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A REVIEW OF LOW CARBON PORTS OPERATION MODELING BASED ON CONTAINER TRUCK RESERVATION

Peng Gao, Lei Shi*, Qian Wang and Xiaodan Zhang

School of Economics and Management
Dalian University
No. 10, Xuefu Street, Jinzhou New District, Dalian 116622, P. R. China
*Corresponding author: Stonex4@126.com

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Abstract. *Congestion of container trucks at ports affects the port collection and distribution efficiency, and the exhaust gas emitted by the container trucks at the ports increases the air pollution of the ports and surrounding areas. Container truck reservation can relieve container truck congestion at the ports, and thus achieve the purpose of reducing port carbon emission. In this paper, on the basis of the research status on container truck reservation, the research of the current container truck reservation is introduced, relevant modeling methods are sorted, reviewed and associated with the research issues, and finally the future research is prospected.*
Keywords: Container truck reservation, Low carbon operation, Port congestion

1. **Introduction.** Current container terminal is an important node in the international logistics network, with the development of ship's large-scale trend gradually obvious, ship-upsizing tendency in shipping enterprises brings the scale economy effect and at the same time, also contributes to the port transportation road and congested roads connecting points traffic jamming, resulting in terminal set a large number of greenhouse gas emissions. Sim's research shows that the carbon emissions generated by the card-collecting operation account for a large proportion of the total carbon emissions of the container terminal [1]. For this reason, some studies suggest to reduce the emission of card collecting operation by optimizing vehicle driving path [2,3], or make better scheduling plans by improving the prediction accuracy of card collecting arrival [4]. In order to reduce the carbon emission of container trucks at ports and relieve port congestion, different countries take different countermeasures, a major one of which is container truck reservation. Container truck reservation systems are implemented successively in some domestic and foreign ports, like Port of Los Angeles and Port of Long Beach in USA, Vancouver Port in Canada and Port of Tianjin in China. The container truck reservation period corresponding to each container ship and the share of container truck reservation within the reservation period are arranged in an optimized way to reduce the container truck arrival amount in peak periods, thus achieving the purposes of relieving container truck congestion at the ports and reducing port carbon emission.

2. Research Status on Container Truck Reservation.

2.1. Container truck reservation mechanism.

Researches of container truck reservation aim to reduce port congestion and carbon emission of container trucks at ports. External container trucks are dispatched on the basis of port characteristics, port capabilities and container truck arrival characteristics. Container trucks are usually reserved in such a way: a reservation share, i.e., acceptable amount of incoming and outgoing

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container trucks is set for each period at the container ports, and the truck drivers (or fleets) choose the period of arrival through the reservation system; when a period is full, the drivers choose other periods; after successful reservation, they arrive at the ports at the reserved periods to start operation. Acceptable amount of container trucks is set for different periods to reduce the arrival amount in peak periods. It is an effective way to reduce port congestion and improve the operation efficiency. Currently, researches of the container truck reservation mechanism mainly focus on determination of the reservation share and formulation of the reservation strategy.

2.2. **Researches of container truck reservation share.** To determine the reservation share reasonably, it is necessary to determine how many periods a day is divided into and acceptable truck reservation amount in each period, so as to shorten the waiting time of the trucks at the ports [5]. Zeng et al. try to describe the status of container truck in the process of terminal services by establishing based on basket Chandy Muntz Palacios (BCMP) secondary queuing network and non-stationary queuing model, and therefore establish theories of container truck reservation optimization model to optimize the reservation share of container trucks in various time periods [6,7]. The current researches of reservation share mainly focus on truck reservation amount in each period. Compared to that, researches on reservation period segmentation are less. That is because, each reservation period has almost the same length, while the truck arrival amount in each period is relatively random. Therefore, it is easier to determine the reservation periods in a day than the reservation amount. Container truck reservation share is broadly researched currently, while researches on the reservation period length are insufficient. The latter also plays a very important role in improving the truck reservation system.

2.3. **Researches of container truck reservation strategies.** The container truck reservation strategy affects the truck arrival distribution. The reservation strategy includes control of interaction cost of the container trucks at the ports [8,9], truck arrival within designated time windows [10,11], design of the truck reservation strategy [12,13], etc. Container truck reservation is similar to out-patient reservation. The nature of the two lies in resource distribution under uncertain conditions in consideration of benefits of the two parties, aiming to optimize the reservation system with regard to the established performance indexes by deciding the dispatching schemes. The differences between the two are that, patients can better control their own arrival than the trucks, while truck arrival is affected by the drivers, city traffic, weather and other external factors. Therefore, it is hard for the trucks to arrive at the ports at designated time points. In the current researches of the container truck reservation strategy, researches on cost control are more than those on the other two aspects, since by describing the truck queuing process, it is easy to find out factors affecting port and truck cost changes and to establish cost functions, and the advantages of the reservation system are directly reflected.

3. **Researches of Container Truck Reservation System Models.** Reservation service means that the service system is reasonably operated by using the approaches or skills of the service providers within pre-determined time periods under designated environmental conditions, so that the service objects are served in order. The earliest reservation service was the research of scholars Bailey and Lindley on out-patient reservation in 1952. It was gradually applied to container truck reservation at ports. The current researches on container truck reservation models can be roughly categorized into queuing models, mathematical programming models and revenue management models.

3.1. **Researches based on queuing models.** Researches of container truck reservation based on the queuing models mainly aim to formulate a truck reservation strategy such that one of the indexes of the queuing system is optimized, e.g., the queue waiting time,

including optimization of truck arrival and reservation intervals. Due to the similarity of truck reservation to out-patient reservation, the modeling idea of the latter is referenced in some researches. By referencing the queuing model of out-patient reservation, Chen et al. changed the original M(t)/M(t)/1 queuing at the gate into more practical M(t)/M(t)/C, to optimize truck arrival, so as to minimize inconvenience to the truck drivers and total queue waiting time of the trucks [14]. On the basis of the research of Chen et al., Zeng et al. established a BCMP queuing model to shorten the turnover time of external trucks at the ports and optimize the reservation share in each period [6]. By referencing the stationary multi-server arrival queuing model, Guan and Liu analyzed the gate operation cost and truck waiting cost [10].

The queuing model of truck reservation is classified by arrival distribution, service condition, queuing network type and research issue and listed in Table 1. It can be seen that most of the queuing models target at truck reservation share, and the queuing models have been widely applied in truck reservation.

Table 1. Classification of queuing models of container truck reservation

Queuing model research	Arrival distribution	Service condition	Queuing network type	Research issue
Moghadam et al. [5]	Stationary arrival	Single-Server	Primary queuing network	Reservation share
Guan and Liu [10]	Stationary arrival	Multi-Server	One-stage queuing network	Reservation strategy
Chen et al. [14]	M(t)/M(t)/C	Multi-Server	Primary queuing network	Reservation share
Vlugt [15]	Poisson arrival and uniform arrival	Multi-Server	Two-stage queuing network	Reservation strategy
Chen et al. [11]	Nonstationary arrival	Multi-Server	Two-stage queuing network	Reservation strategy
Zeng et al. [6,7,16]	Nonstationary arrival	Multi-Server	Two-stage queuing network	Reservation share

3.2. **Researches based on mathematical programming models.** Researches of reservation based on mathematical programming models aim to find out the optimal reservation scheme by certain criteria under designated constraint conditions (charge desks, gates and other resources), including the optimal reservation amount and reservation period length. Namboothiri and Erera constructed a container truck dispatching model by using integer programming to research the influence of truck reservation to fleet transportation efficiency [8]. The result showed that if the throughput of container trucks at the ports increased by 30%, the production capability of truck companies would increase by 10%-24%. Phanthi and Kim used the minimal sum of truck arrival and waiting cost as the target function to establish a nonlinear integer programming model to optimize the truck arrival amount at each yard within each time window [17]. In order to shorten truck queuing time and reduce pollutant emission caused by it, Zeng et al. established a bi-level programming model for truck congestion charging to determine the optimal congestion charge [7].

3.3. **Researches based on revenue management models.** Revenue management models are a kind of models seeking for maximum revenues, in which different price standards are implemented for customers on the basis of different customer demand characteristics and price elasticity, to develop potential market demands to the largest extent and increase the revenues.

Originally, revenue management models were also used for out-patient reservation. To determine the optimal patient reservation amount and to achieve the highest hospital revenue, LaGanga and Lawrence established a revenue management model to decide the amount of optimally scheduled patients and corresponding scheduling schemes [18]. Currently, the revenue management models are also broadly used in container truck reservation. Targeting at the highest yard revenues of the ports, Asperen et al. estimated the influences of the container truck reservation strategy to yard storage rules [9]. They found that if the truck departure time was informed in advance, the yard storage efficiency wound be remarkably improved and the shift rate would be reduced. In view of the similarity of truck reservation to out-patient reservation, in consideration of possible situations like late arrival of the trucks and no arrival with reservation, Huynh and Walton established a revenue management model to compare two strategies (individual reservation and block reservation), aiming to achieve the lowest costs of the ports and fleets [13].

Researches of the container truck reservation strategies through mathematical programming models and revenue management models are classified as follows in Table 2.

Table 2. Classification of models of container truck reservation strategy

Model type		Reference	Research issue
Mathematical programming model	integer programming	Namboothiri and Erera [8]	Cost control
	nonlinear integer programming	Phanthi and Kim [17]	Cost control
	bi-level programming	Zeng et al. [12]	Strategy design
Revenue management model		Asperen et al. [9]	Cost control
		Huynh and Walton [13]	Strategy design

It can be seen in Tables 1 and 2 that the current researches on container truck reservation mainly focus on the reservation share and control of truck/port costs, and there is a small amount of literature on researches of truck reservation strategies, especially of reservation strategy design. In the current truck reservation researches, the queuing models are used the most. Research models of interaction costs are widely applied, the queuing, mathematical programming and revenue management models are all discussed, and the queuing models are inclined to researches of the reservation share.

4. **Summary and Prospect.** It can be found in the review of the current container truck reservation that, in most of the current researches, the queuing theory is used to formulate preliminary reservation strategies, and there is a large amount of researches on the reservation share and cost control of the truck reservation system. However, the fact that the shortest truck waiting time does not ensure uniform truck arrival is neglected in the researches based on the shortest truck waiting time or lowest system costs. Besides, it is common that the trucks arrive late, break the appointment or arrive at random without reservation due to the traffic, weather or other external factors. By referencing relevant researches on out-patient reservation, the future researches will focus on re-reservation or automatic delay to the next period in these circumstances. The current researches on the reservation system mainly regard the container ports as the subjects without giving consideration to the subjective decisions of the container yards and truck drivers. With the rise of the game theory, the focus will lie in use of queuing game to make dynamic decisions between the container yards and ports.

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REFERENCES

[1] J. Sim, A carbon emission evaluation model for a container terminal, *Journal of Cleaner Production*, vol.186, pp.526-533, 2018.

[2] M. Sha, T. Zhang, Y. Lan, X. Zhou, T. B. Qin, D. Y. Yu and K. Chen, Scheduling optimization of yard cranes with minimal energy consumption at container terminals, *Computers & Industrial Engineering*, vol.113, pp.704-713, 2017.

[3] L. Heilig, E. Lalla-Ruiz and S. Voss, Multi-objective inter-terminal truck routing, *Transportation Research Part E – Logistics and Transportation Review*, vol.106, pp.178-202, 2017.

[4] A. Hill and J. W. Boese, A decision support system for improved resource planning and truck routing at logistic nodes, *Information Technology & Management*, vol.18, no.3, pp.241-251, 2017.

[5] M. K. Moghadam, J. Sayareh and S. N. Amin, A simulation framework for optimising truck congestions in marine terminals, *Journal of Maritime Research*, vol.7, pp.55-70, 2010.

[6] Q. C. Zeng, X. J. Zhang and W. H. Chen, Optimization model for container truck reservation at ports based on BCMP queuing model, *Journal of Systems Engineering*, vol.28, no.5, pp.592-599, 2013.

[7] Q. C. Zeng, W. H. Chen and X. P. Hu, Optimization model and algorithm for external container truck reservation at container ports, *Chinese Journal of Management Science*, vol.23, no.10, pp.125-130, 2015.

[8] R. Namboothiri and A. L. Erera, Planning local container drayage operations given a port access appointment system, *Transportation Research Part E: Logistics and Transportation Review*, vol.44, no.2, pp.185-202, 2008.

[9] E. V. Asperen, B. Borgman and R. Dekker, Evaluating impact of truck announcements on container stacking efficiency, *Flexible Services & Manufacturing Journal*, vol.25, no.4, pp.543-556, 2013.

[10] C. Guan and R. Liu, Container terminal gate appointment system optimization, *Maritime Economics & Logistics*, vol.11, no.4, pp.378-398, 2009.

[11] X. Chen, X. Zhou and G. F. List, Using time-varying tolls to optimize truck arrivals at ports, *Transportation Research Part E: Logistics and Transportation Review*, vol.47, no.6, pp.965-982, 2011.

[12] Q. C. Zeng, W. H. Chen and L. Huang, Congestion charging model and algorithm for container trucks at container ports, *Journal of Dalian University of Technology*, no.1, pp.73-80, 2015.

[13] N. Huynh and C. M. Walton, *Improving Efficiency of Drayage Operations at Seaport Container Terminals Through the Use of an Appointment System*, Springer, New York, 2011.

[14] G. Chen, K. Govindan and M. M. Golias, Reducing truck emissions at container terminals in a low carbon economy: Proposal of a queueing-based bi-objective model for optimizing truck arrival pattern, *Transportation Research Part E: Logistics and Transportation Review*, vol.55, no.6, pp.3-22, 2013.

[15] D. Vlugt, Truck congestion at and in the terminal – A simulation study, *Journal De Physique*, vol.35, no.3, pp.193-198, 2009.

[16] Q. C. Zeng, X. J. Zhang and Q. Zhang, Container truck optimization model at ports with cooperative services of internal and external container trucks, *Journal of Traffic and Transportation Engineering*, vol.16, no.1, pp.115-122, 2016.

[17] M. H. Phanthi and K. H. Kim, Redistribution of truck arrivals to minimize congestion at container terminals, *Proc. of International Forum on Shipping, Ports and Airports (IFSPA)*, Hong Kong, China, pp.199-207, 2013.

[18] L. R. LaGanga and S. R. Lawrence, Appointment overbooking in health care clinics to improve patient service and clinic performance, *Production & Operations Management*, vol.21, no.5, pp.874-888, 2012.