DISCRETE EVENT SIMULATION OF TRUCK APPOINTMENT SYSTEMS IN CONTAINER TERMINALS: A DUAL TRANSACTIONS APPROACH

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1. ABSTRACT

Marine Container Terminals (CT) are vital hubs in the global maritime logistics network. They act as the link between sea-borne and landside-based operations. Effective planning and execution of drayage operations remain paramount in optimizing resource usage and enhancing port efficiency. Congestion remains to be a serious challenge in and around the CT. This is primarily due to the unmanaged arrival of External Trucks (ETs), which eventually leads to the buildup of lengthy queues at the gates of the CT and yard area. As a result, it detrimentally impacts the average Truck Turnaround Time (TTT) and the overall port efficiency. In response to the aforementioned challenge, this study seeks to develop a simulation model of a Truck Appointment System (TAS) that leverages a dual transactions approach to effectively mitigate congestion and further reduce the number of empty truck trips while performing pick-up or drop-off tasks. The outcomes of the study will be beneficial to both terminal managers and Trucking Companies (TCs). Firstly, port managers will be able to match the available yard resources with the requested appointments in advance to eliminate gate and yard queues and reduce waiting times. Consequently, trucks are expected to arrive at the terminal at the stipulated times to perform specific tasks. Secondly, the drayage operators are expected to improve the utilization of their trucks since the dual transactions approach allows truckers to drop off and pick up a container in a single trip, thus cutting down on empty truck trips.

2. INTRODUCTION

The growth rate in international trade has, as of 2022, stood at an average value of 11.45%, signifying an increase in millions of tonnes of transported goods in the form of exports and imports (United Nations Conference on Trade and Development 2022). Despite recent disruptions, including the COVID-19 pandemic, which impacted the global supply chains, sea-borne logistics have steadily picked up, depicting a clear sign of economic recovery. This has subsequently demanded better handling and operational efficiency in the CTs to match the increase in ship population.

CT can be divided into three sections: quayside, yard side, and landside (Fleming, Huynh, and Xie 2013). The quayside encompasses both the berth and the quay. The yard side comprises yard blocks that act as the storage area for the container blocks. It interacts with both the landside and the seaside. The ETs arriving at the landside enter the gate and proceed to the yard queue for service by a Yard Crane (YC). At the seaside, the quay cranes (QC) discharges containers from the ship and load them on the internal trucks (IT), which are then transferred to the yard blocks. Inside the CT, a road network connects the gate, yard, and quay areas. Truck congestion is one of the problem faced at the gate and the yard area of CTs. It is primarily attributed to the unmanaged influx of external trucks into the CT outside the appointed time, as provided by the terminal operator(Torkjazi, Huynh, and Asadabadi 2022). The presence of these queues causes significant snarl-ups in the vicinity, leading to longer waiting times and, as a result, disrupting the entire transportation process. Moreover, pollution due to carbon dioxide emissions is witnessed due to truck idling (Giuliano and O'Brien 2007). The truckers also incur costs and penalties due to waiting, demurrage, and inconvenience.

TTT is among the key performance indicators of an efficient port (Abdelmagid, Gheith, and Eltawil 2022). It may be defined as the total time an ET spends in the CT from entry to exit, performing the required tasks. Previous research has focused on minimizing the TTT to serve more trucks in each time horizon. Further, truckers are encouraged to complete dual transactions where possible to reduce the count of empty truck trips (Li et al. 2022).To overcome the above challenges, CTs have continuously adopted the use of TAS to manage the arrivals of trucks (Caballini et al. 2020). In a TAS, a trucker can book a preferred arrival time slot provided by the terminal operator before driving into the CT. Upon arrival, trucks travelling to the CT without a prior appointment will be turned away. This will smoothen the usual peak arrivals at a certain time of the day.

The effective administration of CTs, which serve as crucial nodes in the worldwide supply chain, has progressively started to rely on advanced approaches and scientific frameworks. TASs have become essential in addressing the prevalent challenges of truck congestion and operational inefficiencies in container terminals. These systems are based on the principles of optimization, queuing theory, and discrete-event simulation. This paper uses Discrete event simulation (DES) to study the impact of adopting dual transactions of ETs on the TTT and, by extension, port congestion. A simulation model was built to mimic the arrivals, entry of ETs into the yard area, container loading/unloading, and exit. Simulation experiments were conducted to verify the model performance given a set of hypothetical operational data. Statistics of the model cycle time for different replications were collected and analyzed accordingly.

The remainder of the paper is organized as follows: Section 3 discusses the literature review on TAS, Section 4 describes the problem under study, Section 5 discusses the simulation model development, Section 6 discusses the findings, and Section 7 outlines the conclusion and future research directions.

3. LITERATURE REVIEW

External truck appointment scheduling and optimization in CTs have attracted great interest among the research community. The study of the design and use of TAS for truck arrivals management in a CT can be further clustered with respect to the methodologies used, such as queuing theory, mathematical models, simulations, and a mix of the latter two methodologies as reported in the literature.

The establishment of optimum quota allocation using a Time Window (TW) control program was investigated by (Chen, Govindan, and Yang 2013). They use a non-stationary queuing model to estimate the truck queue length. Further, a vacation queuing model was also proposed by (Zhang, Zeng, and Yang 2019) to optimize a TAS to reduce the waiting times of the ETs at the gate and the Internal trucks (IT) at the yard. A Mixed Integer Quadratic Programming mathematical model is also formulated to minimize drayage operation time (Shiri and Huynh 2016). To demonstrate the TTT's variability, a stochastic TAS model was formulated and solved using the Sample Averaging Approximation (SAA) algorithm (Torkjazi and Huynh 2021).

During service delivery, the terminal operators must always consider the customer satisfaction level. A negotiation process is introduced to us by (Phan and Kim 2015) to smooth the arrivals of trucks during peak hours, considering the yard workload in the CT. Further, a collaborative framework for use in TAS is proposed by (Schulte, González, and Voß 2015), which aims to cut on empty trips, costs, and emissions. In extending the latter work, (Schulte et al. 2017) presented a graph-based mathematical model to optimize trucker collaboration and maximize revenue. A collaborative method for profitable trip sharing in drayage operations among truckers of multiple companies is given to us by (Caballini, Sacone, and Saeednia 2016). A mechanism to compensate competing carriers when they share trips is further presented to encourage collaboration.

Researchers have recently attempted to blend machine learning and optimization techniques to address CT congestion further to yield robust TAS. Regression methods were used to build a robust optimization model that minimizes the average TTT and truck deviation from their preferred arrival time while considering the uncertainty (Sun et al. 2022). Similarly, (Caballini et al. 2020) presented a two-phase approach that combines clustering analysis and lexicographical optimization to minimize TTT and reduce the number of empty truck trips. However, the empty truck trips can be reduced by adopting a dual transactions approach. A novel approach is proposed by (Li et al., 2022) to handle the truck arrivals in CT including those engaged in dual transactions. The three-level vocation queuing model estimates the internal truck and ET queuing times for single or dual operations. Results reveal a considerable decrease in the number of ETs completing dual transactions in the queue, demonstrating its usefulness in real-world operations.

The use of simulation to improve decision-making has remained popular due to the flexibility that comes along with its use and application to specific problems. A Limited Entering Time Slots method is introduced to us by (Do et al. 2016) to reduce truck and crane emissions. They use a Simulation-based genetic algorithm to obtain the near-optimal timeslot assignment. A DES model is presented by (A. E. Azab and Eltawil 2016) to investigate the effect of ETs' arrival patterns on the TTT and gate congestion. A simulation optimization iteration approach is proposed by (Zhou, Zhao, and Li 2021) to study the integration of yard allocation to address truck congestion problems in a CT.

The dynamic berth resources allocation problem was studied by (Ilati, Sheikholeslami, and Hassannayebi 2014) using a simulation-based optimization approach. The authors of (Peng et al. 2018) estimated the port network delay time which is challenging to compute theoretically owing to its complexity by using a simulation-based dynamic programming technique. In their study, (Zhou et al. 2018) also demonstrated that employing a simulation-based optimization technique allowed them to determine the ideal truck arrival process parameters in this particular context, hence maximizing congestion in transfer terminals.

After reviewing prior works, the existing TAS might be improved and re-designed to perform more effectively using simulation. In this paper, the dynamic factors that may affect congestion in CT including traffic delays while considering dual transactions approach was studied. This was achieved by modeling the road network using the blocks from the Road Traffic Library in the AnyLogic DES software. Furthermore, the results from this study were going to provide insight into the benefits of evaluating the effect of incorporating uncertainty on the performance of the schedules in a CT.

4. PROBLEM DESCRIPTION

The study assumed a conventional CT with a single gate of entry and exit gates, each with three counters of truck queue service, as shown in Figure 1. The CT also has eight-yard blocks (YB), three export blocks, and five import blocks as shown in Figure 2. Each block has a single YC to load and/or discharge the containers from the incoming trucks one at a time. Each YB has one exchange point where the truck stops and waits to be served upon reaching the assigned block.

The YBs are assumed to be equally spaced from one another and are arranged in a parallel 4-column by 2-row configuration. A road network complete with intersections which connects the yard area, and the gates was also modelled. The roads are bi-directional in nature to allow movements in both directions where necessary. The ETs are cleared to proceed to the YB queue for service after completing the relevant customs checks and document verification. The YC service is conducted on a First In First Out (FIFO) basis.

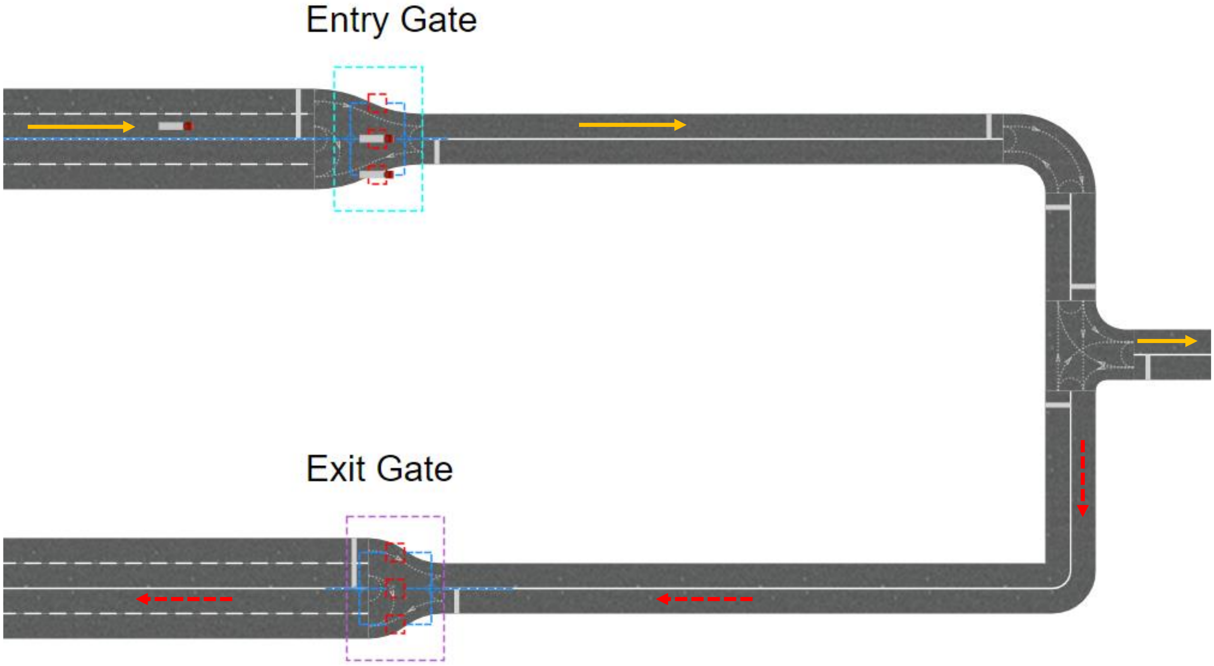

Figure 1: 2-D CT simulation model (gate area)

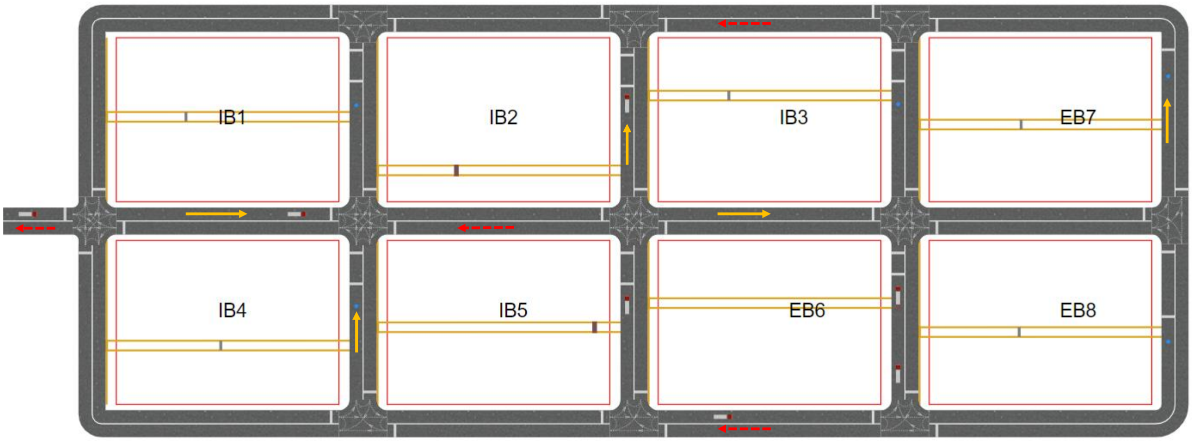

Figure 2: 2-D CT simulation model (yard area)

The arrival of trucks into the CT is assumed to be at random times throughout the scheduled time slots of the day with respect to their preferred times. A one-day horizon is divided into three shifts of 8 hours starting from midnight. Each shift consists of eight one-hour time windows (TW), available for trucker reservations. Before arriving at the CT gate, the truckers are expected to have indicated and reserved a slot in the schedule as provided for by the terminal operator. The trucks waiting time at the gate depends on the truck arrivals rate and the efficiency of operations at the gate, as the arrival of trucks is unpredictable and cannot be anticipated in advance (Chamchang and Niyomdecha 2021).

The buildup of queues at the CT gate is normally due to delays in gate service, which might be due to a lack of proper documentation or deviation from the terminal appointed time. Also, it might be due to delays in the service at the block because of YC breakdowns or that YTs are receiving priority service while attending a berthing vessel. A TAS simulation model must be developed to examine the impacts of adopting dual transactions on the efficiency of the CT.

5. DEVELOPMENT OF THE SIMULATION MODEL

5.1 Justification for using simulation modelling.

This paper uses DES as the preferred tool to model CT because the operations of interest can be abstracted as real-world systems involving entities, resources, and processes. Further, the processes, such as the arrival of ETs and the service durations at the gate and yard, remain uncertain. The movement of the entities through the model is assumed to follow a process-centric approach that entails a seize-delay-release mechanism. Since it is sometimes not feasible to conduct many physical experiments to test the different what-if scenarios in new or existing CTs, DES was chosen to model and test the dual transaction enhanced truck appointment schedule being studied in this paper.

5.2 Model assumptions

The model is built based on the following assumptions:

- Only one container can be loaded or offloaded to the ET at a time.

- An ET can drop off up to 2-20ft TEU equivalent containers per trip and collect up to 2-20ft TEU equivalent containers per trip.
- Failures and repairs are not considered for all the gate and yard equipment.

The assumed simulation model parameters are shown in the table below.

Table 1: Model input parameters

Gate parameters	
Shift 1 working hours	12:00 a.m. – 8:00 a.m.
Truck speed (max)	18km/hour (A. Azab, Karam, and Eltawil 2017)
Entry processing time	TRIA(0.5, 1, 4) minutes (Huynh 2009)
Exit processing time with no survey of container	TRIA(0.02, 0.099, 0.3) minutes (Huynn, Walton, and Davis 2004)
Number of gate counters at Entry	3
Number of gate counters at Exit	3
Yard parameters	
Number of import blocks (IB)	5 (Talaat et al. 2023)
Number of export blocks (EB)	3 (Talaat et al. 2023)
Number of Yard Cranes (YC)	8 (Talaat et al. 2023)
Unloading/Loading time	0.26+LOGN(0.941,0.519) minutes (Huynh 2009)
Yard bridge speed(Gantry travel) max	135m/min (KoneCranes 2021)
Trolley speed(max); with/without load	82m/min (KoneCranes 2021)
Hoist speed(max)with load	31m/min (KoneCranes 2021)
Road parameters	
Lane width	3.5m
Number of Gate Entry/Exit lanes	2

5.3 Logic modeling

The CT simulation model in this paper is developed using AnyLogic 8.8.4. It has a collection of libraries where one can find block elements to build a flowchart and space markup elements to build sophisticated animations. The process flow chart describing the sequence of events starting from the point when the trucks arrive at the CT, joins the gate queue for service, proceeds to the yard area for loading/unloading operation and exit/departure at the gate is as captured in Figure 3 below.

The movement of the entity throughout the model is defined by the sequence of the actions contained in the blocks. Prior to entering the scheduled YB queue for crane service, the entity(truck) checks against a set condition and proceeds to join the target queue if the condition has been satisfied. Else, it proceeds to the subsequent block until it finds a matching condition or exit the yard area and travel to the exit gate upon completion of assigned tasks.

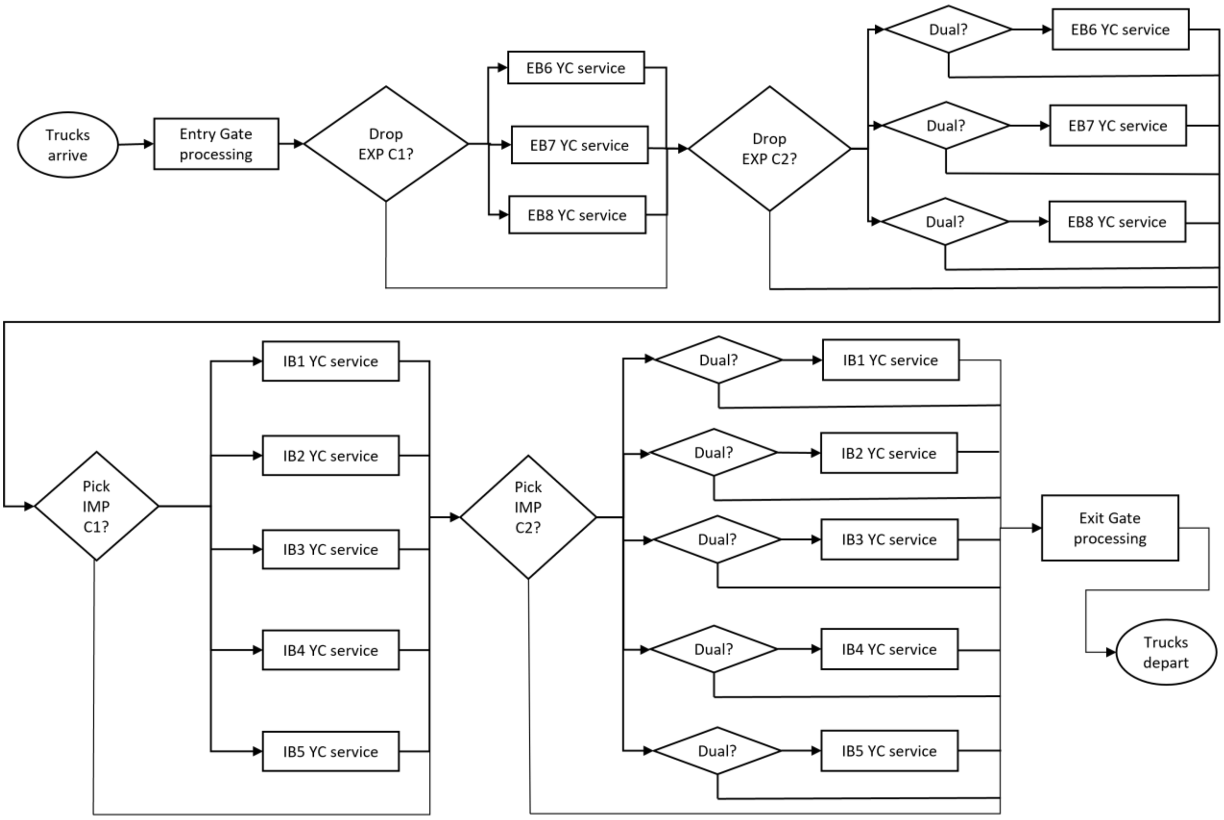

Figure 3: Process flow of container drop-off and pickup operations

The utilized libraries include Process Modelling Library (PML), Material Handling Library (MHL), and Road Traffic Library (RTL), as illustrated in Figures 5 as well. The entry/exit gates and yard blocks were built using PML, while the Cranes and their components were built using the MHL. The road network consisting of the roads, intersections, and stop lines was built using the RTL. AnyLogic also has 3D objects such as trucks and containers to facilitate the visualization of entities as they move through the model during animation as shown in Figure 4 below.

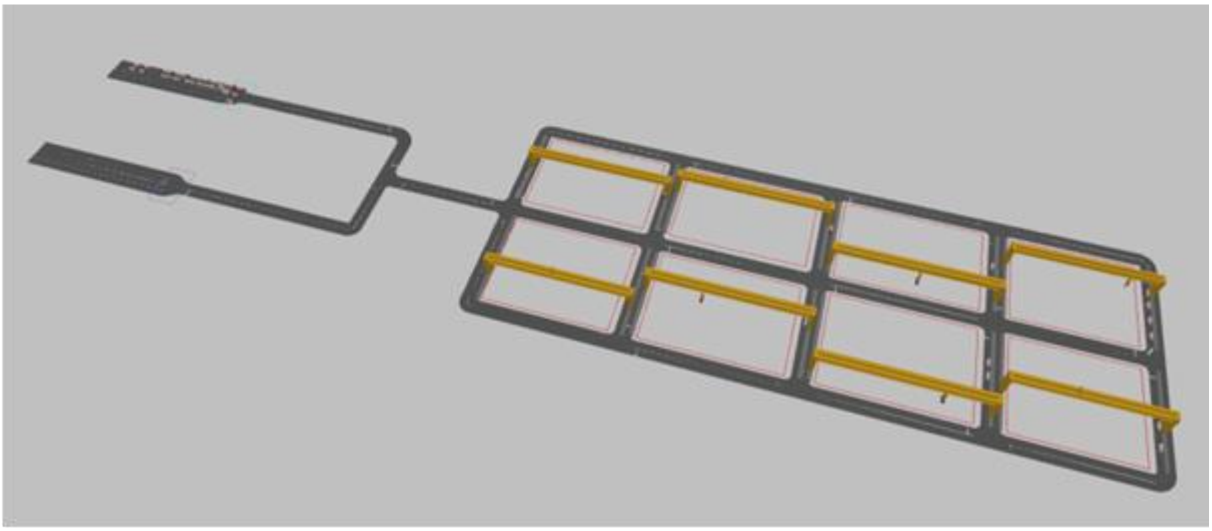

Figure 4: 3D-view of the CT simulation model

In the simulation model, the trucks are set to arrive at the CT entry gate based on an input tuple list obtained from work previously done by (Talaat et al. 2023). The tuple list in Table 2 summarizes each truck trip, including the container ID, preferred arrival TW and the designated YBs to visit according to the nature of the transaction type. For each instance, the arrival timestamps are randomly generated for each preferred TW.

To describe Table 2 further, an example of the first column can be selected and discussed as follows. Truck Trip No.1 involves a dual transaction trip in which the truck is expected to arrive at the CT at TW3 (which is between 2:00 a.m. - 3:00 a.m.) while carrying 2 Export Containers (ExpC). The first 2 ExpC are set to be offloaded at export block 7. The truck then proceeds to pick up 2 Import containers (ImpC) at import block 3 and travels to the exit gate. The truck trip is assigned a higher priority index of 2 since if it is of a dual transaction in nature and should be granted express service over single transactions in order not to wait for longer in the yard area.

Table 2: Tuple list

Truck Trip No.	Export	Import	A1	A2	A3	A4	Preferred TW	Priority Index
1	(2, 33)	(373, 391)	7	7	3	3	3	2
2	(280, 312)	(408, 661)	6	7	3	3	2	2
3	(335, 406)	(551, 565)	7	8	4	4	3	2
4	(509, 533)	(18, 124)	6	7	3	3	3	2
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
287	(None, None)	(544, None)	0	0	5	0	8	1

The processes of the YC in each block include loading and unloading, as shown in Figure 4, and movement from the pickup node to the yard block or vice versa. Moving the ET includes truck arrival from the source block, movement to the buffer area through the gate, waiting, movement to the block, loading and/or unloading, and exiting through the CT gate.

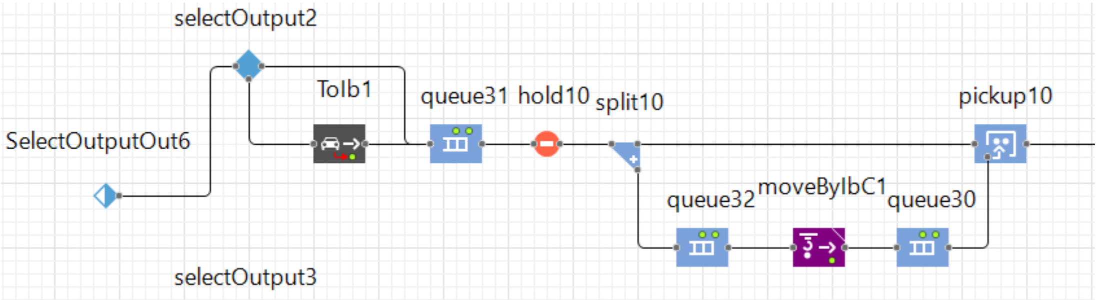

Figure 5: Single and dual transactions using RTL-PML-MHL

6. RESULTS

6.1 Simulation experiments

The simulation experiments were conducted on a desktop PC with the specifications: Lenovo, Core i7-10700, CPU at 2.90GHz 2.90GHz, 8GB RAM. The arrivals of the incoming trucks in each TW were randomized throughout the duration of the TW. The model was set to terminate upon the exit of the last truck at the exit gate of the CT. The statistics collected during the study include the cycle time of each incoming truck, representing the study's TTT. It includes the time the truck takes from when it joins the terminal gate queue, travels, and waits at the YB, performs pick-up and/or drop-off in the YB, travels to the exit gate, and leaves. In order to measure the individual TTT, trucks are assigned variables of start time, stop time and cycle time to record and store the values of the timestamps which are recorded as they enter the port gate and leave the exit gate upon completion of the scheduled tasks.

6.2 Simulation results

A random seed, 50 replications, fixed parameter (3 counters at both entry and exit gates) simulation run was conducted to obtain the measured values of TTT output value since the simulation model under study is stochastic. The counters are assumed to be open and functional throughout the entire simulation period. For every simulation run, the arrivals of trucks at the gate were modelled to follow a uniform random distribution. The gate counters processing and YC service times also follows triangular and log normal probability distributions as indicated in section 5.2, therefore yielding varying output values of TTT for different replications of a single simulation run. The mean values of TT of arriving trucks over time were then calculated over the entire replication length. Two scenarios were investigated in this study. The first one is the baseline scenario in which the trucks arrived at the CT within the preferred TW slots. The second scenario is when some of the trucks are assumed to have arrived outside the preferred TW due to unforeseen circumstances such as poor weather or traffic in access roads to the port which may result to a delay.

6.2.1 Scenario 1: Arrivals within the preferred TW

The arrivals of trucks into the Entry gate of the CT are modelled so as to follow a uniform distribution of with a minimum of 0 and a maximum of 60 minutes in correspondence to the preferred arrival TW. A delay block was introduced between the carSource and Entry Gate Service blocks so as to enable the randomly generated trucks to arrive at the gate at the desired TW. A cyclic event which occurs hourly throughout the simulation period was set up to introduce the required number of trucks into the model at specific times as per the input tuple list. The time plots of minimum, maximum and mean TTT for the 50 replications were subsequently plotted and presented as shown in Figure 6.

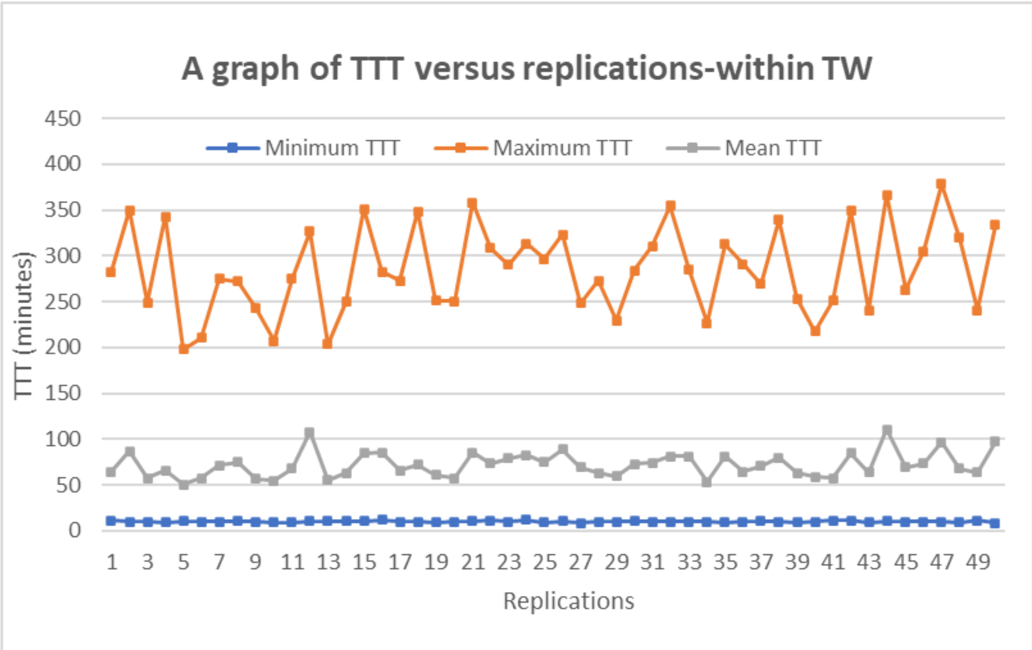

Figure 6: Line Plot of Average Truck Turnaround Times (Within the TW)

From the measured results, it can be reported from the data of maximum TTT that a higher and lower value of 378.17 and 198.02 minutes were recorded whereas from the data of minimum TTT, a higher and lower values of 8.644 and 11.25 minutes respectively were also recorded. The higher values which were observed in different replications possibly indicated the presence of relatively longer queue lengths in specific YBs during crane service. It could have been as a result of the arriving trucks joining the existing queues for either single transactions or a part of drop-off or pick-up tasks regardless of the priority level. It is also prudent to report that the simulation model in this paper maintained that the service of trucks at both the gates and yard area was conducted on a FIFO basis.

6.2.2 Scenario 2: Arrivals outside the preferred TW

Similar to Scenario 1 above, the arrival of trucks into the CT gate are modelled so as to follow a uniform distribution but with a minimum of 0 and maximum of 90 minutes which is outside the TW length of 1 hour. In this manner, a portion of trucks which were supposed to arrive at their preferred

TW definitely ended up receiving gate service in the succeeding TW. This set-up is analogous to a scenario where the trucks are first made to report to the Logistics Support Area(da Silva, Agostino, and Frazzon 2023) for pre-gate operations as they wait to join the gate queue. By doing so, the terminal operators will be able to manage the entry of trucks into the yard. In the eventuality, the truckers will be delayed slightly by a few minutes while getting to the CT gate. The time plots of minimum, maximum and mean TTT for the 50 replications were subsequently plotted and presented as in Figure 7. From the results of maximum TTT it can be deduced that a higher and lower value of 391.87 and 197.11 minutes were recorded whereas from the data of minimum TTT, 8.669 and 11.95 minutes respectively were recorded as higher and lower values.

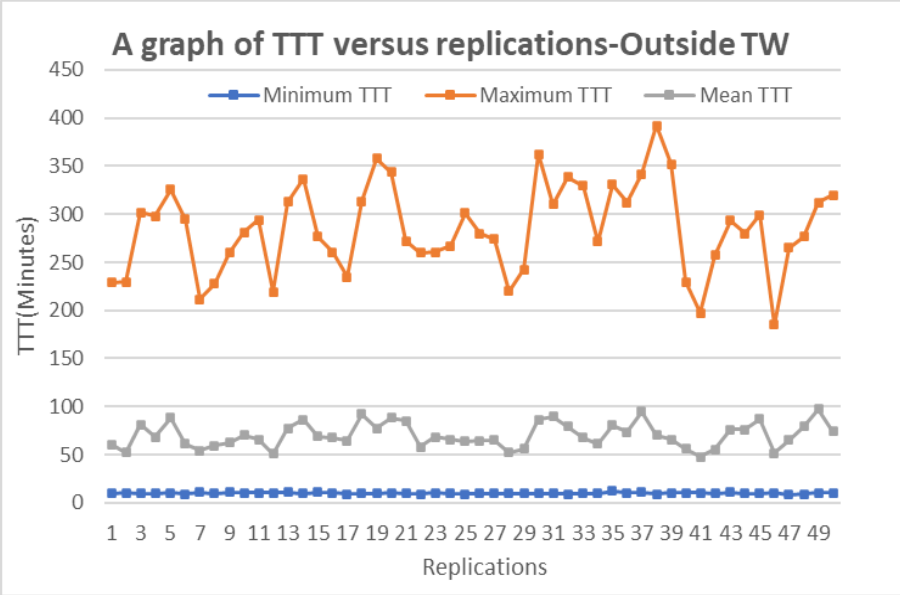

Figure 7: Line Plot of Average Truck Turnaround Times (Outside the TW)

The outlined values are slightly lower as compared to those of scenario 1 because of the advantage culminating from the slightly extended delay of trucks before being allowed in to proceed for the gate service. This limits the number of trucks getting into the CT yard area at a given time period. Just as in the latter scenario, trucks which are affected in most of the cases included the ones which were headed to a specific YB to perform a fraction of the dual transaction tasks (i.e. YB destination moves) and in the process it finds a queue of trucks already lined up. Therefore, limiting the entry of trucks to the yard area minimized the congestion at the subsequent blocks to be visited.

Also, from both Figures 6 and 7, the plot of minimum TTT for both scenarios appears relatively smooth and horizontal. The recorded values indicate that the minimum time the truck can spend within the CT for the given set of parameters lies within the presented range of values.

6.2.3 Mean TTT for 95% Confidence Interval

A 95% Confidence Interval (CI) for the multiple values of TTT for the 50 replications was constructed to obtain the mean TTT value as well as the upper and lower CI values. The calculated values for both scenarios were plotted and reported as shown in Figures 8 and 9. For scenarios 1 and

2, the mean TTT value of the from the mean values of the entire replications was found to be 71.961 and 70.286 minutes. It can also be observed from Figure 8 that scenario 1 records up to a peak value of close to 120 minutes in one of the replications as opposed to a value slightly above 100 minutes in scenario 2 for upper CI (95%) value.

Further, it can be seen that the gap between the limits for scenario 2 is slightly significant as compared to scenario 1. This implies that a slight delay in the entry times of trucks arriving at the CT gate has a positive effect on the time that it is expected to spend inside the CT. Nevertheless, it becomes a disadvantage to the terminal operator as the terminal gates have to be engaged until overtime hours since there still will be trucks waiting to enter by the end of the planned gate closing time. Further study should therefore be conducted to improve the operations at the gate including managing truck arrivals and entry in a manner that it can yield a TTT that is beneficial to both stakeholders.

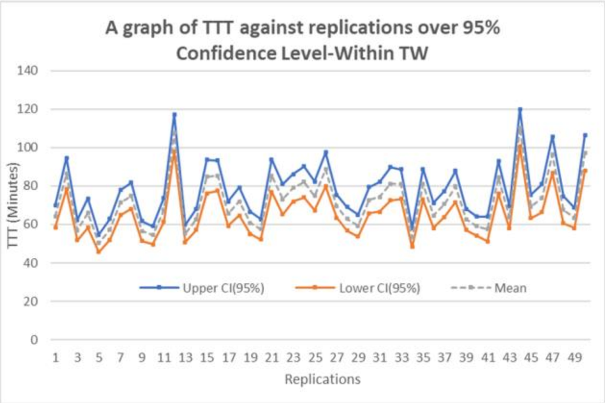

Figure 8: Plot of mean TTT for arrivals within TW

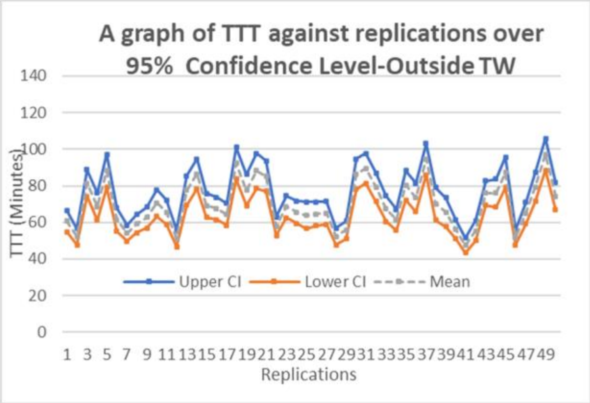

Figure 9 : Plot of mean TTT for arrivals outside TW

Further, the cumulative average TTT values for each outgoing truck were calculated using the data obtained from the measured values for the entire replications. The cumulative average TTT value is obtained by adding newly recorded TTT to the current average TTT and dividing it by the number of already served trucks. A 95% confidence interval was then also constructed to obtain the mean, upper and lower CI values and plotted as shown in figures 10 and 11 below.

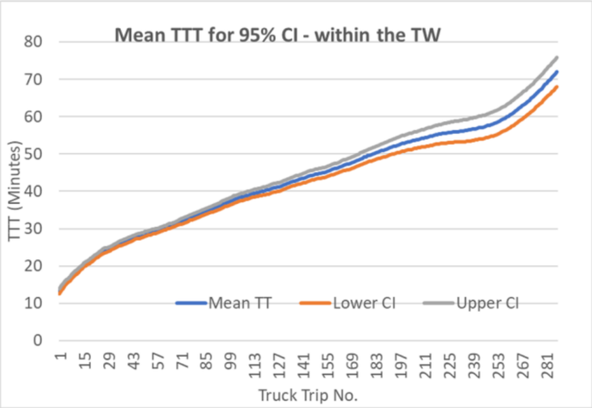

Figure 10: Plot of cumulative mean TTT over 95% CI for arrivals within TW

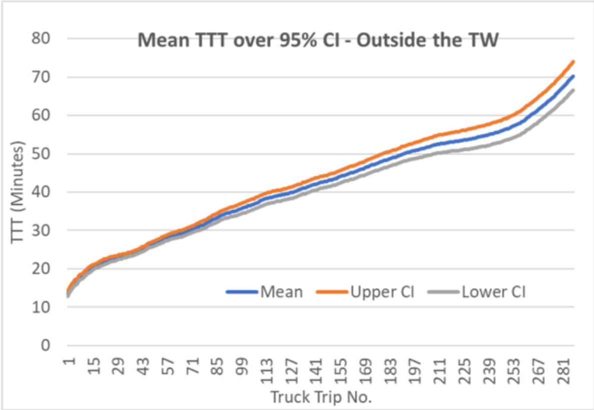

Figure 11: Plot of cumulative mean TTT over 95% CI for arrivals outside TW

6.3 Comparison with other studies

The below comparison in Table 3 is conducted to compare our outcome with a study conducted earlier concerning dual transactions. It is also paramount to remember that the proposed approach is conducted to evaluate the effect of uncertainty on the schedule's performance.

Table 3: Comparison with other studies

Approach	**Reference**	**Average Truck Turn Time**
Mathematical modelling with dual transactions	(Talaat et al. 2023)	56.67 minutes
Discrete Event Simulation with dual transactions	Our approach	71.96 minutes (Within TW) 70.29 minutes (Outside TW)

From the above data, it is evident that the mathematical modelling approach considering dual transactions with a similar arrival schedule yields comparatively shorter TTT by not more than 15.29 minutes as compared to our approach. Nevertheless, the disparity in results suggests that the results obtained from mathematical model might have not considered the uncertainty during model formulation which herein our study has been captured by the stochasticity of the random arrival, gate processing and yard cranes service times. Moreover, it is necessary to further conduct an evaluation of the underlying assumptions as well as refining the simulation methodology in order to realize improved TTT in CTs.

7. CONCLUSIONS

Terminal congestion has continued to elicit interest from academic researchers and industry practitioners. This is because there is a need to unlock the potential of the operations research techniques to optimize the CT operations and enhance overall efficiency. This study proposes a DES model built in AnyLogic software that leverages a dual transactions approach to minimize congestion in the CT. The model is applied to hypothetical CT data while considering other practical assumptions to verify the performance. Two scenarios were considered : first is when the trucks arrive normally and enter the gate according to the preferred schedule and second is when they arrive and enter the gate outside the preferred TWs. Results from the end of a 50-replications single simulation run with three gate counters yielded mean TTT values of 71.96 and 70.29 minutes for scenarios 1 and 2 respectively. In comparison with previous near similar works but with mathematical modelling approach, results showed that the proposed approach yielded a prolonged TTT by a value close to 16 minutes which may be due to the fact that they considered a deterministic case. Further research is being conducted to optimize the gate operations of the developed simulation model to achieve an enhanced TTT.

8. ACKNOWLEDGMENTS

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9. REFERENCES

[1] Abdelmagid, Ahmed Mohssen, Mohamed Samir Gheith, and Amr Bahgat Eltawil. 2022. "A Comprehensive Review of the Truck Appointment Scheduling Models and Directions for Future Research." *Transport Reviews* 42 (1): 102–26. https://doi.org/10.1080/01441647.2021.1955034.

[2] Azab, Ahmed E, and Amr B Eltawil. 2016. "Ahmed E. Azab, Amr B. Eltawil (2016). A Simulation Based Study Of The Effect Of Truck Arrival Patterns On Truck Turn Time In Container Terminals, ECMS 2016 Proceedings Edited by: Thorsten Claus, Frank Herrmann, Michael Manitz, Oliver Rose European Council" 2 (Cd): 7. https://doi.org/10.7148/2016-0080.

[3] Azab, Ahmed, Ahmed Karam, and Amr Eltawil. 2017. "A Dynamic and Collaborative Truck Appointment Management System in Container Terminals." *ICORES 2017 - Proceedings of the 6th International Conference on Operations Research and Enterprise Systems* 2017-Janua (Icores): 85–95. https://doi.org/10.5220/0006188100850095.

[4] Caballini, Claudia, Maria D. Gracia, Julio Mar-Ortiz, and Simona Sacone. 2020. "A Combined Data Mining – Optimization Approach to Manage Trucks Operations in Container Terminals with the Use of a TAS: Application to an Italian and a Mexican Port." *Transportation Research Part E: Logistics and Transportation Review* 142 (August): 102054. https://doi.org/10.1016/j.tre.2020.102054.

[5] Caballini, Claudia, Simona Sacone, and Mahnam Saeednia. 2016. "Cooperation among Truck Carriers in Seaport Containerized Transportation." *Transportation Research Part E: Logistics and Transportation Review* 93: 38–56. https://doi.org/10.1016/j.tre.2016.05.007.

[6] Chamchang, Panida, and Hussen Niyomdecha. 2021. "Impact of Service Policies on Terminal Gate Efficiency: A Simulation Approach." *Cogent Business and Management* 8 (1). https://doi.org/10.1080/23311975.2021.1975955.

[7] Chen, Gang, Kannan Govindan, and Zhongzhen Yang. 2013. "Managing Truck Arrivals with Time Windows to Alleviate Gate Congestion at Container Terminals." *International Journal of Production Economics* 141 (1): 179–88. https://doi.org/10.1016/j.ijpe.2012.03.033.

[8] Do, Ngoc Anh Dung, Izabela Ewa Nielsen, Gang Chen, and Peter Nielsen. 2016. "A Simulation-Based Genetic Algorithm Approach for Reducing Emissions from Import Container Pick-up Operation at Container Terminal." *Annals of Operations Research* 242 (2): 285–301. https://doi.org/10.1007/s10479-014-1636-0.

[9] Fleming, Matthew, Nathan Huynh, and Yuanchang Xie. 2013. "Agent-Based Simulation Tool for Evaluating Pooled Queue Performance at Marine Container Terminals." *Transportation Research Record*, no. 2330: 103–12. https://doi.org/10.3141/2330-14.

[10] Giuliano, Genevieve, and Thomas O'Brien. 2007. "Reducing Port-Related Truck Emissions: The

Terminal Gate Appointment System at the Ports of Los Angeles and Long Beach." *Transportation Research Part D: Transport and Environment* 12 (7): 460–73. https://doi.org/10.1016/j.trd.2007.06.004.

[11] Huynh, Nathan. 2009. "Reducing Truck Turn Times at Marine Terminals with Appointment Scheduling." *Transportation Research Record*, no. 2100: 47–57. https://doi.org/10.3141/2100-06.

[12] Huynn, Nathan, C. Michael Walton, and Jeff Davis. 2004. "Finding the Number of Yard Cranes Needed to Achieve Desired Truck Turn Time at Marine Container Terminals." *Transportation Research Record*, no. 1873: 99–108. https://doi.org/10.3141/1873-12.

[13] Ilati, Gholamreza, Abdorreza Sheikholeslami, and Erfan Hassannayebi. 2014. "A Simulation-Based Optimization Approach for Integrated Port Resource Allocation Problem." *Promet - Traffic - Traffico* 26 (3): 243–55. https://doi.org/10.7307/ptt.v26i3.1337.

[14] KoneCranes, Company. 2021. "Konecranes RTG : From the Creator of the Modern RTG Typical Dimensions." 2021. https://www.konecranes.com/sites/default/files/2021-06/RTG_typical_tech_specs_0.pdf.

[15] Li, Na, Hercules Haralambides, Haotian Sheng, and Zhihong Jin. 2022. "A New Vocation Queuing Model to Optimize Truck Appointments and Yard Handling-Equipment Use in Dual Transactions Systems of Container Terminals." *Computers and Industrial Engineering* 169 (April). https://doi.org/10.1016/j.cie.2022.108216.

[16] Peng, Yun, Wenyuan Wang, Xinglu Xu, Modi Chen, Xiangqun Song, and Xiangda Li. 2018. "A Simulation-Based Dynamic Programming Method for Interchange Scheduling of Port Collecting and Distributing Network." *Journal of Advanced Transportation* 2018. https://doi.org/10.1155/2018/4805250.

[17] Phan, Mai Ha, and Kap Hwan Kim. 2015. "Negotiating Truck Arrival Times among Trucking Companies and a Container Terminal." *Transportation Research Part E: Logistics and Transportation Review* 75: 132–44. https://doi.org/10.1016/j.tre.2015.01.004.

[18] Schulte, Frederik, Rosa G. González, and Stefan Voß. 2015. "Reducing Port-Related Truck Emissions: Coordinated Truck Appointments to Reduce Empty Truck Trips." *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 9335: 495–509. https://doi.org/10.1007/978-3-319-24264-4_34.

[19] Schulte, Frederik, Eduardo Lalla-Ruiz, Rosa G. González-Ramírez, and Stefan Voß. 2017. "Reducing Port-Related Empty Truck Emissions: A Mathematical Approach for Truck Appointments with Collaboration." *Transportation Research Part E: Logistics and Transportation Review* 105: 195–212. https://doi.org/10.1016/j.tre.2017.03.008.

[20] Shiri, Samaneh, and Nathan Huynh. 2016. "Optimization of Drayage Operations with Time-Window Constraints." *International Journal of Production Economics* 176: 7–20. https://doi.org/10.1016/j.ijpe.2016.03.005.

[21] Silva, Maurício Randolfo Flores da, Icaro Romolo Sousa Agostino, and Enzo Morosini Frazzon. 2023. "Integration of Machine Learning and Simulation for Dynamic Rescheduling in Truck Appointment Systems." *Simulation Modelling Practice and Theory* 125 (April 2022): 102747. https://doi.org/10.1016/j.simpat.2023.102747.

[22] Sun, Shichao, Yong Zheng, Yao Dong, Na Li, Zhihong Jin, and Qing Yu. 2022. "Reducing External Container Trucks' Turnaround Time in Ports: A Data-Driven Approach under Truck Appointment Systems." *Computers & Industrial Engineering*, 108787. https://doi.org/10.1016/j.cie.2022.108787.

[23] Talaat, Ahmed, Junichi Iijima, Mohamed Gheith, and Amr Eltawil. "An Integrated k-Means Clustering and Bi-Objective Optimization Approach for External Trucks Scheduling in Container Terminals." In *10th International Conference on Industrial Engineering and Applications, ICIEA 2023*, pp. 805-814. IOS Press BV, 2023.

[24] Torkjazi, Mohammad, Nathan Huynh, and Ali Asadabadi. 2022. "Modeling the Truck Appointment System as a Multi-Player Game." *Logistics* 6 (3): 1–25. https://doi.org/10.3390/logistics6030053.

[25] Torkjazi, Mohammad, and Nathan N. Huynh. 2021. "Design of a Truck Appointment System Considering Drayage Scheduling and Stochastic Turn Time." *Transportation Research Record* 2675 (12): 342–54. https://doi.org/10.1177/03611981211029643.

[26] United Nations Conference on Trade and Development. 2022. "Merchandise:Total Trade Growths, Annual." https://unctadstat.unctad.org/datacentre/dataviewer/US.TradeMerchGR.

[27] Zhang, Xiaoju, Qingcheng Zeng, and Zhongzhen Yang. 2019. "Optimization of Truck Appointments in Container Terminals." *Maritime Economics and Logistics* 21 (1): 125–45. https://doi.org/10.1057/s41278-018-0105-0.

[28] Zhou, Chenhao, Haobin Li, Byung Kwon Lee, and Zhipeng Qiu. 2018. "A Simulation-Based Vessel-Truck Coordination Strategy for Lighterage Terminals." *Transportation Research Part C: Emerging Technologies* 95 (July): 149–64. https://doi.org/10.1016/j.trc.2018.07.015.

[29] Zhou, Chenhao, Qitong Zhao, and Haobin Li. 2021. "Simulation Optimization Iteration Approach on Traffic Integrated Yard Allocation Problem in Transshipment Terminals." *Flexible Services and Manufacturing Journal* 33 (3): 663–88. https://doi.org/10.1007/s10696-020-09393-5.