics Systems and Management 24 113-136
[6] Jin J G, Lee D H and Hu H 2015 Tactical berth and yard template design at container transshipment terminals: A column generation based approach Transportation Research Part
[7] Karam A and Attia E A 2018 Integrating collaborative and outsourcing strategies for yard trucks assignment in ports with multiple container terminals *International Journal of Logistics and Systems Management* (in press)

[8] Dhingra V, Kumawat G L, Roy D and Koster R d 2018 Solving semi-open queuing networks with time-varying arrivals: an application in container terminal landside operations *European Journal of Operational Research* **267** 855-876

[9] Zhen L 2014 Container yard template planning under uncertain maritime market *Transportation Research Part E* **69** 199-217

[10] Tan C M, He J L and Wang Y 2017 Storage yard management based on flexible yard template in container terminal *Advanced Engineering Informatics* **34** 101:113

[11] Azab A E, Karam A and Eltawil A B 2017 A dynamic and collaborative truck appointment management system in container terminals *ICORES* 85-95