

# The efficiency of major container terminals in China: super-efficiency data envelopment analysis approach

Major  
container  
terminals

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## Abstract

**Purpose** – Seaports are a signifier for the world economy and international trade. Notwithstanding the considerable role of Chinese ports in global trade, only few studies have explored the efficiency of Chinese container terminals. Furthermore, studies on Chinese port efficiency has typically centered on port-level analysis, not terminal level. Therefore, this study aims to examine the operation efficiency of Chinese container terminals.

**Design/methodology/approach** – This study uses super-efficiency data envelopment analysis (SE-DEA) approach. SE-DEA is superior than basic DEA model because it is feasible for categorizing and ranking the efficiency of container terminals more accurately and comprehensively. In the basic model, if the several decision-making units (DMUs) are efficient, the efficiency value of them is “1.” However, in the SE-DEA model, the most efficient DMU is over “1.” Based on the level of container throughput in 2018, the top 20 Chinese container terminal companies were selected. Various production quotas were selected as inputs, while the container throughput was considered output.

**Findings** – The findings show that Terminal Shanghai Mingdong Container Terminal Co., Ltd. was ranked 1, followed by Shanghai Shengdong International Container Terminal Co., Ltd., Shanghai International Port (Group) Co., Ltd. and Yidong Container Terminal Branch.

**Originality/value** – This study contributes to providing some insights into Chinese container terminal industry to augment the efficiency. This study also provides practical and policy implications (e.g. better terminal operations) for container terminals.

**Keywords** China, Data envelopment analysis, Container terminal, Port efficiency, Super-efficiency DEA

**Paper type** Research paper



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## 1. Introduction

Since 2003, China became the world's largest container throughput, ahead of the USA based on countries' container throughput. The rapid development of China's economy after the reform and opening up has led to highly improved maritime trade. Container terminal has also steadily developed in terms of throughput. Regarding China's port yearbook of 2019, among the world top 10 ports, seven are in China, namely, Shanghai, Shenzhen Port, Ningbo Zhoushan Port, Hong Kong Port, Guangzhou Port, Qingdao Port and Tianjin Port. Thus, the ports in China occupy pivotal positions in the world. Besides, ports are necessary components in trade facilitation. [Blonigen and Wesley \(2008\)](#) stated that ports are closely related to trade. If port efficiency improves, trade volume increases significantly. Ports are strongly associated with economic development ([Shan et al., 2014](#); [Park and Seo, 2016](#); [Seo and Park, 2018](#); [Kim et al., 2020](#)). Furthermore, port efficiency is not only essential to trade but also an essential predictor of a country's competitiveness ([Micco et al., 2003](#)).

Well-operated ports facilitate a country's import and export activities. Furthermore, the "relative efficiency" of a port is evaluated based on its measured efficiency with other ports within the group ([Kutin et al., 2017](#)). For a more accurate "relative efficiency," examining the container terminal rather than the container port might result in a better analysis. For example, numerous studies have used port depth as an input for examining port efficiency and suggested a certain depth (e.g. 18 meters). However, a certain port has multiple terminals, but prior studies did not mention how the port's depth was calculated (e.g. when Terminal A's depth is 18m, Terminal B: 20m, Terminal C: 17m). Therefore, exploring the efficiency of container terminals appears more accurate. Competitiveness of the terminals can be significantly improved by enhancing their service levels. Complete usage of the input resources of terminals, berths, yards and equipment is one method to augment terminal efficiency ([Zheng and Park, 2016](#)).

An efficient container terminal uses least investment to earn maximum profit, which can help the regional economy and develop the port. The lack of efficient container terminals leads to excessive waste of production resources. Traditional methods for analyzing container ports focus on the production ratio or internal indicators, such as the number of workers in the port, the production volume of each crane during a certain time, the number of berth ships staying and the number of days staying. [Li et al. \(2013\)](#) analyzed 42 coastal ports in China using a three-stage data envelopment analysis (DEA). They used wharf length handling equipment (bridge, mobile and beam cranes) and number of employees as input variables. [Wilmsmeier et al. \(2013\)](#) also used ship-to-shore crane capacity equivalent and number of employees as input variables. [Tongzon \(2001\)](#) employed port authority employees, container terminal labor and other labor expenditures, total wages and salaries paid to employees and the number of employees as input variables. However, owing to the fast-developing world of automation and industrialization, some indicators included in the efficiency analysis of present-day container terminals may be erroneous. For instance, several studies have focused on migrant workers or total employees as indicators. However, automated industrialization has led to machines replacing manual operation, leading to a substantial reduction in the number of laborers. Qingdao Port, globally ranked 8, officially operated the fully automated container terminal in May 2017. The average single-machine operating efficiency reached 39.6 natural containers per hour, thus creating the world's highest average single-machine operation of automated terminals. Therefore, this study considers the rational and practical development of analysis of container terminal enterprise efficiency from various aspects.

Most studies focus on the efficiency analysis of container ports, while a few analyze the efficiency of container terminal companies. However, these few studies are obsolete because

of the rapid development of container terminals. Based on the literature review, this study provides a direction for container terminal efficiency in port competition and development by evaluating the efficiency of major container terminals in China. This rest of this study is presented as follows. Section 2 presents the literature review of major studies on evaluation of container terminal efficiency. Section 3 presents the DEA methodology, DEA-CCR and Super Efficiency DEA (SE-DEA) model, which are applied for a more reliable and comprehensive container terminal efficiency ranking. Section 4 introduces the comparative analysis of each result after DEA analysis. Finally, Section 5 shows the main results, conclusions and implications.

## 2. Literature review

Maritime transportation is a stronger necessity for economic growth than air and land transportation (Park *et al.*, 2019; Seo and Park, 2016). Recently, General Secretary Xi Jinping proposed at the 19th CPC National Congress to build transportation power. Ports are an important part of transportation power and have an irreplaceably special status and role. Furthermore, container terminals and ports are both important parts of the modern economy. Therefore, trade scholars have focused on port performance and efficiency research.

Numerous studies on the effectiveness of ports and port efficiency were conducted using the DEA approach. Roll and Haugh (1993) were considered to initially apply DEA to assess port efficiency. However, they compared the performance of 20 ports through a hypothetical numerical example. Tongzon (1995) analyzed 23 international ports and showed that port performance and efficiency analysis can be modeled. Subsequently, most studies focus on port efficiency studies. Cullinane and Wang (2006) used DEA to study the efficiency of container terminals in Europe. Wanke (2013) used Network-DEA to study the efficiency of 27 Brazilian ports. Guimarães *et al.* (2014) investigated 15 Brazilian container terminals used CCR-DEA and BCC-DEA. Lim *et al.* (2011) analyzed 26 Asian container terminals by context-dependent DEA. Among which, a comparative analysis using super-efficiency DEA model research on China container terminal is even rarer. Lin *et al.* (2019) measured efficiency of container ports and analyzed consumer resources by considering undesirable outputs using the inverse DEA model. Zheng and Park (2016) investigated major large ports of Korea and China using DEA. A few studies have focused on container terminals. Koster *et al.* (2009) calculated benchmarking container terminals using DEA and expressed the irrationality of some studies on terminals such as the comparison between large and small container terminals. Finally, an analysis of the efficiency of seven container terminals in the world showed that the efficiency of the first US terminal is relatively low and the transshipment terminal is more efficient than the import/export terminal and proved that the greater the throughput of the container terminal, the higher is the efficiency.

Most studies choose the basic DEA model for analysis. Earlier studies examined at the port level or container port level. In addition, DEA's basic models, namely, Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Cooper (BCC), are also used to verify the holistic, scale and technical efficiency of the analysis objects. Ding *et al.* (2015) evaluated operational and productivity efficiency change in 21 coastal small and medium sized-port container terminals in China. Almawshaki and Shah (2015) investigated the technical efficiency of 19 container terminals in the Middle Eastern region based on DEA. Pjevcevic *et al.* (2016) revealed the efficient container port handling processes by DEA. Kutin *et al.* (2017) examined the relative efficiencies of 50 ASEAN container ports and terminals. Mustafa *et al.* (2021) compared the technical efficiency of less explored South Asian and Middle Eastern ports with the East Asian ports and suggested ways for their efficiency

enhancement and management optimization. Recent studies on the efficiency of container terminals include that by [Tally et al. \(2014\)](#). Although the two basic models of the DEA can accurately analyze whether ports or container ports are efficient, they can only distinguish between efficient and inefficient ports. However, when the analysis results are 1, it proves that the analyzed ports or terminals are all efficient, and this drawback cannot be addressed. [Shan et al. \(2014\)](#) argued that Super-efficiency DEA solves one problem perfectly. It can re-analyze the efficient of ports or terminals to find their differences and rank them. It helps in in-depth analysis by sorting the results. Therefore, this study included the top 20 Chinese container terminal companies based on the level of container throughput. Various production quotas are chosen as inputs, while the container throughput was considered as outputs. The DEA has been a popular approach in port efficiency for the past two decades. [Cullinane et al. \(2004\)](#) used DEA windows analysis and panel data to examine the world's major container terminals for deducing their relative efficiency. The findings showed that the estimated efficiency of container terminals was not constant. [Wu and Goh \(2010\)](#) used DEA-CCR to compare the efficiency of port operations in emerging markets (BRIC and the Next-11) with the more advanced markets (G7). The results showed that seaports in the developing countries seem to be more efficient than those in the developed countries.

DEA has several applications to the seaport and related industries ([Tongzon, 2001](#)). Moreover, DEA is considered a suitable overall method for analyzing port production and performance ([Seo et al., 2012](#)). At present, several studies have analyzed the environmental, operational and production efficiency of general or container ports. [Kutin et al. \(2017\)](#) analyzed the data of 43 largest Vietnamese ports using the bootstrapped DEA model and SFA and DEA models, respectively. [Dong et al. \(2019\)](#) evaluated the environmental performance and operational efficiency of container ports onward the Maritime Silk Road. Although several scholars focus on the efficiency of ports and container ports, they ignore the fact that the general DEA model cannot obtain a complete ranking of effective decision-making units (DMUs). This means that effective DMUs have a defect of fuzzy distinction. [Xue and Harker \(2002\)](#) found that the inability to distinguish efficiency units results in a peak  $d$  distribution with an efficiency score equal to 1. This complicates any post-DEA statistical inference analysis. It is also proved in many cases, further differentiation between high-efficiency DMUs is also ideal or even necessary. However, few empirical studies compare the efficiency of China's container terminals. Accordingly, this study uses the latest data for Super-Efficiency DEA analysis.

### 3. Methodology

#### 3.1 Data envelopment analysis

The research object in DEA is a DMU. In this study, DMUs are container ports. The CCR and BCC models are the most basic DEA models. The CCR ([Charnes et al., 1978, 1979](#)) or the BCC model ([Banker et al., 1984](#)) is nonparametric and uses the extreme value method of production frontier estimation and DMU's efficiency evaluation ([William et al., 2004](#)). This study uses the output-oriented DEA-CCR and Super-Efficiency DEA models. The DEA technique is useful in resolving the measurement of terminal efficiency because the calculation is nonparametric, it can handle multiple outputs, and no explicit *a priori* relationship between output and input is required.

$X$  and  $Y$  are the input and output matrixes, respectively, with  $n$  being the number of inputs and  $m$  being the number of outputs, where the CCR-DEA model can be stated as follows:

$$\text{Max } \alpha = \frac{\sum_{j=1}^n I_{jk} x_j}{\sum_{i=1}^m O_{ik} y_i}$$

Subject to

$$\frac{\sum_{j=1}^n I_{jk} x_j}{\sum_{i=1}^m O_{ik} y_i} \leq 1$$

$$x_j, y_i \geq 0$$

where  $k$  denotes the  $k$ th DMU,

$$I_{jk} \ (j = 1, 2, \dots, n) \text{ and}$$

$O_{ik} \ (i = 1, 2, n)$  express the inputs and outputs of the  $k$ th container terminal, and  $x_j \ (j = 1, 2, n)$  and  $y_i \ (i = 1, 2, n)$  are the weight vectors of the container terminals inputs and outputs ([Dong et al., 2019](#)).

### 3.2 Super efficiency data envelopment analysis

Terminal efficiency can be measured using the DEA technique because, considering the nonparametric calculations, the DEA method can manipulate multiple outputs and minimize the need for a clear prior recognition of the association between outputs and inputs. However, insufficient discrimination of multiple-efficiency DMU's is frequent when assessing the efficiency of the DEA technique. Consequently, a considerable number of DMUs are labeled as efficient or above ([Cooper et al., 2001](#)).

SE-DEA has several advantages compared to basic DEA. Basic models such as CCR-DEA and BCC-DEA cannot consider random errors. In the basic model, if the several DMUs are efficient, the efficiency value of them are "1." Accordingly, it is impossible to distinguish the efficiency between them. Therefore, the efficiency of the DMUs cannot be evaluated reasonably, and only efficient or inefficient can be determined in the basic DEA model. In the SE-DEA model, an effective DMU can increase its input according to the ratio, while its efficiency can remain unchanged. Increase rate of DMUs' input become its super efficiency evaluation value in the SE-DEA model. According to [Andersen and Petersen \(1993\)](#), under the SE-DEA, the efficiency score of the low-efficient port remains unchanged. Still, the efficiency score of the high-efficiency port is allowed to be greater than 1, thereby allowing the allocation of levels.

To magnify the distinction between multiple effective DMUs with an efficiency of 1, [Andersen and Petersen \(1993\)](#) demonstrated an approach to use other non-radial models to

minimize deficiencies (William *et al.*, 2006). Therefore, radial super efficiency DEA (SE-DEA) can be used to solve the basic DEA model with multiple-efficiency issues, where SE-DEA model is shown as follows (William *et al.*, 2006):

$$\begin{aligned} \theta^* &= \min_{\theta, \lambda, s^-, s^+} \theta - \varepsilon s^+ \\ \text{Subject to : } \theta x_0 &= \sum_{j=1, \neq 0}^n \lambda_j x_j + s^- \\ y_0 &= \sum_{j=1, \neq 0}^n \lambda_j y_j + s^+ \end{aligned}$$

3.3 Data collection

For container terminals, the throughput of containers reflects the terminal’s production capacity. Therefore, this study selected the top 20 Chinese container terminal companies based on the level of container throughput in 2018. The data set included three container terminal companies in Ningbo and Guangzhou, eight in Shanghai, one in Dalian and two in Shenzhen and Tianjin. Table A1 in Appendix presents the detailed container terminal companies. Furthermore, various production quotas are chosen as inputs, while the container throughput is considered outputs (Table 1). Input and output variables should reflect the actual process of container terminal production as accurately as possible (Cullinane *et al.*, 2004), considering the production capacity of the container terminal. Accordingly, the terminal area, terminal length and water depth are the most suitable agents for the input of “land” elements. The number of quay cranes and yard equipment is the most appropriate proxy for “equipment” input factors and used by most previous studies (Trujillo *et al.*, 2013).

The data of the set criteria were taken from the Chinese ports yearbook (Table 2). Initially, this study found it feasible to use the number of employees in the terminal as an input indicator. For instance, Chang (2013) treated labor as input indicators. However, as port automation advanced, for instance, Qingdao Port, Asia’s first fully automated terminal, realized “5G” remote crane operation in actual production environments in 2019. The Yangshan Port Terminal, also located in Shanghai, officially opened the port in December 2017 in the Deepwater Port District Phase 4 Automation Terminal. Therefore, the number of employees does not reflect port productivity. Therefore, labor was changed to the number of Bridge Crane and Rubber Tire container Gantry (RTG) crane in this study.

**Table 1.**  
Compilation input  
and output

| Input(s)                               | Output(s)                  |
|----------------------------------------|----------------------------|
| I1: Berth length (m)                   | O1: Throughput (TEU: 1000) |
| I2: Yard area (m <sup>2</sup> )        |                            |
| I3: The number of Bridge Crane and RTG |                            |
| I4: Dock front water depth (m)         |                            |

| Port      | Terminal | Berth length (m) | Yard area (m <sup>2</sup> ) | No. of BC and RTG | Dock front water depth (m) | Container throughput (TEU) |
|-----------|----------|------------------|-----------------------------|-------------------|----------------------------|----------------------------|
| Shanghai  | SH4      | 350              | 1,480,000                   | 124               | 16                         | 8,855,068                  |
|           | SH5      | 450              | 1,470,000                   | 106               | 17.5                       | 7,630,553                  |
|           | SH6      | 1,634            | 1,020,000                   | 105               | 13.7                       | 6,551,991                  |
|           | SH7      | 2,068            | 1,130,000                   | 28                | 12.8                       | 6,252,083                  |
|           | SH14     | 1,250            | 980,000                     | 65                | 12.5                       | 4,102,826                  |
|           | SH15     | 1,641            | 370,000                     | 62                | 10.5                       | 4,005,157                  |
|           | SH20     | 900              | 280,000                     | 53                | 12                         | 2,602,149                  |
| Shenzhen  | SZ1      | 7,382            | 4,170,000                   | 326               | 17.6                       | 13,159,705                 |
|           | SZ9      | 3,457            | 1,180,000                   | 145               | 17                         | 5,101,727                  |
|           | SZ11     | 3,440            | 1,050,000                   | 140               | 16.5                       | 5,620,332                  |
| Ningbo    | NB2      | 3,410            | 1,800,000                   | 193               | 17                         | 10,300,344                 |
|           | NB13     | 1,800            | 970,000                     | 81                | 19.5                       | 4,150,437                  |
|           | NB17     | 1,238            | 700,000                     | 75                | 15                         | 3,262,076                  |
|           | NB18     | 1,500            | 1,280,000                   | 67                | 17.5                       | 3,160,318                  |
| Guangzhou | GZ8      | 1,400            | 1,050,000                   | 79                | 15.5                       | 5,805,069                  |
|           | GZ10     | 350              | 1,060,000                   | 86                | 15.5                       | 5,164,924                  |
|           | GZ12     | 346              | 850,000                     | 96                | 16                         | 4,600,126                  |
| Tianjin   | TJ16     | 2,300            | 1,960,000                   | 81                | 16                         | 3,530,034                  |
|           | TJ19     | 1,090            | 540,000                     | 44                | 16                         | 2,839,036                  |
| Dalian    | DL3      | 4,390            | 1,730,000                   | 129               | 17.8                       | 9,512,743                  |

Major container terminals

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**Table 2.**  
Top 20 input and output data C container terminal

**Source:** Container Ports of China Yearbook (2018) and dock company official website

## 4. Results

**Table 3** summarizes the results of inputs and outputs. As five variables are included in the analysis, the sample size is in compliance with DEA minimum sample size.

In the CCR-DEA model, there are five efficiency container terminals, which accounts for 25% of the total container terminals (**Table 4**). Among the five container terminals, Yantian International Container Terminal Company (SZ1), Ningbo Port Group Beilun Third Container company (NB2), and Shanghai Shengdong International Container Terminal Company (SH4) were the container throughput top 5 container terminals in China for 2018. Especially, Shanghai International Port (Group) Co., Ltd. Yidong Container Terminal Branch (SH15) ranked 15 in the container throughput of 2018. However, the CCR-DEA model showed that it is the efficiency DMU. The data reveal that SH15 terminal has a small yard area, long berth length and high container throughput. It maintains low input but has a high output. Consequently, Shanghai International Port (Group) Co., Ltd. Yidong Container Terminal Branch (SH15) is an efficient terminal. **Figure 1** shows the CCR-DEA efficiency profile.

|         | Berth length | Yard area | The number of Gantry Crane | Dock front water depth | Container throughput |
|---------|--------------|-----------|----------------------------|------------------------|----------------------|
| Max     | 7,382        | 417       | 326                        | 19.5                   | 13,159,705           |
| Min     | 346          | 27.5      | 28                         | 10.5                   | 2,602,149            |
| Average | 2,019.795    | 125.239   | 104.25                     | 16.41                  | 5,810,335            |
| SD      | 1,667.726    | 79.69096  | 63.5428                    | 3.792611               | 2,742,226            |

**Table 3.**  
Summary statistics of variables for efficiency analysis

**Table 4.**  
Efficiency value  
results by CCR and  
Super-Radial DEA  
model

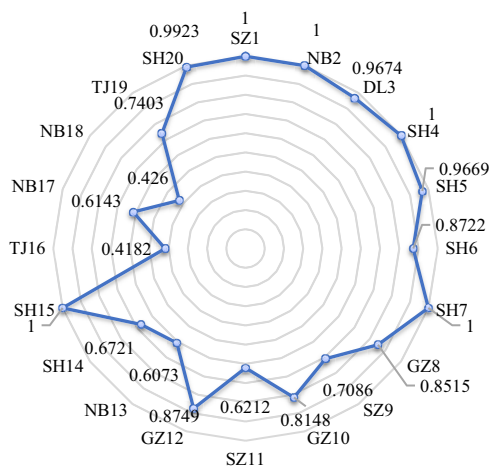
| Port                       | Terminal | CCR   | SE-DEA |
|----------------------------|----------|-------|--------|
| Shanghai                   | SH4      | 1     | 1.492  |
|                            | SH5      | 0.967 | 0.967  |
|                            | SH6      | 0.872 | 0.872  |
|                            | SH7      | 1     | 3.028  |
|                            | SH14     | 0.672 | 0.672  |
|                            | SH15     | 1     | 1.376  |
|                            | SH20     | 0.992 | 0.992  |
| Shenzhen                   | SZ1      | 1     | 1.234  |
|                            | SZ9      | 0.709 | 0.709  |
|                            | SZ11     | 0.621 | 0.621  |
| Ningbo                     | NB2      | 1     | 1.060  |
|                            | NB13     | 0.607 | 0.607  |
|                            | NB17     | 0.614 | 0.614  |
| Guangzhou                  | NB18     | 0.426 | 0.426  |
|                            | GZ8      | 0.852 | 0.852  |
|                            | GZ10     | 0.815 | 0.815  |
|                            | GZ12     | 0.875 | 0.875  |
| Tianjin                    | TJ16     | 0.418 | 0.418  |
| TJ19                       | 0.740    | 0.740 |        |
| Dalian                     | DL3      | 0.967 | 0.967  |
| Container terminal Average |          | 0.807 | 0.968  |

**Table 5.**  
Top 20 container  
terminals CCR and  
SE-DEA rank

| Port      | Terminal | CCR | SE-DEA |
|-----------|----------|-----|--------|
| Shanghai  | SH4      | 1   | 2      |
|           | SH5      | 8   | 8      |
|           | SH6      | 10  | 10     |
|           | SH7      | 1   | 1      |
|           | SH14     | 15  | 15     |
|           | SH15     | 1   | 3      |
|           | SH20     | 6   | 6      |
| Shenzhen  | SZ1      | 1   | 4      |
|           | SZ9      | 14  | 14     |
|           | SZ11     | 16  | 16     |
| Ningbo    | NB2      | 1   | 5      |
|           | NB13     | 18  | 18     |
|           | NB17     | 17  | 17     |
|           | NB18     | 19  | 19     |
| Guangzhou | GZ8      | 11  | 11     |
|           | GZ10     | 12  | 12     |
|           | GZ12     | 9   | 9      |
| Tianjin   | TJ16     | 20  | 20     |
|           | TJ19     | 13  | 13     |
| Dalian    | DL3      | 7   | 7      |

The SE-DEA model shows five efficiency container terminals (Table 4). Among the five container terminals, the Shanghai Mingdong Container Terminal Company (SH7) is the most effective terminal with an efficiency value of 3.02. Shanghai Shengdong International Container Terminal Company (SH4) is the second effective terminal with an efficiency value of 1.49. Shanghai International Port (Group) Co., Ltd. Yidong Container Terminal Branch

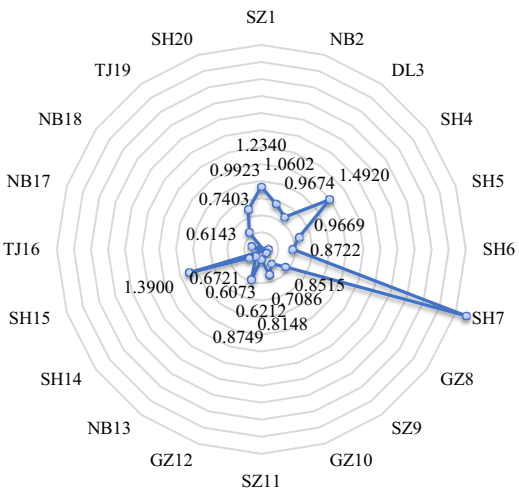
**Figure 1.**  
Top 20 container  
terminal CCR-DEA  
efficiency



(SH15) is the third effective terminal with an efficiency value of 1.39. Yantian International Container Terminal Company (SZ1) is the fourth effective terminal with an efficiency value 1.23. Ningbo Port Group Beilun Third Container Company (NB2) is the least effective terminal with an efficiency value of 1.06. [Figure 2](#) shows the SE-DEA efficiency profile.

Inefficient DMUs are the input indicator slack variable that help in analysis. According to inefficiency DMUs, input indicator calculation is a slack value. Subsequently, the improvement investment (usually refers to the increase or decrease of the corresponding investment) is based on the slack value so that DMUs become effective DEA ([Table 6](#)).

According to the input indicator slack variable in [Table 6](#), Dalian Container Terminal company (DL3) reduces the berth length investment by 1,486.3. Similarly, Shenzhen Port Shekou Container Terminal Company (SZ9) and Chiwan Container Terminal company (SZ11) must reduce the berth length investment by 352.5 and 310.3,



**Figure 2.**  
Top 20 container  
terminal SE-DEA  
efficiency

**Table 6.**  
CCR-DEA input  
indicator slack  
variable inefficiency  
DMUs results

| DMU  | Rank | S1        | S2     | S3     | S4    |
|------|------|-----------|--------|--------|-------|
| DL3  | 7    | 1,486.265 | 0      | 0      | 0     |
| SH5  | 8    | 0         | 14.027 | 0      | 3.022 |
| SH6  | 10   | 0         | 0      | 0      | 11.94 |
| GZ8  | 11   | 0         | 0      | 0      | 1.26  |
| SZ9  | 14   | 352.526   | 0      | 3.183  | 0     |
| GZ10 | 12   | 0         | 0      | 0      | 3.215 |
| SZ11 | 16   | 310.295   | 0      | 0.616  | 0     |
| GZ12 | 9    | 0         | 0      | 19.093 | 5.421 |
| NB13 | 18   | 0         | 0      | 0      | 2.771 |
| SH14 | 15   | 0         | 0      | 0      | 0.113 |
| TJ16 | 20   | 0         | 14.157 | 0      | 0     |
| NB17 | 17   | 0         | 0      | 0      | 2.011 |
| NB18 | 19   | 0         | 0      | 0      | 1.279 |
| TJ19 | 13   | 0         | 0      | 0      | 5.559 |
| SH20 | 6    | 0         | 0      | 13.003 | 5.467 |

**Note:** \*S1 is the berth length, S2 is the yard area, S3 is the number of BC and RTG, and S4 is the dock front water depth

respectively. Shanghai Guandong International Container Terminal Company (SH5) and Tianjin Port Pacific International Container Terminal Company (TJ16) must reduce the value of yard areas by 14 and 14.2, respectively. Shekou Container Terminal company (SZ9), Chiwan Container Terminal company (SZ11), Guangzhou Port Co., Ltd. Nansha Container Terminal Branch (GZ12), Shanghai Pudong International Container Terminal Company (SH20) must reduce by 3.2, 0.6, 19.1 and 13, respectively, in the investment of bridge and gantry cranes. Ultimately, except Dalian Container Terminal company (DL3), Shenzhen port Shekou Container Terminal company (SZ9), Chiwan Container Terminal company (SZ11) and Tianjin Port Pacific International Container Terminal Company (TJ16), all other remaining container terminal companies must adjust the water depth in front input of the terminal.

Adjusting input variables alone is not enough to convert the inefficiency DMUs to efficiency DMUs. The output must be maximized using a low input. Therefore, increasing cargo handling capacity and container throughput can also drive the efficiency of container terminals.

Although SE-DEA reanalyzes the specific efficiency DMUs of each effective unit based on the efficiency DMUs, not all super-efficiency DMUs are 100% valid. Each DMU must adjust. For instance, Table 7 includes five super-efficiency DMUs; the most efficient DMU is

**Table 7.**  
SE-DEA Input  
indicator slack  
variable efficiency  
DMUs results

| DMU  | Score | S1        | S2          | S3      | S4     |
|------|-------|-----------|-------------|---------|--------|
| SH7  | 3.028 | 3,376.644 | 2,275,103.6 | 0.000   | 27.059 |
| SH4  | 1.492 | 0.000     | 501,590.6   | 62.003  | 3.564  |
| SH15 | 1.376 | 1,026.340 | 0.000       | 10.651  | 0.000  |
| SZ1  | 1.234 | 4,753.102 | 2,846,286.3 | 155.722 | 0.000  |
| NB2  | 1.060 | 2,554.846 | 0.000       | 46.886  | 0.000  |

**Note:** \*S1 is the berth length, S2 is the yard area, S3 is the number of BC and RTG, and S4 is the dock front water depth

the Shanghai Mingdong Container Terminal company (SH7). However, SH7 input indicator slack variable also lacks investment.

From the perspective of the container terminal infrastructure, it is generally adapted to demand, but there are structural shortcomings, and there are great differences between (among) different terminals. Some terminals are very efficient. Although a few terminals must augment their expenditure to improve efficiency, most terminals have the problem of wasting resources. In addition, most of the port and terminal studies have pointed out the fact that most ports and container terminals waste resources.

## 5. Concluding remarks

With an increased focus on ports, container terminals, which normally affect the efficiency of container ports, have also received increased attention. In addition, as an essential condition for transportation, ports must inevitably enhance their efficiency. Therefore, China's major container terminal companies are also seeking more ways to improve the efficiency and productivity of container terminals and maximize their own interests. This study combines efficiency and super-efficiency methods to evaluate the most representative container terminal enterprises in China's top 20 throughputs to verify the actual efficiency and response strategies of major container terminals.

The DEA analysis results show that the overall mean efficiency of the top 20 container terminal companies in China selected in 2018 is 0.807. Among these, only five were effective terminals, which indicate low overall efficiency of China's container terminal enterprises. However, compared with previous studies on Chinese container terminals, the efficiency of container terminal enterprises is growing. [Li et al. \(2013\)](#) concluded that the terminal efficiency in the Yangtze River Delta region is relatively high, while that in the Bohai Rim region is relatively low. However, the terminal efficiency of Yangtze River Delta region and the Bohai Rim region are still more efficient than the Pearl River Delta and the southwest coastal region. However, this study has reached similar but different conclusions. In this study, the container terminal companies in the Yangtze River Delta region have superior efficiency, outperforming the container terminal companies in the Pearl River Delta region because the economy and the geographical location of the ports around the Bohai Rim region are better than those in the Pearl River Delta region. However, now the Pearl River Delta port group has rising stars: Shenzhen Port and Guangzhou Port. Moreover, with the rapid advancement of China's hinterland economy and foreign trade, the Pearl River Delta region has become one of China's important economic centers. This study selects the latest data to analyze the top 20 container terminals in China. The results show that only 5 of these 20 container terminals are efficient. Some container terminals invest in infrastructure to optimize production efficiency and economic efficiency, for example, expanding the yard area and increasing equipment. However, the results show that some terminal companies need more input to expand output. More terminal enterprises have highly invested in infrastructure and have not improved the efficiency or increased the throughput. Instead, excessive investment caused a waste of resources.

Furthermore, [Koster et al. \(2009\)](#) proved that the greater the throughput of the container terminal, the higher is the efficiency. However, this study shows that the conclusion is not quite the same. The results might infer that production scale and terminal scale indicators are not the main factors for efficiency or inefficiency because some small and medium terminals are more efficient than large terminals. For instance, Shanghai Mingdong Container Terminal Co., Ltd. is efficient in both the basic CCR-DEA model and the super-efficient DEA model. Besides, in the basic CCR-DEA model,

Yantian International Container Terminal Co., Ltd., which has the highest container throughput, is the most efficient container terminal enterprise. However, in the Super-efficiency-DEA model, Yantian International Container Terminal Co., Ltd., which has the highest container throughput, ranks fourth for relative efficiency. In contrast, Shanghai Mingdong Container Terminal Co., Ltd., which ranks seventh in container throughput, is the most efficient container terminal. From the perspective of infrastructure, SH7 has seven container berths of over 70,000 tons, with a total shoreline length of 2,068 meters and a water depth of 12.8 meters. Yantian International Container Terminal Co., Ltd. has 20 large container berths with a coastline of 90,787 meters and a water depth of 17.6 meters. This shows that Shanghai Mingdong Container Terminal Co., Ltd. maximizes the output under the existing input, so Shanghai Mingdong Container Terminal Co., Ltd. has the highest efficiency. Yantian International Container Terminal Co., Ltd., which has the highest container throughput, can further improve. In 2019, Yantian International Container Terminal Co., Ltd. has the world's largest container ship, the "Mediterranean Gurson," the first voyage. The ship has a total length of 400 meters and a width of 62 meters. It can hold 23,756 standard containers with a total tonnage of 230,000 tons. It is the largest container ship in the global shipping market (Yantian International Container Terminal Co., Ltd. website). Follow-up can also track the latest status of the efficiency of Yantian International Container Terminal Co., Ltd.

This study examined the production efficiency of container terminal enterprises. The Ministry of Transport should also increase its focus on container terminals to comprehensively evaluate the efficiency and development of container terminal enterprises every year. Such efficiency assessments can not only help terminal business operators to cope with the pressure of international competition, but also provide countermeasures for the effective development of container terminals.

This study examines only the basic efficiency and super-efficiency analysis of 20 Chinese container terminal enterprises. However, because the super-efficiency model cannot change the efficiency value of the DMU that was originally invalid, it can only explain which of the effective decision units is more effective. Therefore, for future research, above all, more recent data about the port or terminal for analysis must be gathered.

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### Further reading

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| Ranking | Container terminal                                                             | City      | Year 2018  |
|---------|--------------------------------------------------------------------------------|-----------|------------|
| SZ1     | Yantian International Container Terminal Co., Ltd.                             | Shenzhen  | 13,159,705 |
| NB2     | Ningbo Port Group Beilun Third Container Co., Ltd.                             | Ningbo    | 10,300,344 |
| DL3     | Dalian Container Terminal Co., Ltd.                                            | Dalian    | 9,512,743  |
| SH4     | Shanghai Shengdong International Container Terminal Co., Ltd.                  | Shanghai  | 8,855,068  |
| SH5     | Shanghai Guandong International Container Terminal Co., Ltd.                   | Shanghai  | 7,630,552  |
| SH6     | Shanghai Port Group Zhendong Container Terminal Branch                         | Shanghai  | 6,551,991  |
| SH7     | Shanghai Mingdong Container Terminal Co., Ltd.                                 | Shanghai  | 6,252,082  |
| GZ8     | Guangzhou Port Nansha Port Affairs Co., Ltd.                                   | Guangzhou | 5,805,069  |
| SZ9     | Shekou Container Terminal Co., Ltd.                                            | Shenzhen  | 5,620,332  |
| GZ10    | Guangzhou Nansha Sea Port Container Terminal Co., Ltd.                         | Guangzhou | 5,164,923  |
| SZ11    | Chiwan Container Terminal Co., Ltd.                                            | Shenzhen  | 5,101,727  |
| GZ12    | Guangzhou Port Co., Ltd. Nansha Container Terminal Branch                      | Guangzhou | 4,600,126  |
| NB13    | Ningbo Meishan Island International Container Terminal Co., Ltd.               | Shanghai  | 4,150,437  |
| SH14    | Shanghai Hudong Container Terminal Co., Ltd.                                   | Shanghai  | 4,102,825  |
| SH15    | Shanghai International Port (Group) Co., Ltd. Yidong Container Terminal Branch | Shanghai  | 4,005,157  |
| TJ16    | Tianjin Port Pacific International Container Terminal Co., Ltd.                | Tianjin   | 3,530,033  |
| NB17    | Ningbo Zhoushan Port Co., Ltd. Beilun Second Container Terminal Branch         | Ningbo    | 3,262,075  |
| NB18    | Ningbo Daxie Merchants International Terminal Co., Ltd.                        | Ningbo    | 3,160,318  |
| TJ19    | Tianjin Port Union International Container Terminal Co., Ltd.                  | Tianjin   | 2,839,036  |
| SH20    | Shanghai Pudong International Container Terminal Co., Ltd.                     | Shanghai  | 2,602,149  |

**Table A1.**  
Summary of the top  
20 Chinese container  
terminals and their  
ranking in China in  
terms of volume for  
the year 2018 (unit:  
TEU)

**Source:** Container Ports of China Yearbook (2018)

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