IMPROVING THE PRE-NOTIFICATION PROTOCOL OF THE CONTAINERS PICK-UP PROCEDURE
An Agent-based Approach

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Abstract: As the global container traffic flow is consequently increasing, the maritime container terminals (CTs) are seeking new ways to improve their service. Taking the container import pick-up context as a test case, we show that operational service can be improved by re-evaluating the information protocol. In this study, we analyze and propose measures to improve the existing pre-notification approval protocol, the procedure that bridges the CT and the incoming drayage trucks (DTs) in the container pick-up process. We put the emphasis on the importance of considering the containers' exact location in the pre-notification approval request. The proposal is assessed by conducting agent based simulation experimentations. The results reveal the opportunities to improve the CT's performance in terms of the reshuffling frequency, the truck turn-around time, and the average queue length at the CT's gate-in, in favour of the proposal.

1 INTRODUCTION

The increasing container traffic has enhanced business opportunities for all businesses that support the supply chain, especially for the container terminals (CT) community. Nowadays, the CTs are expected to serve more transshipment requests within a shorter service period. While most CT operation problems are mitigated by focusing solely on the physical flow analysis, this study's main goal is to show that operational performance can also be increased by improving the information flow. As a test case, we have analyzed the existing pre-notification approval protocol for the container pick-up process. We put the emphasis on the importance of considering the containers' exact location in approving the pre-notification request sent by the freight forwarders. By conducting agent based simulation studies, we demonstrate that operational performance (i.e. reshuffling frequency, truck turn-around time, and truck queue length) can indeed be improved by improving the information protocol.

To present the study, the paper is organized as follows. In the next section, we discuss the related literatures. Then, we explain the existing container pick-up procedures. This is followed by problem identification and the solutions proposal sections. Then, we describe the agent based simulation setup, present the simulation results and discussion, and list some conclusions.

2 RELATED LITERATURE

The improvement of CT operation has received a lot of attention from the research community. For many years, this field has been dominated by operations research (OR) studies (Stahlbock & Voss, 2008). Although not as extensive as done by the mentioned school of thought, the studies that apply Agent Based Models (ABM) in tackling numerous CT operations have also emerged (Davidsson et. al., 2005). In the earliest phase, the ABM studies were mainly focusing on the conceptual level. For example, the work of Rebollo, et al. (2000) presents an ABM architecture concept for solving automatic transshipment problems for the operations of all four of the CT's sub systems: the marine side interface, the transfer system, the container storage system, and the landside interface. Another conceptual study

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is presented by Thurston and Hu (2002). They put forward an ABM architecture concept for handling three different operations: the containers' retrieval from the stacking yard, the containers' transportation between the yard and the quay area, and the containers' transfer from the quay side to the vessel.

More recently, more validated CT-ABM studies have emerged. These do not only propose ABM architecture concepts for specific operation application; validated studies normally also present simulation works to validate their proposals (Davidsson et. al., 2005). One good example is the work of Henesey (2006). In his study, he presents a thorough overview of the CT operations, proposes a concept of ABM architecture, and elaborates on several simulation studies focusing on numerous operational issues such as: vessel arrival sequencing, vessel berthing, inter-terminal transportation, etc. Another recent work is carried out by Winikoff et. al., (2011). They present an ABM open source emulation platform (*ContMAS)* that is intended as a decision support system for assessing different CT policies. Moreover, in their study, they present a negotiation-based module for container moves allocation to the CT's internal transporters and they also propose a genetic-algorithm based solution for allocating the containers in the yard.

We noted that most studies focus on the CT's marine interface operation (Henesey, 2006). The landside interface operation is largely unexplored. We have noted (only) one ABM study that analyzed the interface operations between the CT and the land carriers (Vidal & Huynh, 2010). Focusing on the containers' pick-up operation context, they have analysed the impact of applying different yard crane strategies to the drayage trucks' service time. Instead of solely focusing on the crane's operational strategy as was done in the study by Vidal and Huynh (2010), we have extended their research by concentrating more on the information protocol improvement issue.

3 PROBLEM DESCRIPTION

The CT conducts two services: the marine interface and the landside interface operations. The marine interface operations are all activities that correlate with the vessel service. The landside interface operations deal with the service of land connecting carriers (i.e. trains and trucks). In this study, we focus on the CT's landside interface operations. More specifically, we analyze the container pick-up process carried out by the drayage trucks (DTs).

The container pick-up process consists of two different procedures: the pre-arrival and the on-arrival procedures. In the following sections, we will discuss each procedure in detail and we will discuss the opportunity to improve operational performance of the pick-up process by synchronizing both procedures.

3.1 Container Pickup - Pre-arrival Procedure

Prior to the container pick-up by the DT, the freight forwarder has to finalize the pre-arrival formalities. The pre-arrival procedure, which is actually a request for pick-up confirmation, consists of several information exchange formalities. The formalities are regulated by the United Nations Committee for Electronic Data Interchange for Administration, Commerce, and Transport (UN/EDIFACT)'s regulation. Figure 1 represents the pre-arrival procedure.

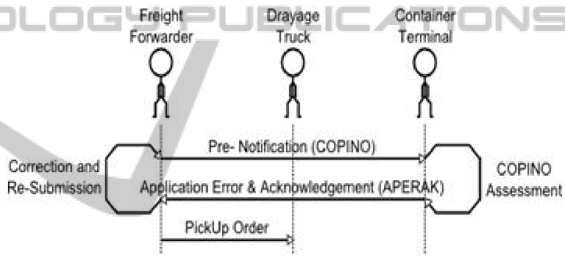

Figure 1: Container pick-up pre-arrival procedure.

As portrayed, firstly, the freight forwarder sends a container pick-up permission request to the CT in the pre-notification message format, COPINO. A COPINO message contains numerous details that have to be completed by the freight forwarder. In short, the COPINO confirms three important issues: the identity of the container, the identity of the DT that will pick up the container, and the proposed pick-up date. Note that an incomplete COPINO form may lead to request rejection.

Once the COPINO is received by the CT, several checks will be carried out, including the evaluation of the information details completeness, the presence of the container in question at the CT, the customs clearance procedures and some operational issues. Once all the checks have been finalized, the CT sends a reply message to the freight forwarder. The reply is written in an APERAK (Application Error and Acknowledgement) format. APERAK indicates the approval/rejection status of the COPINO.

Upon receipt of the APERAK, if the COPINO request has been approved, the freight forwarder can send an order to the DT for pick-up execution. However, if the freight forwarder receives an APERAK indicating COPINO rejection, a pick-up order will not be sent. The freight forwarder might review the reason for the rejection indicated in the APERAK, carry out corrective actions, and re-submit the COPINO for approval.

3.2 Container Pickup - On-arrival Procedure

In this section, we discuss the pick-up on-arrival operation. This procedure is only executed after completion of the pre-arrival procedure. From the CT's perspective, the on-arrival procedure starts when the DTs reach the gate-in area. As shown in Figure 2a, especially at peak hours, the DTs normally have to wait in a queue before receiving service at the gate.

Whenever it is a DT's turn, the gate-in officer will check the DT's documentation, ensuring that the DT's pick-up service request has already been pre-registered in the CT's EDI system (via the COPINO-APERAK mechanism). After finalization of the documentation check, the officer will give permission for service, and will show the DT where the container in question is located in the yard.

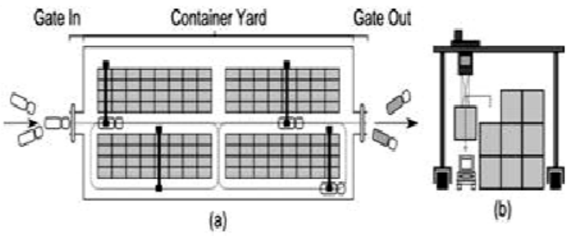

Figure 2: (a) Container pick-up operation overview (b) A stacker crane servicing a truck.

Upon the DT's arrival at the predefined location, the DT will wait for the quay crane to come and deliver the container. As shown in Figure 2b, once the crane approaches the DT and stops at the same row, the crane will then pick up the container from the stack and place it on the truck's trailer. After delivery of the container, the truck will go to the gate-out for the final administrative formalities before departing from the CT.

3.3 Problem Indication

Figure 2b shows the ideal situation of a truck pick-up service; it portrays a quay crane serving a container that sits on top of other containers and is right next to the DT. However, the service condition is not always ideal. Many of the quay cranes have to serve requests for containers that sit beneath other containers, which results in extra work. This type of service will occupy the quay cranes for a longer period than the one requesting for the topmost containers. Moreover, the request will also result in negative consequences for the other DTs as they will need to wait much longer in the queue. As a result, the total DT's turn-around time (i.e. the sum of the waiting time and the service time) also increases.

3.4 Solution Proposal

To mitigate the inefficiencies, we propose a measure to solve this issue. Our main concern lies with the existing pre-arrival procedure (section 3.1). As explained before, the approval of the pre-notification (COPINO) request is determined by the evaluation of two main aspects: the completeness of information details and the presence of the container in question. None of those aspects incorporate the container's exact location in the yard as an approval criterion. Thus, we put forward a proposal to incorporate the container's exact location in the pre-notification approval process. We propose that the CT's pick-up performance can be significantly improved if the pre-notification approval gives higher priority to the service requests for the topmost containers.

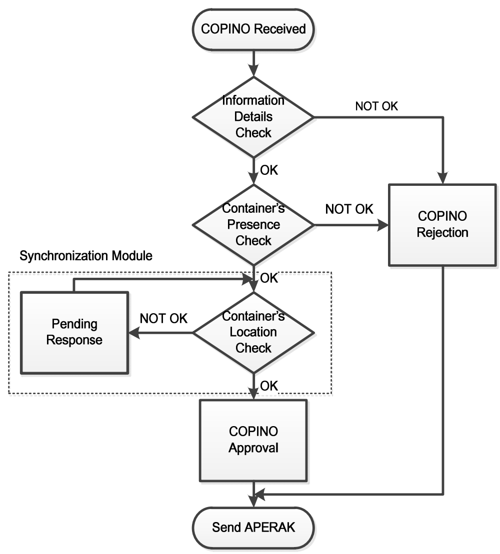

Figure 3: The insertion of the synchronization module to the existing COPINO approval system.

Responding to the stated supposition, we are proposing to embed a synchronization (container's location checking) module in the existing pre-notification approval system (see Figure 3). This module will give priority to any pick-up request for containers in the top layer. Since the introduction of such a module may initiate several follow up customizations in the existing EDI (electronic data interchange) system that may cost a considerable budget allocation, a preliminary feasibility study is required.

4 SIMULATION SETUP

For the feasibility study, we have conducted ABM simulations to assess the effectiveness of the proposed synchronization module to the CT's pick-up key performance indicators/KPIs (i.e. reshuffling frequency, truck turn-around time, and gate-in queue length). We define the reshuffling frequency as the fraction (percentage) of DT's request services that require reshuffle operations. The truck turn-around time is defined as the total time spent by the DT in the CT (i.e. the sum of the waiting time and the service time). The gate in's queue length is defined as the number of trucks waiting in front of the entrance gate.

For executing the study, we have extended the agent-based container terminal simulation platform developed by Vidal and Huynh (2010). To align the existing platform with our needs, we introduced several customizations. First, in the referred platform, 1000 containers are generated and distributed randomly across four yard blocks at the start of the simulation. In reality, the containers come off the vessels continuously. Thus, we continuously generate containers arrival during the simulation run at 2 hour intervals (7200 ticks) to maintain the containers' buffer level at 1000.

Another customization concerns the crane utility function definition. In the previous study, they analyze the operation of the cranes that work opportunistically based on three different utility functions: distance based (OB-1), time based (OB-2), and the combination of the two. Realizing the importance of the reshuffling factor, we extended the distance based utility by adding the extra reshuffling consideration factor, so that the crane will give priority to the truck that requires total minimum crane occupation. We call this strategy the *processing-time-based* utility function, OB-3 (see equation 1).

$$u_c^h = -\left[t_m \cdot d_{m(c,t)} + t_h \cdot n_h + t_r \cdot n_r + \sum_{i=1}^{4} x_i \cdot o_{i[p(c,t)]}\right] \qquad (1)$$

where:

u_c^h = *crane's utility*
t_m = *time required to move to the truck position.*
$d_{m(c,t)}$ = *the distance between the crane and the truck.*
t_r = *time required to do hoisting activity.*
n_r = *number of required hoisting activity.*
t_r = *time required to do reshuffling activity.*
n_r = *number of required reshuffling activity.*
x_i = *penalty.*
o_1 = *are there any other crane on path?*
o_2 = *turn is required?*
o_3 = *change heading is required?*
o_4 = *is it not the nearest truck?*

The final important customization is the implementation of the pre-notification synchronization concept. While in Vidal and Huynh (2010), the incoming trucks request random containers regardless of their position, in our study we introduce the synchronization policy (i.e. assigning the requests of the incoming trucks to the topmost containers). The share of trucks that follow the synchronization policy is controlled by the sync platform utilization variable. Sync platform utilization of 100% means that all incoming trucks obey the proposed policy, thus only those requesting the topmost containers will be served. On the other hand, sync platform utilization of 0% reflects the existing situation, where the pre-notification approval is given regardless of the container's position in the yard.

Recall that our main interest is to analyze the impact of applying the pre-notification synchronization concept to the CT's performance. In response, we test the performance of the system at three levels of sync platform utilization: 0%, 50%, and 100%. To test the system's performance under different levels of occupation, we set different levels for the CT's workload by simulating 4 truck arrival rate alternatives. In addition, we are also interested in comparing the performance of different crane's working modes (i.e. OB-1, OB-2, and OB-3). In this study, each crane agent will work opportunistically.

In total, we run 4*3*3 experiment set-ups (see Table 1). Each experiment run lasts for 201,600 ticks (7 working days). We treat the first 57,600 ticks (2 days) as the warm-up period. In addition, we employ 4 cranes, so that each crane will be responsible for one container block area (see Figure 2a). Note that other than the customizations stated in this paper, all simulation set-up details are similar to the benchmark paper.

Table 1: Simulation scenario.

Control Variable	Setup	Unit
Simulation Length	201,600	Ticks
Warm-up Period	28,800	Ticks
Sync Platform Utilization	0, 50, 100	%
Truck Arrival	0.25, 0.50, 0.75, 1	Trucks/ Minute
Crane's Utility Function	Distance Based (OB-1), Time Based (OB-2), Processing-Time Based (OB-3)	

5 SIMULATION RESULTS

Figure 4 indicates the impact of applying the pre-notification synchronization module to the reshuffling probability at different levels of utilization and different experimentation conditions. Without the application of the module (i.e. platform utilization of 0%), the reshuffling probability per container service is more than 40%. The ideal situation with a sync platform utilization of 100% will decrease the reshuffling probability to less than 1%. The mentioned situation is idealistic of course; however, as the results indicate, by applying the proposed module at only 50% use, we will have an opportunity to decrease the reshuffling probability between 23% and 30%, regardless of the CT's occupation level (i.e. truck arrival rate) and the crane's utility function.

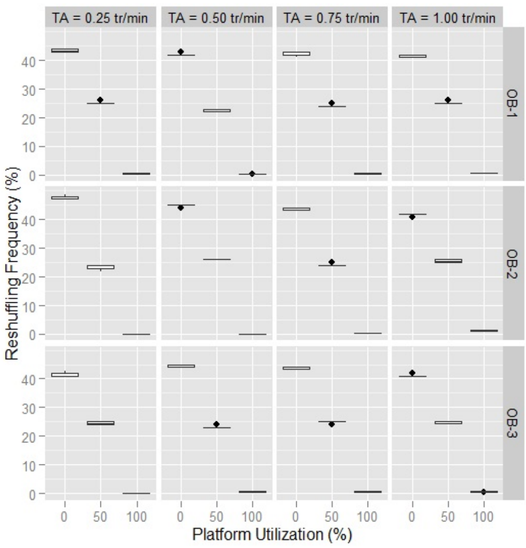

Figure 4: The impact of synchronization module utilization on the reshuffling frequency.

The application of the synchronization module will also improve the CT's performance in terms of the truck's turn-around time and the queue length in front of the gate in area. As shown in Figure 5 and Figure 6, the level of improvement increases as the truck arrival rate goes up. This means that the proposed platform offers bigger improvements when the CT's workload is high. As indicated also, the improvement magnitude grows even higher when the CT applies the OB-2 operational policy to the yard cranes. Recall that the OB-2 is indeed the existing crane strategy that is based on a first-in-first-out policy. At an extremely busy day (i.e. truck arrival = 1 truck per minute), if we apply the location synchronization module to the existing system (OB-2), we can improve the truck's turn-around time from 30 minutes to less than 12.5 minutes. The improvement in the truck turn-around time is consequently accompanied with the queue length reduction also (see Figure 6).

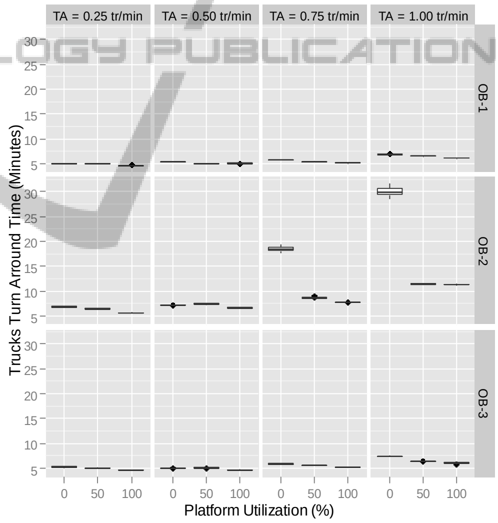

Figure 5: The impact of synchronization module utilization on the truck's turn-around time.

In comparison with the time based crane operation (OB-2), the distance based (OB-1) and the processing time based (OB-3), are more robust in coping with the CT's occupational intensity fluctuation. For both utility functions, as the truck arrival rate is increasing, the truck's turn-around time and the queue length is increasing moderately. Although both non-time based utility functions are already robust to the increase of CT's workload, the synchronization module application still brings considerable improvements at any level of occupancy. In general at each experimental condition setup, higher module utilization indicates better CT's performance.

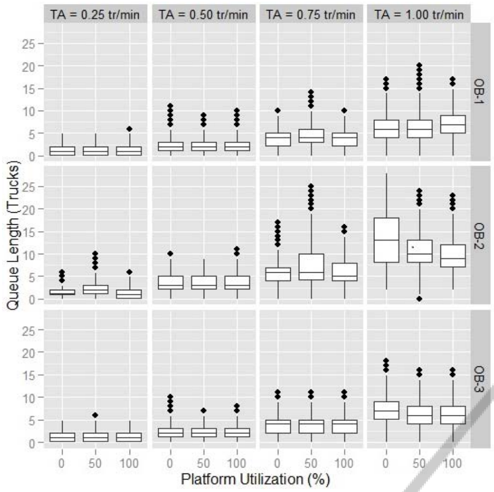

Figure 6: The impact of synchronization module utilization on the trucks' queue length.

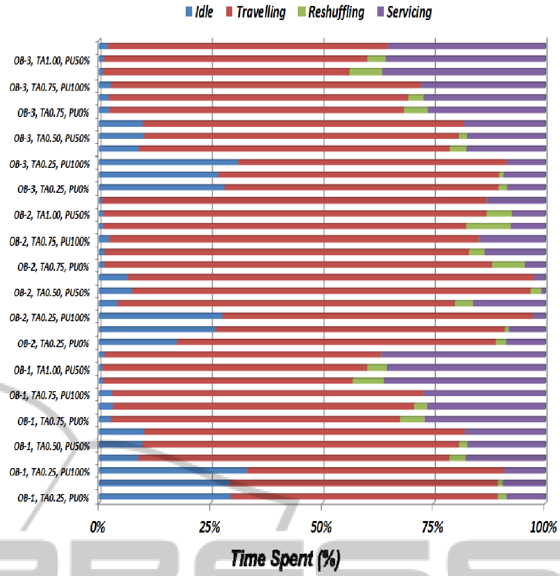

Figure 7: The overview of the yard cranes' activity.

6 DISCUSSION

Although the application of the synchronization module application is delivering better CT's performance at any experimental setup, the implementation of the processing time based crane strategy, OB-3, does not deliver considerable improvement in comparison with the distance based strategy, OB-1. This is contrary to our previous conjecture. We expect that by applying a crane's strategy which considers the holistic processing time, we will gain a better performance than applying the crane's strategy that omits the importance of the reshuffling activity.

Triggered by this question, we re-evaluated the simulation result data log and did an assessment to the time fraction that is spent by the yard cranes for conducting each activity (i.e. idle, travelling, reshuffling, and servicing).

As we analyse the activities composition (Figure 7), we remark that the time spent in conducting the reshuffling activities is surprisingly small. At high occupation level (e.g. 1 truck per minute), the cranes are allocating not more than 7.5 % of their time for operationalizing reshuffling activities. The number shrinks even lower when the truck arrival rate plummets and the sync module utilization increases. In addition, if we set the module utilization near to 100%, in principal there will be no (less) pick up requests that require reshuffling activity. In this situation, the introduction of the reshuffling factor applied in the processing-time based strategy will have diminishing impact in comparison with the distance based crane strategy.

7 CONCLUSIONS

In this study we analyze and propose the application of a synchronization module to improve the existing pre-notification approval protocol. We do preliminary study to assess the impact of applying a synchronization module to the CT's performance by conducting agent based simulation. The results reveal opportunities to improve numerous CT's performance by considering the container's physical location in the CT's pre-notification protocol. In this study we also introduce and assess the new processing time based crane operation strategy that behaves equally well with the distance based crane strategy.

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