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Data and model dual-driven approach optimizing appointment quota of external container truck

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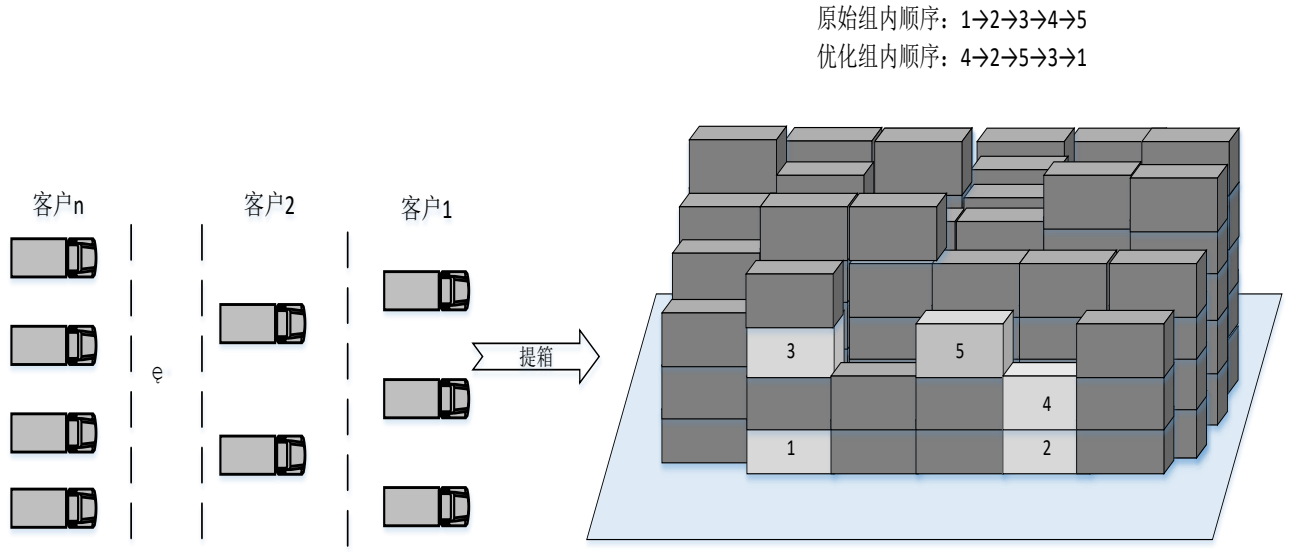
Introduction

Non-Uniform Arrival of External Container Trucks

External Truck Arrival Sequence Directly Affects Container Yard Reshuffle Operations



Introduction

Port Traffic Congestion

(1) Port Authority Constraint
(2) Rush Time Charge
(3) Truck Arrival Appointment

Truck appointment process

Guidance Information

Arrival Period Selection

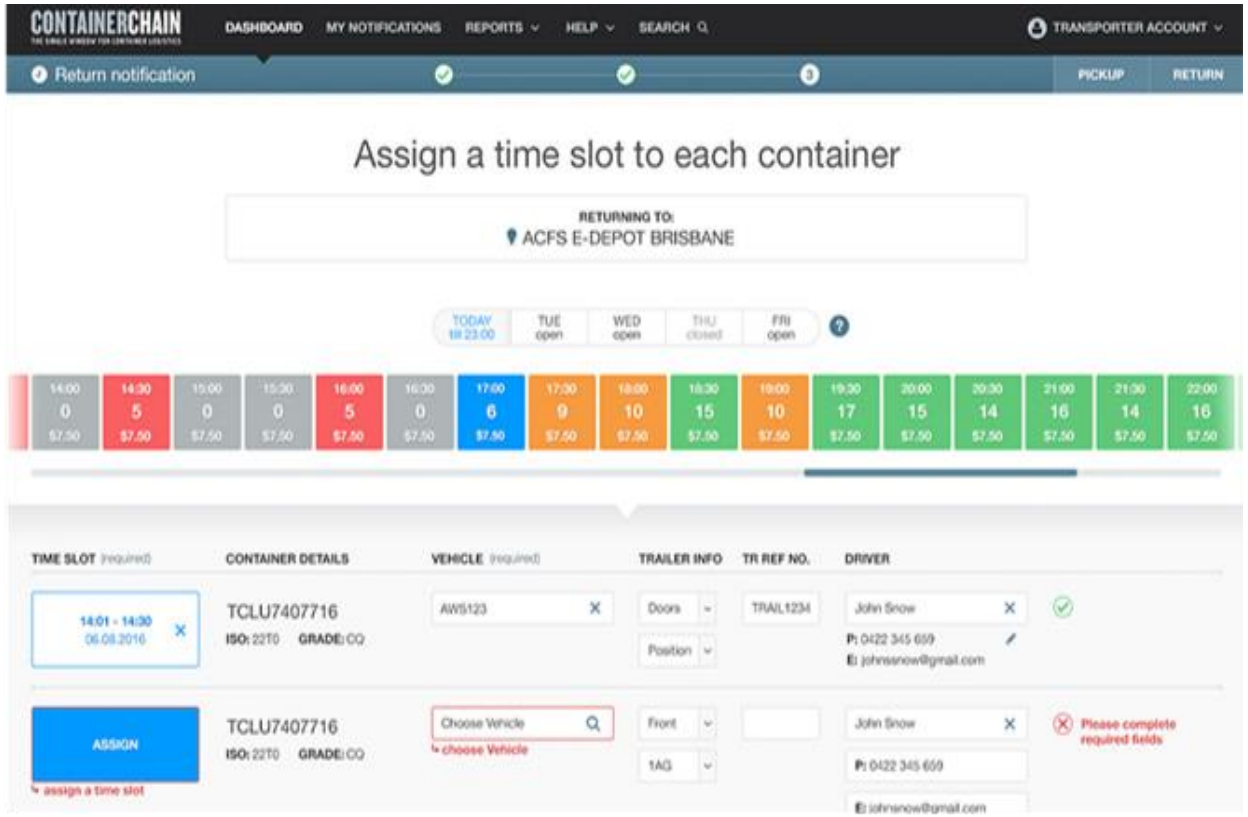
Truck Drivers

Gate MIS

- Arrival Appointment Based on Guidance Information

- Forecast Waiting Time/Operation Time
- Give Priority to Appointment Truck
- Provide Appointment Truck Number

Truck appointment system interface



Limitation of truck quota within each appointment period

Literature

Model-driven approach

- Zhang et al. developed a BCMP queuing network to represent the queuing process of trucks.
- Ramírez-Nafarrate et al. constructed a discrete event simulation model to assess the effects of TAS.
- Li et al. proposed a hierarchical queuing network with prioritization to estimate the length of the truck queue【9】

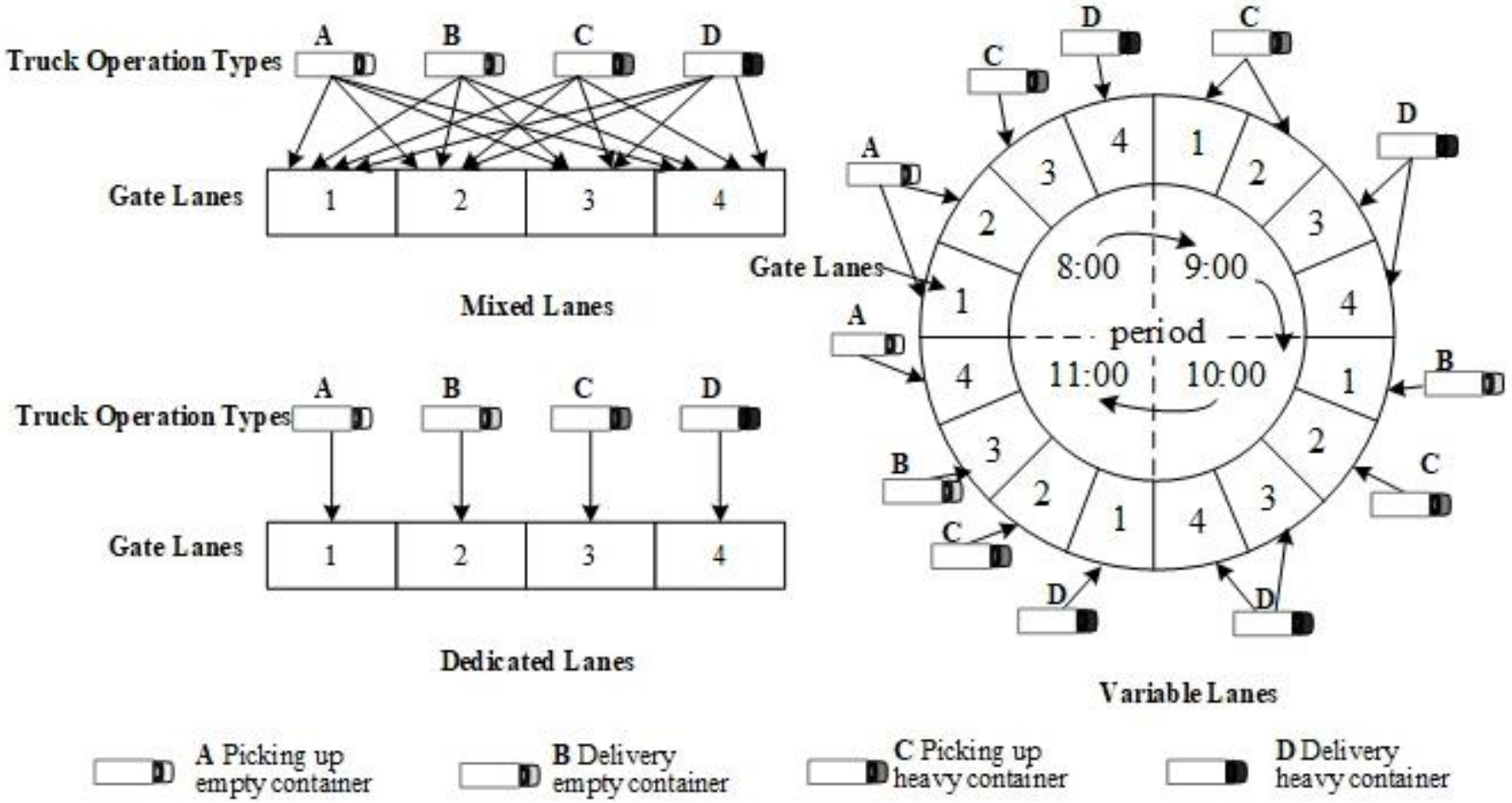
Data-driven approach

- Azab et al. used a simulation-based optimization method to arrange the scheduling of truck.
- Caballini et al. optimized the truck appointment quotas by clustering the demand for truck operation tasks.
- Li et al. have created a deep learning model that combines the Gated Recurrent Unit (GRU) and Fully Connected Neural Network (FCNN) to accurately forecast daily container arrivals【16】

Main contribution

- The paper proposes an external container truck appointment quota optimization model that combines both data-driven and model-driven.
- The data-driven approach analyzes the relationship between the number of arriving external trucks and the truck turnaround time.
- The model-driven approach aims to minimize the waiting costs and the transfered number of external trucks.
- The truck appointment quota optimization model considers the impact of the operation type of container truck.

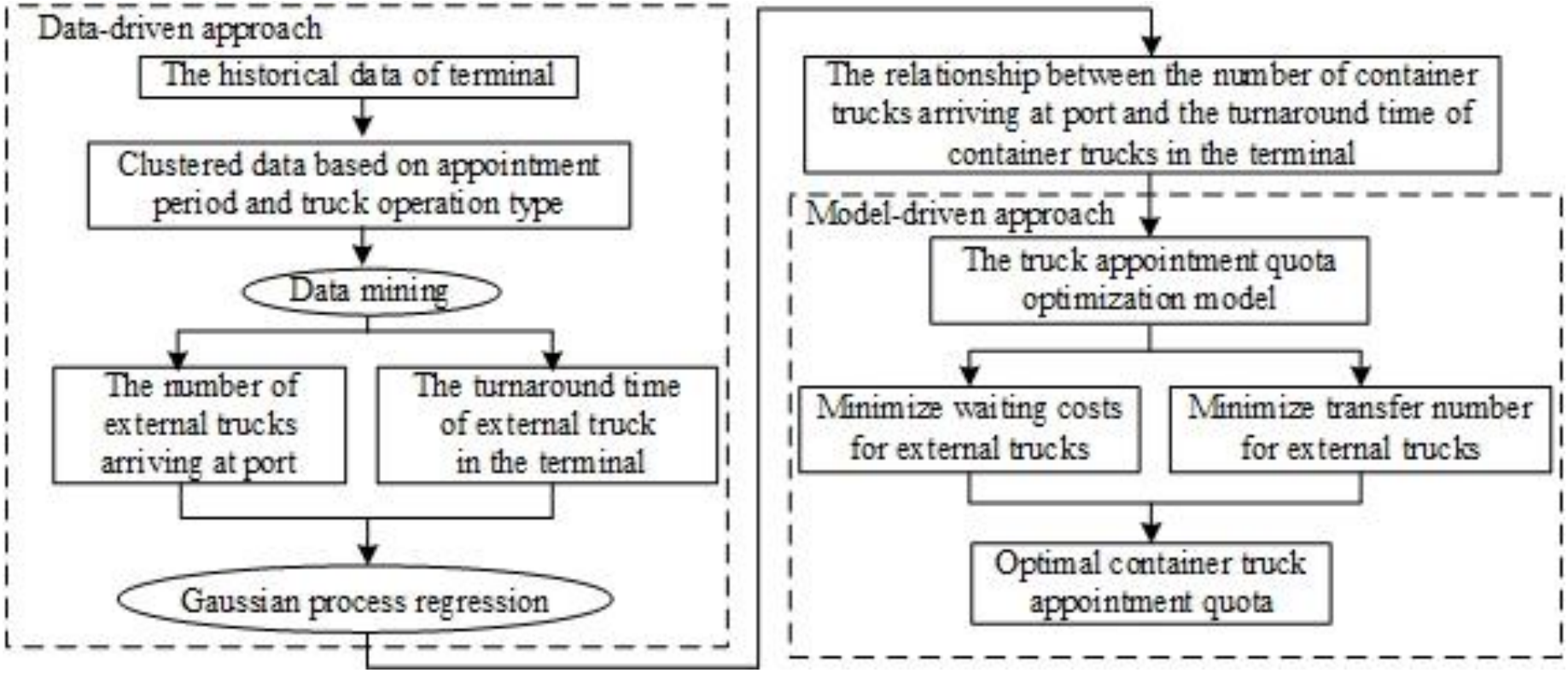
Subdividing truck operation types



The key fields of collected data

Key fields	**Meaning**
CNTR_ID	The ID of the container
TRUCK_ID	The ID of the truck associated with the container
GATE_IN_DT	The timestamp of the container truck arrived at the terminal
GATE_OUT_DT	The timestamp of the container truck departing from the terminal
OPERATION_TYPE	The operation type of truck: picking up empty containers, delivering heavy containers, picking up heavy containers, delivering empty containers

General framework



Gaussian process regression

$$y(x) \sim N\left(\mu(x), k\left(x, x'\right)\right)$$

↓

Set $\mu(x) = 0$

↓

Revise Gaussian kernel function

$$k\left(x, x'\right) = \sigma_f^2 \exp\left[\frac{-\left(x - x'\right)^2}{2l^2}\right] + \sigma_n^2 \delta\left(x, x'\right)$$

↓

The maximum likelihood estimation solves hyperparameters

$$\log(y|X) = -1/2(\log|K_{XX}| + n\log 2\pi + y^T (K_{XX} + \sigma_n^2 I_n)^{-1} y)$$

↓

Get predicted results

$$y_*| \ \mathbf{y} \sim \mathrm{N}\left(K_* K^{-1}\mathbf{y}, K_{**} - K_* K^{-1} K_*^{\mathrm{T}}\right)$$

Programming modeling

$$\min Z = \sum_{w=1}^{W}\left[\sum_{p=1}^{P} c_w T'_{wp} + \sum_{p=1}^{P}\sum_{q=p}^{P} \alpha_w \left|g_{wpq}(q-p)\right|\right] \quad (1)$$

The objective function

waiting time

transfer number and transfer period

$$n_{wp} = N_{wp} + \sum_{q=1}^{|P|} g_{wqp} - \sum_{q=1}^{|P|} g_{wpq}, \forall w \in W, p \in P \quad (2)$$

$$\sum_{p=1}^{|P|} n_{wp} - \sum_{p=1}^{|P|} N_{wp} = 0, \forall w \in W \quad (3)$$

The constraint of the appointment quota, the transfer number and the truck demand

$$T'_{wp} = f(n_{wp}), \forall w \in W, p \in P \quad (4)$$

The truck turnaround time obtained from GPR

$$g_{wpq} = 0, \forall q \notin \left(\max(0, p-\delta_w), \min(|P|, p+\delta_w)\right) \quad (5)$$

The deviation range of the transfer truck

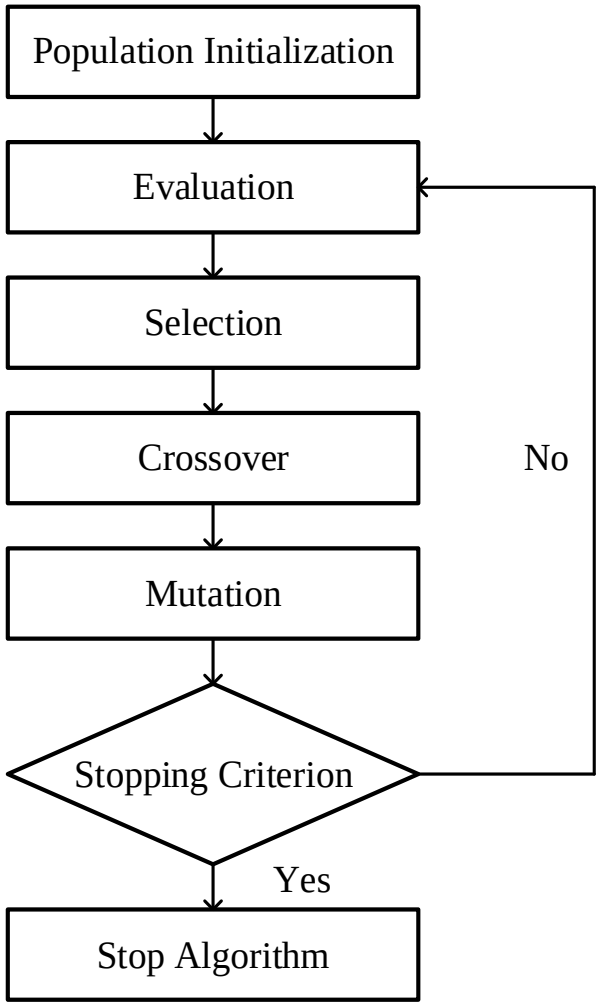
$$n_{wp} \le m_w, \forall w \in W, p \in P \quad (6)$$

$$g_{wpq}, n_{wp} \in \mathbf{N} \quad (7)$$

$$T'_{wp} \in \mathbf{R} \quad (8)$$

The range of variables

Solution



Population Initialization

w=1	0	0	5	3	2	0	5	10	2	1	…	25	41	42	0	0
w=2	0	0	8	1	2	0	6	12	7	2	…	36	39	25	0	0
w=3	0	0	10	5	4	0	1	15	4	2	…	18	25	11	0	0
w=4	0	0	1	1	2	0	5	20	5	1	…	27	25	15	0	0
	p=1					p=2						p=24								

$\delta_w = 2$

w=1 p=2 N_{wp} 18

=

w=1 0 + 5 + 10 + 2 + 1 $2\delta_w + 1$

p=0 p=1 p=2 p=3 p=4

Beyond decision period

The analysis of the data-driven approach

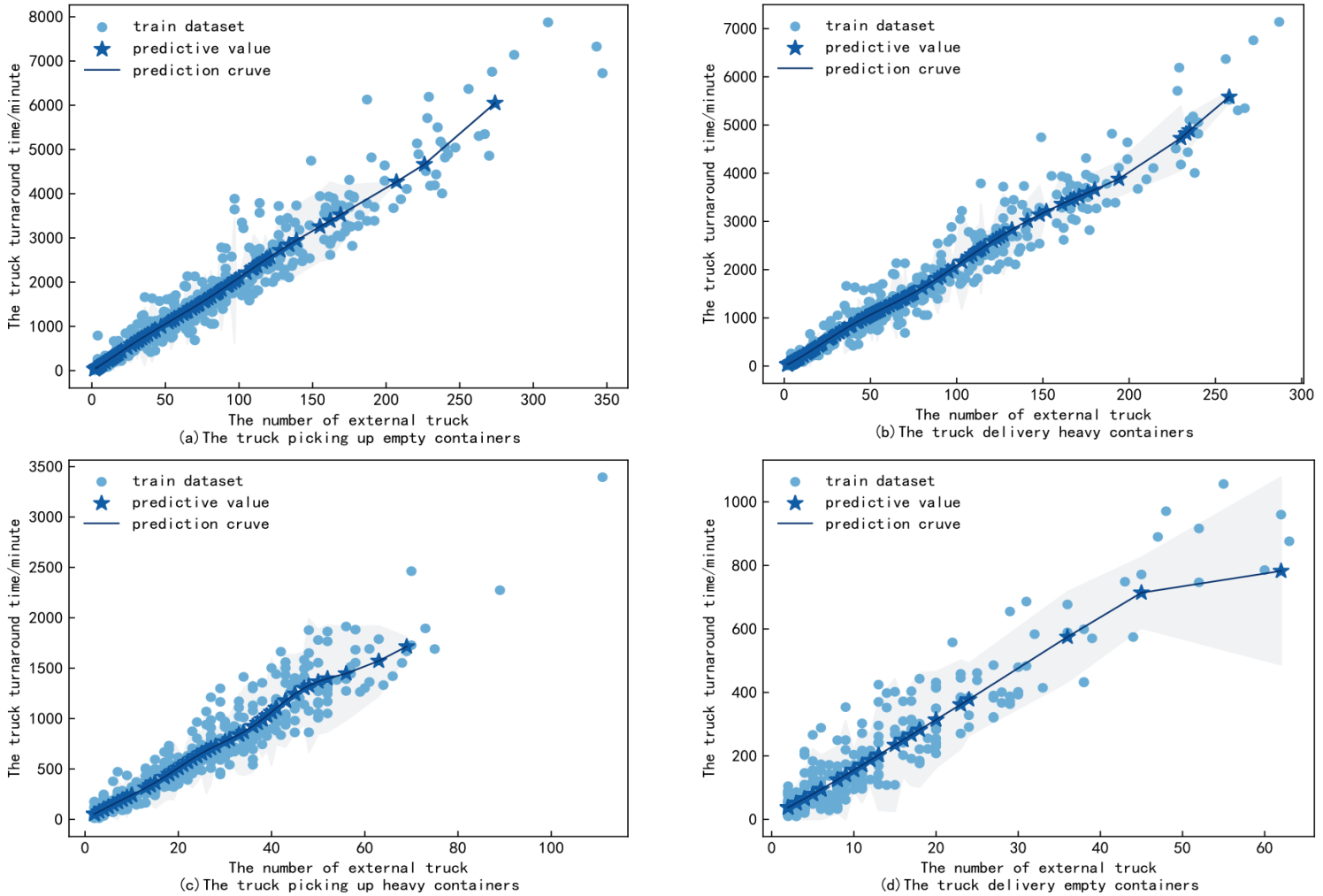


Figure 1: The relationship between the number of external trucks and the total truck turnaround time

The analysis of the data-driven approach

Table 1. The prediction results of Gaussian process regression

Truck operation type	σ_f	l	R^2	MAPE (%)
Picking up empty containers	0.312	54.63	0.98	4.93
Delivering heavy containers	0.474	39.87	0.97	6.72
Picking up heavy containers	0.261	10.63	0.98	4.68
Delivering empty containers	0.914	21.87	0.97	7.71

Table 2. The prediction results of polynomial regression

Truck operation type	Displayed formula	R^2	MAPE (%)
Picking up empty containers	$y = 0.007x^2+16.21x+0.82$	0.94	7.46
Delivering heavy containers	$y = 21.22x$ - 10.45	0.96	8.42
Picking up heavy containers	$y = 26.83x$ - 15.78	0.97	8.83
Delivering empty containers	$y = 0.011x^2$ +16.29x -1.71	0.96	8.18

The results of the dual-driven approach

Table 3. The results of the proposed dual-driven approach

Truck operation type	Pre-optimization cost	After-optimization cost	The number of transferred trucks	The deviation periods
Picking up empty containers	34,066	30,545	135	173
Delivering heavy containers	33,834	32,448	32	36
Picking up heavy containers	27,296	26,571	23	26
Delivering empty containers	4,359	3,884	15	21

The results of the dual-driven approach

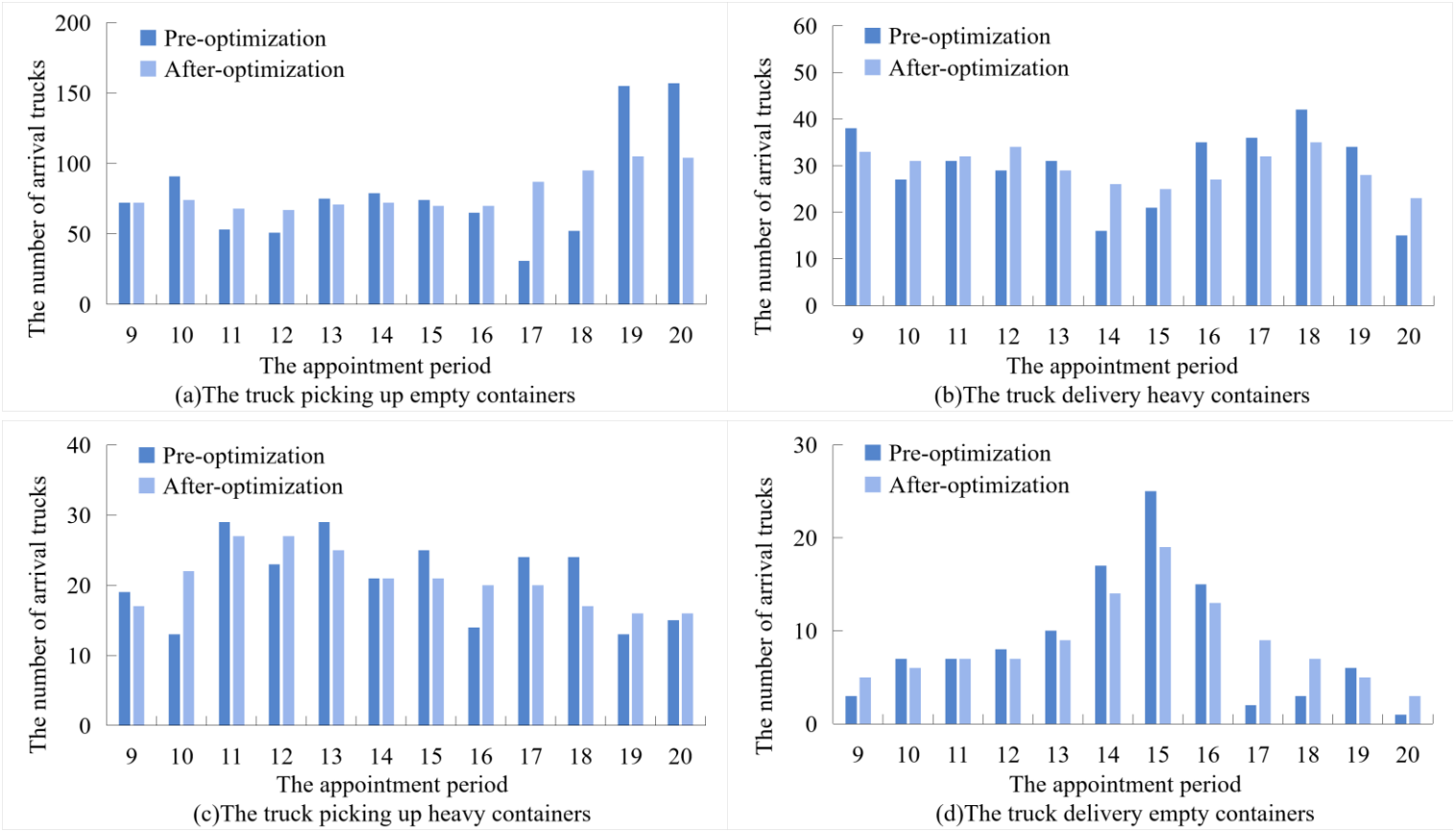


Figure 2: The respective appointment quota plans of four truck operation types

The analysis of the dual-driven approach

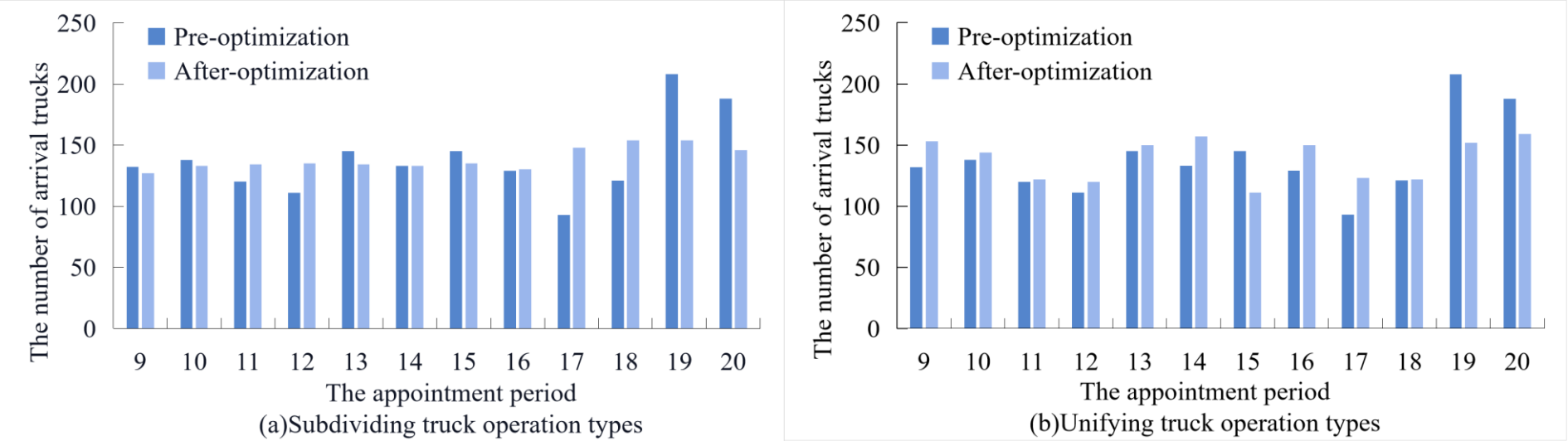


Figure 3: The appointment quota plans of subdividing and unifying truck operation type

Conclusion

- Dual-driven Approach:

  Establishes a dual-driven approach combining Gaussian process regression and a programming model to optimize the truck appointment quota.

- Model Comparison:

  The results of Gaussian process regression have lower errors compared to polynomial regression.

- Optimization Impact:

  Optimizing by means of subdividing truck operation types is more efficient, and the extreme of the truck appointment quota gets smaller.
  The dual-driven truck appointment quota optimization approach utilizes historical data to accurately describe the relationship between the number of external trucks and the total truck turnaround time.

Future reserach

- Optimization of variable gate configuration based on subdividing truck operation types.

  The truck turnaround time forcasted based on subdividing truck operation types.
  The optimization of variable gate configuration based on forcasted truck turnaround time.

- Consider the subdividing truck operation types with dual transactions container trucks.

  Subdividing dual transactions container trucks and single transaction container trucks.

Thanks for attention

& welcome to DMU

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