

Towards Integration of Truck Appointment System and Direction for Future Research

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Abstract

Congestion in the container terminal stems from many external trucks queuing up to pick up or deliver containers. The congestion makes increasing of truck turnaround time which is a vital key performance indicator for both container terminal and trucking companies. Based on the results of the analysis obtained two alternative solutions; speed up container service time and control the arrival time of external trucks. Controlling the arrival time of external trucks can be done by implementing a truck appointment system. This paper categorized studies on truck appointment systems based on the methods including the determination of reservation quotas, scheduling and optimization of truck arrivals, minimization of empty truck trips, and others. The study of truck appointment systems can also be grouped based on the methodologies used, including queuing theory, mathematical models, simulations, and a combination of the two methodologies. In this paper, the research of integration and collaboration in a container terminal is also reviewed. In research on integrated scheduling in container terminals, most studies integrate scheduling in the seaside and yard area. Research that integrates scheduling starting from a seaside, yard area, and landside especially external truck operations is limited. In future research, the integrated scheduling that combines seaside and landside operations that emphasize the performance indicator of truck turnaround time and vessel berthing time is promising. The methodology to handle various stakeholder interests is agent-based. Besides, real-time scheduling is appropriate for the development of new smart port technology.

Keywords

Truck appointment system, container terminal, integrated scheduling, congestion in port, real-time agent-based simulation.

1. Introduction

The port is one of the main infrastructures in the logistics network in the world. From the UNCTAD (2021) statistics, the volume of international trade in goods carried by sea is around 80%. However, the increase in port activity causes congestion. One of the reasons for the congestion stems from many external trucks queuing up to pick up or deliver containers.

Congestion in the port can cause losses for the container terminal, shipping companies, and consignees. For the container terminal, the loss from the high level of congestion in the port results in the delay or at worst the cessation of operations at the stacking yard. This happened because many external trucks in the stacking yard made it difficult for the yard crane to move or could not move at all. In addition, the high level of congestion can make container terminals unattractive in the eyes of shipping companies (Parola et al. 2016). Shipping companies prefer to dock at ports with lower congestion levels because their customers, namely consignees, are more profitable to pick up or deliver containers at ports with lower congestion levels.

High levels of congestion in ports can also cause losses for shipping companies. Losses are experienced in the form of additional shipping time and costs required for the process of loading and unloading ships at the port than they should be (Gui et al. 2022). This is due to a decrease in the efficiency of port operations because of congestion. For example, if there is no congestion, the port can serve loading and unloading activities at a rate of 100 containers per hour, but there is a decrease to 60 containers per hour if there is congestion. High congestion at ports can also result

in changes to shipping lanes from what was previously planned (Notteboom 2006). Changes in the route can reduce the level of service of the shipping company itself.

Finally, the party who suffers losses due to the high level of congestion at the port is the owner of the container, consignee. High levels of congestion make the time it takes to pick up or deliver a container longer than it should. The additional time can cause an increase in the cost of fuel and truck drivers used. High congestion is also one of the causes of the scarcity of container supply (UNCTAD, 2021). The scarcity of containers makes the cost of renting a container higher because the demand for containers is more than the amount of supply available.

The level of congestion at the port can be measured using the average external truck turnaround time parameter. The overall turnaround time of the external truck is the time it takes for the external truck from entering the container terminal until it finishes picking up or delivering the container. The congestion makes increasing of truck turnaround time. Truck turnaround time is a vital key performance indicator for both the terminals and the trucking companies (Abdelmagid, Gheith, and Eltawil 2021). In addition, this high proportion of waiting time can also cause a decrease in the efficiency of activities at the container terminal stacking field (Zhao and Goodchild 2013).

Based on the results of the analysis obtained two alternative solutions; speed up container service time and control the arrival time of external trucks. There have been many research journals that have researched and discussed these two methods to reduce the average time value of external trucks at the container terminal. Controlling the arrival time of external trucks can be done by implementing a truck appointment system. Huiyun et al (2018) present the literature review of truck appointments at container terminals from the aspects of control and decision perspective, truck queuing structure, modeling methodology, and coordinated optimization. Three years later, Abdelmagid et al (2021) presents a comprehensive review of the external truck appointment scheduling problem. Each research proposes potential future directions. However, the integration of seaside and landside is insufficiently introduced in previous studies which leads to the future direction. Besides truck turnaround time, vessel berthing time is also the performance indicator of the container terminal. The idea of integrating these two indicators is prospective.

The evolution of the method of truck appointment system is presented in section 2. Section 3 includes the research of integration collaboration in container terminal. Section 4 presents the research gaps and direction for future research. Agent based truck appointment system is mentioned as the future direction of truck appointment system, Finally, the conclusions are illustrated in Section 5.

1.1 Objectives

This paper aims to present (1) a summary of existing publication regarding alternative solutions to reduce the average time value of external trucks at the container terminal, speeding up the service time of containers and controlling the arrival time of external trucks and review and (2) a review of existing publication regarding integration scheduling in the container terminal. Based on those two reviews, then this paper identifies the research gap in the are of truck appointment system and propose the future direction of the research in the research area.

2. Methodology

The procedure of this paper is identifying the journal articles by searching in the academic search engine such as google scholar and library databases such as Elsevier. This study is reviewed by using these keywords: *truck appointment systems, external truck, truck turnaround time* for the literature of truck appointment system and *integrated scheduling, container terminal, integration container terminal* for the literature of integrated scheduling in container terminal.

The journal articles were assessed from different point of view from the previous studies. The review of truck appointment system articles is investigated based on the method and methodology. The method categorized by two point of views, internal container terminal and external container terminal. From the internal container terminal, it proposed speeding up the service time while from the external container terminal, it proposed controlling the arrival times. The review of integrated scheduling in container terminal is investigated based on the area of study implementation in the container terminal namely seaside, yard area, and landside. The objective of the study is identified to review the whether the parameter related to the landside (truck appointment system) is included in the study of integration scheduling article.

Following the above procedure, gap analysis and state of the art of the research is identified.

3. Method of Truck Appointment System

There have been many research journals that have examined and discussed two methods to reduce the average time value of external trucks at the container terminal, either by speeding up the service time of containers or controlling the arrival time of external trucks. Controlling the arrival time of external trucks can be done by implementing a truck appointment system. Figure 1 shows the number of papers related to truck appointment system until this year including the review paper.

Speeding up container service time can be done by increasing the number of cranes operating in the stacking yard and minimizing the number of container relocations (Huynh et al., 2004) (Boysen and Emde 2016). Huynh et al (2004) conducted a study using the simulation method to determine the additional number of yard cranes to achieve the target average value of the overall external truck turning time. Based on this research, the additional number of cranes operating in the stacking yard can significantly reduce the average value of the overall turnaround time of external trucks. Then one of the problems that can increase the service time of external trucks at the container terminal is container relocation. When serving external trucks to pick up or deliver containers, sometimes the container storage position is located under other containers. As a result, the above containers must first be relocated to another place. Boysen & Emde (2016) discuss solving these problems using operational research methods so that they can speed up the service time of external trucks.

A truck appointment system is a system related to an operational decision-making process that considers two things, namely the time available for container terminal resources and trucking company resources (trucks, drivers, etc.) and container terminal capacity related to truck density and space storage (Abdelmagid, Gheith, and Eltawil 2021). Meanwhile, according to Huiyun et al (2018), the truck appointment system is a two-dimensional decision-making system based on the space-time concept that focuses on balancing the number of trucks arriving at the gate in the time dimension to reduce pressure on the dimensions of the container terminal port space.

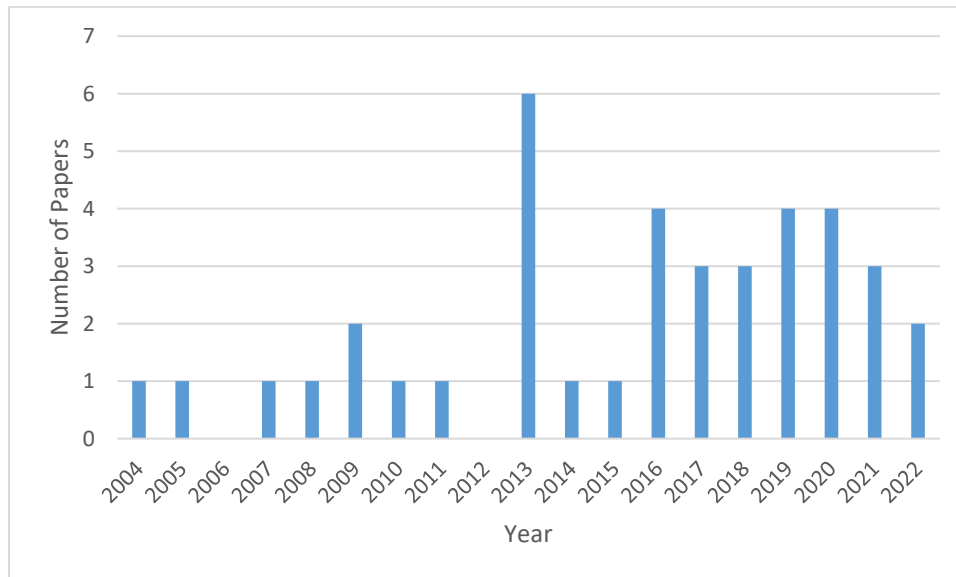


Figure 1. Number of papers related to truck appointment system

This paper categorized studies on truck appointment systems based on the methods include the determination of reservation quotas, scheduling and optimization of truck arrivals, minimization of empty truck trips, and other. The study of truck appointment systems can also be grouped based on the methodologies used, including queuing theory, mathematical models, simulations, and a combination of the two methodologies found in various literatures.

The first method, the container terminal set the number of trucks allowable to come during each time window namely quota. Chen et al (2013) proposed a method called 'vessel dependent time windows (VDTWs)' to control truck arrivals, which involves partitioning truck entries into groups and assigning different time windows to the groups. Gracia, et al. (2017), conducted a study on the effect of the gradual implementation of a truck appointment system and an external truck entry lane strategy on truck waiting times using the simulation method. The results of this study can be concluded that the more trucks that place orders on the truck appointment system, the lower the average waiting time. Meanwhile, Hyunh (2009) conducted a study on the effect of applying truck quotas to the average time value of external trucks using the simulation method. Based on this research, it was found that the optimal number of external truck quotas can reduce the average value of the overall turnaround time of external trucks. Torkjazi et al (2018) proposed approach to distribute the truck arrivals evenly throughout the day to avoid gate and yard congestion while considering the drayage truck tours. The second method, the truck appointment system set the truck arrival schedule based on the objective and constraint of container terminal and trucking company. The appointment scheduling system decided the truck arrival considering objective and constraint from the perspective of container terminal and trucking company.

External trucks are trucks owned by shipping companies and assigned to transport containers from depots to terminals and vice versa (Abdelmagid, Gheith, and Eltawil 2021). External trucks are trucks that are responsible for the operational activities of picking up containers between the terminal gates of the stacking field and vice versa (Huiyun et al. 2018). The external truck scheduling problem is determining the time slot for each truck in the process of picking up/delivering containers from/to the container terminal while taking into account the objectives and limitations of both the terminal and the trucking company (Abdelmagid, Gheith, and Eltawil 2021). According to Huiyun et al (2018), truck scheduling is the selection of the truck arrival time window which is a decision of the trucking company and port. An individual appointment system is where the arrival time is determined by the truck driver. The block system is where the arrival time is determined by the port. Meanwhile, according to Phan & Kim (2016) truck scheduling is defined as the selection of a truck operating schedule by considering the delivery order time window, truck travel time, and operating time at the terminal. Riaventin and Kim (2019) and (2019) study the scheduling method for truck appointment considering various variables. Meanwhile, Chen and Yang (2010) explores managing truck traffic based on time window management.

The third method used in truck appointment system is that truck companies and container terminals collaborate to determine truck arrival schedules and truck operations (Phan and Kim 2016). The mechanism used in it is a negotiation process between a number of trucking companies and class crates terminal operators to schedule the arrival of trucks at the port during peak hours. Phan and Kim (2015) propose a decentralized decision-making model to support negotiations between trucking companies and container terminal operators. Ramadhan and Wasesa (2020) proposes a non-centralized agent-based negotiation model on a truck appointment system by taking into account the estimated waiting time that trucks must spend in the container terminal area. The simulation results show that compared to the centralized appointment mechanism, the proposed multi-agent negotiation mechanism-based truck appointment mechanism results in a faster average waiting time at various truck arrival rates. Azab et al. (2019) proposed dynamic collaboration truck appointment system which integrated discrete event simulation model with a mixed integer programming model.

The fourth method is grouping the delivery of export container and pick up of import container to minimize the empty trips. Islam et al. (2013) is the earliest authors who study the empty container trucks problem. Authors explores a dynamic truck-sharing facility to assign probable export container to available empty slot of a container truck. Schulte et al. (2017) published the truck appointment model which taking into account empty trips and their impact on carbon emissions and costs. The methodology used is based on an optimization model using multiple traveling salesman problems with time windows. Empty trucks that do not carry containers can be caused by unbalanced freight traffic, poor planning, and a lack of coordination between truck drivers. The existence of these empty trucks causes a decrease in profit margins for truck operators, causes congestion, and causes significant emissions (Caballini et al. 2020). Caballini et al (2020) used a combination of operational research and data mining techniques to reduce empty truck trips and increase truck service levels (minimize desired time slot differences and minimize truck time at the container terminal) with a truck appointment system.

Dekker et al (2013) using concept of chassis exchange terminal - off-dock container terminal where truckers exchange chassis, to reduce the congestion. The summary of methods used in truck appointment system can be viewed in Table 1.

Table 1. Methods used in truck appointment system

| Author(s) (Year) | Speeding up the service time | Controlling arrival times | | | | Other | Methodology | | | |
|--------------------------|---------------------------------------|---------------------------|---------------------|-----------------------------|---|---------------------------------|--------------------------|---------|---------------------|--------------------|
| | | Quota | Truck scheduling | Collaboration scheduling | Combine export- import container | | Mathematical modeling | | Simulation Model | Queueing System |
| | | | | | | | Exact | Approx. | | |
| Huynh et al. (2004) | v | | | | | | | v | | |
| Boysen & Emde (2016) | v | | | | | | v | | | |
| Chen et al. (2013) | | v | | | | | v | | v | |
| Gracia et al. (2017) | | v | | | | | | v | | |
| Huynh (2009) | | v | | | | | | v | v | |
| Torkjazi et al. (2018) | | v | | | | v | | | | |
| Chen & Yang (2010) | | | v | | | | v | v | | |
| Riaventin & Kim (2019) | | | v | | | | v | | | |
| Yi et al. (2019) | | | v | | | | v | | | |
| Phan & Kim (2015) | | | | v | | v | | | v | |
| Phan & Kim (2016) | | | | v | | v | | | v | |
| Ramadhan & Wasesa (2020) | | | | v | | | | v | | |
| Azab et al. (2020) | | | | v | | v | | v | | |
| Islam et al. (2013) | | | | | v | Business Process Re-engineering | | | | |
| Schulte et al. (2017) | | | | | v | v | | | | |
| Caballini et al. (2020) | | | | | v | v | | | | |
| Dekker et al. (2013) | | | | | | v | | v | | |

Based on the methodology used in the truck appointment system, the research mainly uses mathematical modelling, simulation, queueing theory, or combination of two methodologies. Phan and Kim (2015, 2016) used mathematical modelling to describe the problem in their research. Murty et al (2005), Huynh et al (2005), Huynh et al (2009) used simulation. Chen et al (2013) and Zhang et al (2013) describe the problem using queueing theory. Azab et al (2019) proposed approach integrates a simulation model with an MIP model with objective of minimizing turnaround times of external trucks and inconveniences resulting from shifting the arrivals of external trucks away from their preferred arrival times.

From the view of objective function, the optimization problem of truck arrival scheduling can aim to maximize resource utilization and minimize truck waiting time, transportation costs, emissions, and empty trips, as well as other parameters. Chen and Yang (2010) build mathematical formulation for operations of export container trucks. The author's objective function is to minimize the total cost of export container operations.

4. Integration and Collaboration in Container Terminal

In research on integrated scheduling in container terminals, most studies integrate scheduling in the seaside and yard area. Chen et al (2013) presents the study and analysis between crane scheduling and yard truck scheduling in container terminal. It aims to improve coordination and productivity in container terminal. Meanwhile Lu and Le (2014) integrates scheduling quay crane, yard crane, and yard trucks which taking into account the uncertain factors. The uncertain factors that are not considered in the previous literature are yard truck travel speed, yard crane speed, and unit time of yard crane hoisting/lowering operation. Lu and Le developed PSO (particle swarm optimization) algorithm. Homayouni et al (2014) presents the genetic algorithm (GA) to integrated scheduling of quay cranes, automated guided vehicles (AGV), and handling platform in split-platform storage/retrieval system (SP-AS/RS). Considering ship operation area and yard operation area in terms of tactical decision, Liu et al (2016) propose joint optimization of berth allocation and yard allocation. Liu et al (2016) use the violation of the vessel's expected turnaround time windows

with timetables and yard transportation as the performance criteria in their model. Feng et al (2017) designs collaboration decision making framework integrated with hybrid NGS-II SA heuristics in hinterland logistics. Its objective function is to minimize total waiting time of barge during operations. Chargui et al (2019) proposes reactive multi-agent system for simultaneous scheduling of vessel, quay crane, operator, dan trucks. The performance indicator in the multi-agent system proposed by Chargui et al (2019) is productivity of port container terminals. Malekahmadi et al (2020) presents an mathematical programming model for integrated continuous berth allocation, quay crane assignment, and quay crane scheduling in container terminals. Muravev et al (2021) developed agent-based discrete-event simulation model to optimize the main parameters of intermodal terminals (dry port). Zehendner and Feillet (2014) combine sizing of a truck appointment system and the allocation straddle carriers. The summary of integration and collaboration research in container terminal can be viewed in Table 2.

Table 2. Integration and collaboration research in container terminal

| No | Author(s) (year) | Area | | | Objective Function | Methodology | | |
|----|----------------------------|-------------------|-----------|----------|---|-----------------------|-----------|------------|
| | | Seaside | Yard Area | Landside | | Mathematical modeling | Heuristic | Simulation |
| 1 | Chen et al. (2012) | v | v | | Improve coordination and productivity at the terminal | v | v | |
| 2 | Lu & Le (2014) | v | v | | Minimize the operating time of quay cranes, yard cranes, and yard trucks | v | v | |
| 3 | Homayouni et al. (2014) | v | v | | Minimize total travel time | | v | |
| 4 | Liu et al. (2016) | v | v | | Minimize ship waiting time deviations and total transportation distance in yards | v | v | |
| 5 | Feng et al. (2017) | v | v | | Minimize the total waiting time as barges come and go from the pier | v | v | |
| 6 | Chargui et al. (2019) | v | v | | Container terminal productivity | v | v | |
| 7 | Melekahmadi et al. (2020) | v | | | Minimize the total waiting time when ships come and go from the pier | v | v | |
| 8 | Muravev et al. (2021) | Dryport - seaport | | | Parameter optimization in intermodal terminal | | v | v |
| 9 | Zehendner & Feillet (2014) | | v | v | Determine the number of truck appointments to offer and an allocation of straddle carriers minimizing overall delays at the terminal. | v | | v |

5. Research Gap and Direction for Future Research

To the best of author knowledge, the agent based of truck appointment system is very limited. Ramadhan and Wasesa (2020) proposed an agent-based model of truck appointment system in the container terminal pick-up procedure. This study has several limitations such as the generations of the truck's appointment request are randomly generated, truck arrival is not set to a specific scheduling decision rule, and the waiting time estimations is rather simplistic based on the average truck's waiting time in that day. However, research that integrates scheduling starting from ship operations, yard operations, and landside operation especially external truck operations is limited. In the future research, the integrated scheduling that combines seaside and landside operation that emphasize the performance indicator of truck turnaround time and vessel berthing time is promising. The methodology to handle various stakeholder interest is agent-based. Besides, the real time scheduling is appropriate with the developing of new smart port technology.

6. Conclusions

In this paper, the method of truck appointment system has been presented. From the point of view integrated and collaboration scheduling, most research focus on seaside and yard area. The research gap comes from the method of

agent-based system which integrated scheduling to optimize truck turnaround time and vessel berthing time simultaneously which scheduled real-time.

Acknowledgments

We gratefully acknowledge the funding from ITB research grant under PPMI (Research, Community Service, and Innovation) 2021 Program”.

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Biography

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