

Research on Green Port Efficiency Evaluation Based on DEA and TOPSIS

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Abstract

With the development of global trade, the status of container transportation has greatly improved. As a very important node of container transportation, the port has gradually become one of the main sources of environmental pollution and energy consumption. Based on the port operation perspective, this paper builds the port efficiency evaluation input-output indicator system based on the overall layout of the container port and the energy consumption between infrastructure equipment, then calculates and analyzes the energy consumption in the actual operation of the container port. By establishing a DEA-TOPSIS combination model, combined with examples to calculate port comprehensive efficiency, pure technical efficiency and scale efficiency. Finally sorting effective solutions to solve the main problems of the port in green environmental protection and development, and give targeted solutions.

Keywords

Green port; DEA model; TOPSIS model; port efficiency.

1. Introduction

In recent years, with the continuous advancement of society, science and technology, the issues of low-carbon emission reduction, energy conservation and environmental protection related to human life have become the primary concern in the world. The port plays an important role in the modern logistics system and is closely related to the basic parts of transportation, storage, packaging, loading and unloading, circulation, etc. It is one of the main sources of energy consumption and environmental pollution. Therefore, energy conservation, emission reduction and the construction of green ports will inevitably affect the development of future ports. Reducing the environmental damage caused by each logistics part and improve port efficiency, Establishing a logistics technology port that coexists with nature and the surrounding environment has become an inevitable trend.

Energy consumption and low carbon emission reduction are important aspects of green port construction. Zhang Yamin[1] analyzed the production and consumption of China's coastal ports and inland ports, and briefly summarized the main components of China's port energy consumption. Lu Yiqin[2] said that low-carbon environmental protection is the main trend of the future construction of the port. The energy consumption of the port is concentrated in the process of loading and unloading, mainly including various loading and unloading and transportation equipment. Berechman[3] evaluates the cost of emissions from ships and trucks in a port, and calculates that the annual emissions of ships and trucks are the main sources of pollution in the port. In order to cope with the complex stochastic process of container terminals, .E.N.G.Yun[4] establishes a quantitative simulation model of carbon emissions in container terminals, aiming at how to quantify the impact of mitigation strategies on port operations and shipping carbon emissions in container terminals without actual energy consumption data. Peng Chuansheng[5] introduced the method of measuring

carbon emissions in container terminals by taking Jurong Port in Singapore as an example. It is proposed that container terminals can further reduce the direct emission of carbon dioxide from ports by adopting energy-saving measures for fuel equipment in ports. Qi Chongbo[6] focuses on the energy-saving, emission-reduction measures and main features of the RTG and RMG. At the same time, it also studies the energy-saving and consumption reduction technology and the effect after the implementation of the RTG at home and abroad.

The study of port efficiency began in the 1980s, and domestic and foreign scholars explored ways to study port efficiency. Wanke[7] uses the two-stage network DEA model to analyze the driving factors of Brazilian port efficiency. Jun Liang He[8] established the hierarchical structure and evaluation factors of energy-saving production in container ports by FAHP fuzzy analytic hierarchy process, and verified the effectiveness of the evaluation model through concrete examples. Gong Zhijun[9] combined the AHP with the fuzzy comprehensive evaluation method to establish a life cycle assessment system for low-carbon ports, and applied the system to the overall evaluation of the port. Guo Zhen[10] uses qualitative and quantitative methods to establish models and determine the weight values of various scientific indicators. Combined with the specific examples of Qinzhou Port, the authors give corresponding development strategies based on empirical analysis. Liu Yong[11] divided the efficiency evaluation process of the port into two stages of green production and cargo specialization, on the basis of undesired output network DEA. Ouyang Bin[12] built a green port assessment system based on comprehensive indicators of comprehensive, systematic, management and characteristic indicators, and proposed corresponding evaluation methods and standards. Wang Xuanshuang[13] starts from the perspective of the port itself, and selects the length of the shoreline, the number of berths, the yard area and the container throughput as the variables to construct the input and output index system. Teng Weichao[14] designed a more scientific evaluation index system from five aspects: port conditions, port productivity level, hinterland city, port development potential and convenience of collection and transportation.

Domestic and foreign research has achieved some results on port energy conservation and emission reduction, but most of them are separately studied on energy consumption or carbon dioxide emissions which cannot comprehensively consider the factors affecting port energy conservation and emission reduction. With the improvement of container terminal automation, the scale, digitization and integration of container equipment continue to improve, container terminals have the hardware technology foundation for energy-saving operation. However, from the perspective of production scheduling, container terminals still lack systems that can balance efficiency, energy consumption and carbon emissions, so there is a certain degree of incompleteness. In addition, in the evaluation method of port efficiency, the AHP and the fuzzy clustering analysis method are subjective. The weight given by the human subjective evaluation method directly affects the analysis results, which makes the results less objective and biased.

In order to explore the efficiency of container ports more comprehensively, objectively and accurately, this paper establishes the DEA-TOPSIS combination model based on the overall layout of the container port and the balance and coordination between the resources such as quay crane, RTG and container semi trailer. Firstly, select relevant indicators to construct the port efficiency evaluation input-output indicator system, and calculate the energy consumption of the facilities and equipment in the actual production process of the container port and the transportation and handling equipment required during the operation. Then according to the DEA-BCC model, combined with examples to calculate port comprehensive efficiency, pure technical efficiency and scale efficiency. Finally, use TOPSIS method to sort the efficiency-effective schemes and systematically evaluate the container ports.

2. Port Efficiency Evaluation Indicator System

The evaluation of port efficiency involves many aspects. Therefore, the evaluation indicators should be as comprehensive, practical and applicable as possible, and the stability of the evaluation model

should be maintained for a certain period of time. The "2018 China Green Development Index Report" pointed out that the essence of green development is to reduce the excessive consumption of resources, strengthen environmental protection and ecological governance to pursue comprehensive, coordinated and sustainable economic, social and ecological development. Therefore, the energy consumption of the port is an important aspect of port efficiency evaluation. It is of great significance for continuously creating port value, building green ports and promoting the development of low-carbon logistics in China.

Based on the basic construction principles of indicators such as integrity, objectivity, comparability, and operability, the indicator system is divided into two levels: the criteria layer and the indicator layer. The criteria layer includes five aspects: basic level, financial support, green performance port, operation capability and return. In addition, due to the availability of port data, choose port cargo throughput, container throughput and profit as output indicators, mechanical utilization rate, berth length, number of 10,000-ton berth, fixed asset investment, and energy consumption as input indicators[15]. Port efficiency evaluation indicator system is shown in Figure 1.

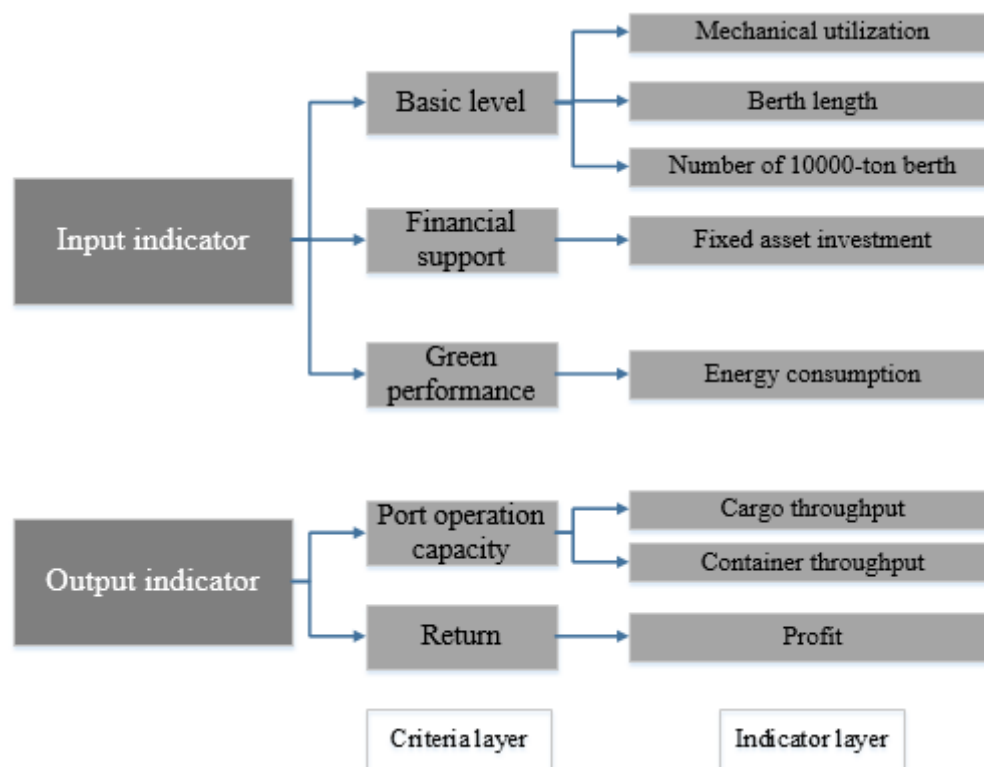


Figure 1. Port efficiency evaluation indicator system

The basic level includes mechanical utilization rate, berth length, and number of 10,000-ton berth, which are used to support the most basic operations of the port and directly affect the production of the port. The mechanical utilization rate affects the operational efficiency of the port. Financial support refers to the investment given by the hinterland and the fixed assets of the port. Green performance is mainly the energy consumption of loading and unloading production, which can be used to evaluate the green level. It is the key to efficiency evaluation. Port operation capacity includes cargo throughput and container throughput. On the other hand, it reveals the energy consumption and pollution emissions brought by the loading and unloading of ships arriving in port., which indirectly reflects the green level of the port. The profit is related to the future development of the port.

3. Research Method

3.1 Research Steps

The port efficiency evaluation model combines with DEA model and TOPSIS model. DEA model focuses on the quantitative calculation of the energy consumption of the container port operation system. On this basis, construct the input-output indicator matrix, and calculate efficiency using DEAP 2.1. Then normalize the matrix according to the TOPSIS method. The weight of each indicator is determined by the entropy weight method then the weighted decision matrix is obtained. Finally rank effective solutions and analyze. The specific steps are shown in Figure 2.

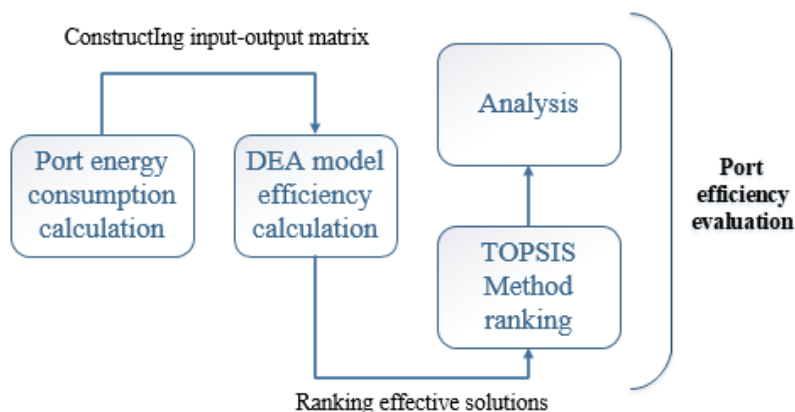


Figure 2. Research steps

3.2 Port Energy Consumption

According to "Port Energy Consumption Statistics and Analysis Methods"(GB/T 21339-2008), the total energy consumption of container ports is mainly composed of the production of comprehensive energy consumption, auxiliary living energy consumption and other aspects of energy consumption. In the comprehensive energy consumption of port production, the energy consumption of loading production is directly used for loading and unloading production. It accounts for the majority of the energy consumption in the normal operation of container ports, mainly including terminal loading and unloading operations, horizontal transportation, warehouse operations and on-site lighting. Power consumption is mainly comes from quay cranes and RMG. Fuel consumption is mainly generated by trucks, RTG, empty container stackers, container forklifts[16], etc.

In the statistical analysis, the total energy consumption unit of each production must be converted into standard coal by standard conversion coefficients. According to “Port Energy Consumption Statistics and Analysis Methods”, the coefficients of various energy conversions to standard coal can be obtained, see Table 1.

Table 1. Coefficients of energy sources converted to standard coal

Energy	Unit	Converting standard coal coefficient	Equivalent value
Row coal	kg standard coal/kg	0.714 3	
Coke	kg standard coal/kg	0.971 4	
Gasoline	kg standard coal/kg	1.471 4	
Diesel	kg standard coal/kg	1.457 1	
Heavy oil	kg standard coal/kg	1.428 6	
Electric power	kg standard coal/kWh	0.404 0	0.1229

The energy consumption to be calculated mainly includes: (1) the power consumption of the quay cranes; (2) the fuel consumption of the RTG and the container semi trailer. Calculation formula as follows.

3.2.1 Port Power Consumption

Single quay crane annual operation operations N_i

$$N_i = \frac{T}{t} = \frac{365 \times 24 \times 60 \cdot \rho_a}{2t_u + t_h} = \frac{525600 \rho_a \cdot v_u \cdot v_h}{2H_u \cdot v_h + (R_0 + D) \cdot v_u} \quad (1)$$

ρ_a —Equipment utilization rate of quay crane;

t_u —Lifting time of quay crane, min;

t_h —Horizontal transportation time, min;

v_u —Lifting speed, m/min;

v_h —Car speed, m/min;

H_u —Lifting height of quay crane, m;

R_a —Out reach of quay crane, m;

D —Distance between quay crane rail and container truck channel, m.

Annual power consumption of single quay crane w_i

$$w_i = \frac{1}{60} \cdot N_i \cdot \left[\frac{2H_{ui} \cdot p_{ui}}{v_{ui}} + \frac{(R_{ai} + D_i) \cdot p_{hi}}{v_{hi}} \right] \quad (2)$$

p_{ui} —Motor power when quay crane lift, kW;

p_{hi} —Motor power of car, kW.

Quay crane annual total power consumption W

$$W = n_a \cdot w_i \quad (3)$$

3.2.2 Port Fuel Consumption

(1) RTG fuel consumption

Single RTG annual operation operations N_{ci}

$$N_{ci} = \frac{365 \times 24 \times 60 \cdot \rho_c}{2t_{cui} + t_{chi}} = \frac{525600 \rho_c \cdot v_{cu} \cdot v_{ch}}{2H_c \cdot v_{ch} + S_c \cdot v_{cu}} \quad (4)$$

ρ_c —Utilization rate of RTG;

t_{cui} —Lifting time of RTG, min;

t_{chi} —Horizontal transportation time of RTG, min;

v_{cu} —Lifting speed of RTG, m/min;

v_{ch} —Car speed, m/min;

H_c —Lifting height of RTG, m;

S_c —Horizontal transport distance for the car, m.

Annual fuel consumption of single RTG q_{ci}

$$q_{ci} = \frac{1}{60000} \cdot N_{ci} \cdot \eta_{ci} \times \left(\frac{2H_{ci} \cdot p_{cui}}{v_{cui}} + \frac{S_{ci} \cdot p_{chi}}{v_{chi}} \right) \quad (5)$$

RTG annual total fuel consumption Q

$$Q = n_c \cdot q_{ci} \quad (6)$$

Container semi trailer fuel consumption

When the container semi trailer is moved between the front of the port and the yard, whether it is loading or unloading, there is always one that is idle and the other is loading. Therefore, in the specific calculation, it is necessary to consider both loading and no-load conditions.

Container semi trailer fuel consumption C_j

$$C_j = n_j \cdot \frac{365 \times 24 \cdot \rho_j \cdot v_j \cdot (\eta_j + \eta'_j)}{2} \quad (7)$$

n_j —Number of container semi trailer;

ρ_j —Utilization rate of container semi trailer;

v_j —Average speed of container semi-trailers, km/h;

η_j —Fuel consumption rate when loading, L/km;

η'_j —Fuel consumption rate when no-load, L/km.

3.3 DEA Model

Data Envelopment Analysis (DEA) is a mathematical programming method for evaluating the relative efficiency between decision making units (DMUs) with multiple inputs and outputs. The DEA method makes a linear plan by inputting variable indicators and output variable indicators. Then solve the maximum value θ of the dual problem according to the dual problem of its linear programming after transforming: (1) When $\theta=1$, it means that the evaluation target DEA is valid, that is, the input/output ratio is the best; (2) When $\theta<1$, it means that the evaluation target is not DEA effective, that is, the input-output ratio is not optimal. Generally speaking, the larger θ indicates that the effect is better.

When measuring whether a decision unit j_0 is valid or not, first select n decision units ($j = 1, 2, \dots, n$), each decision unit has the same m input and the same s output.

All input of decision units can be expressed as

$$X_i = (x_{i1}, x_{i2}, \dots, x_{im})^T, \quad i = 1, 2, \dots, n \quad (8)$$

All output of decision units can be expressed as

$$Y_i = (y_{i1}, y_{i2}, \dots, y_{im})^T, \quad i = 1, 2, \dots, n \quad (9)$$

The efficiency evaluation index of the decision unit can be expressed as

$$E_i = \frac{u^T Y_i}{v^T X_i}, \quad i = 1, 2, \dots, n \quad (10)$$

The DEA method includes two standard analytical models: the CCR model and the BCC model. CCR model is one of the most basic models, which taking production efficiency and marginal production efficiency into account to achieve the best planning results. Model as follows.

$$\begin{aligned} & \max \frac{u^T Y_i}{v^T X_i} \\ & s.t. \begin{cases} \frac{u^T Y_i}{v^T X_i} \leq 1, \quad j = 1, \dots, n \\ u \geq 0, \quad v \geq 0 \end{cases} \end{aligned} \quad (11)$$

The dual model introduces slack variables e^+ , e^- and Non-Archimedean infinitesimal ε

$$\begin{aligned} & \min \theta - \varepsilon(e_1^T s^- + e_2^T s^+) \\ & s.t. \begin{cases} \sum_{i=1}^n X_i \lambda_i - s^+ = \theta X_0 \\ \sum_{j=1}^n Y_j \lambda_j - s^- = Y_0 \\ \lambda_i \geq 0, i = 1, 2, \dots, n \\ s^- \geq 0, s^+ \geq 0 \end{cases} \end{aligned} \quad (12)$$

In the above model, s^- is the slack variable vector corresponding to the input, while s^+ is the slack variable vector corresponding to the output. X_0, Y_0 are the input and output vector of a decision unit being evaluated. If the optimal solution λ of the model make $\theta = 1, s^- = 0, s^+ = 0$, the decision unit DEA is valid.

BCC model is developed on the basis of CCR model. It changes the scale efficiency of the hypothesis in the CCR model to a variable scale efficiency, and refines the comprehensive efficiency to pure technical efficiency and scale efficiency. This paper will use the BCC model to evaluate the efficiency of container ports from three aspects: comprehensive efficiency, pure technical efficiency and scale efficiency.

3.4 TOPSIS Model

TOPSIS method is a method based on the closeness of a limited number of evaluation objects and idealized targets, and sorting them to evaluate the existing evaluation objects. The basic principle is to sort the distance between the object to be evaluated and the optimal solution and the worst solution. Following are specific steps:

Construct a normalized decision matrix

$$\begin{cases} R_{ij} = \frac{X_{j\min}}{X_{ij}} \\ R_{ij} = \frac{X_{ij}}{X_{j\max}} \end{cases} \quad (13)$$

Construct a weighted normalization matrix

To improve the method of determining the weight by the Delphi method in the traditional TOPSIS model, the entropy weight method is used to objectively weight, and the weight W is calculated to obtain the weighted normalization matrix V

$$V = R \times W \quad (14)$$

Positive and negative solutions

$$\text{Positive solution: } A^+ = \max_i [V_{ij}] \quad (15)$$

$$\text{Negative solution: } A^- = \min_i [V_{ij}] \quad (16)$$

Distance

The distance between each decision solution and the positive and negative solution

$$D_i^+ = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^+)^2} \quad (17)$$

$$D_i^- = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^-)^2} \quad (18)$$

The proximity between each decision solution and the positive and negative solution

$$C_i = \frac{D_i^-}{(D_i^+ + D_i^-)} \quad (19)$$

The proximity value is between 0 and 1. The closer the value of the proximity is to 1, the closer the target to be evaluated is to the optimal solution; otherwise, if the value is closer to 0, the closer the target to be evaluated is to the worst solution. Compared with the single-index analysis method, TOPSIS method can focus on the overall situation to achieve comprehensive analysis and evaluation, and significantly improve the scientific, accuracy and operability of multi-objective decision analysis.

DEA method is suitable for multiple input and multiple output problems. However, when there are multiple decision units with a scale efficiency value of 1, it cannot be sorted by this method, and the comprehensive indicator cannot be converted into an intuitive result. TOPSIS method makes up for the shortcomings of the DEA method, and can achieve the ranking of the multi-index comprehensive evaluation results of different programs.

4. Case Analysis

4.1 Energy Consumption Results

Y Port is the largest port in Jiangsu Province, one of the 25 major ports in China's coastal areas, 12 regional main hub ports and the Yangtze River Delta port group. The data comes from the China Port Yearbook from 2000 to 2017, the official website and statistical bureau of the port. Y port is equipped with 13 quay cranes, 29 RTGs and 32 container semi trailers. The parameters of each device are shown in Table 2. The utilization rate of quay crane, RTG and container semi-trailer is based on the mechanical utilization rate in the yearbook, as shown in Table 3.

Table 2. Main equipment parameters

parameter	Quay Crane	RTG	Container semi-trailer
Lifting height (m)	40	16	-
Front reach (m)	65	-	-
Rail span (m)	30	30	-
Lifting speed (m/min)	90	20	-
Car speed (m/min)	240	80	-
Lifting power (kW)	580×2	90×2	-
Car power (kW)	300	22×2	-
Specific fuel consumption rate(g/kWh)	-	420	-
No-load fuel consumption rate (L/km)	-	-	0.75
Full load fuel consumption rate (L/km)	-	-	1.05
Average speed (km/h)	-	-	25

Table 3. Mechanical utilization rate

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Utilization rate (%)	18.2	19.2	19.1	22.6	21.7	21.1	27.4	30.8	30.1

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Utilization rate (%)	26.8	29.2	29.4	30.5	32.1	32.2	27.0	23.2	24.8

According to Table 2 and formula (1)-(7), the power consumption of the quay crane and the fuel consumption of the container semi-trailer and the RTG can be calculated. Then, Combined with the converted standard coal coefficient of diesel and electricity in Table 1, the energy consumption of the port from 2000 to 2017 is obtained. As is shown in Table 4.

Table 4. Y port annual total energy consumption (kg standard coal)

Year	Quay crane	RTG	Container semi-trailer	Annual total
2000	7494391	4362469	1405001	13261861
2001	7906171	4602165	1482199	13990535
2002	7864993	4578195	1474479	13917667
2003	9306222	5417132	1744672	16468025

2004	8935620	5201405	1675194	15812219
2005	8688552	5057587	1628875	15375015
2006	11282765	6567673	2115221	19965659
2007	12682816	7382640	2377694	22443150
2008	12394570	7214852	2323656	21933078
2009	11035697	6423855	2068903	19528455
2010	12023968	6999126	2254177	21277272
2011	12106324	7047065	2269617	21423006
2012	12559282	7310731	2354535	22224547
2013	13218130	7694244	2478051	23390425
2014	13259308	7718214	2485771	23463293
2015	11118053	6471794	2084342	19674190
2016	9553290	5560949	1790990	16905230
2017	10212138	5944463	1914507	18071107

4.2 DEA Efficiency Calculation and Analysis

From the port input-output indicator system in Section 2, combined with the annual energy consumption in Table 4, consult the Y Port Port Authority, the Y Municipal Bureau of Statistics, and the Port Yearbook from 2000 to 2017 to obtain the specific indicator data of mechanical utilization rate, berth length, number of 10, 000-ton berths, fixed asset investment, energy consumption, cargo throughput, container throughput and profit. At the same time, due to the difference in the dimensionality of the data and the difference in magnitude, the indicator data must be nondimensionalized.

Using the software DEAP to calculate the efficiency of each port, the results are shown in Table 5 and Figure 3.

Table 5. Port efficiency evaluation results

firm	crste	vrste	scale	
2000	1.000	1.000	1.000	-
2001	1.000	1.000	1.000	-
2002	0.881	0.995	0.886	irs
2003	0.587	0.868	0.676	irs
2004	0.481	0.851	0.566	irs
2005	0.634	1.000	0.634	irs
2006	0.914	1.000	0.914	irs
2007	1.000	1.000	1.000	-
2008	1.000	1.000	1.000	-
2009	0.955	0.963	0.991	irs
2010	1.000	1.000	1.000	-

2011	1.000	1.000	1.000	-
2012	0.990	0.991	0.999	irs
2013	1.000	1.000	1.000	-
2014	0.987	1.000	0.987	drs
2015	1.000	1.000	1.000	-
2016	1.000	1.000	1.000	-
2017	1.000	1.000	1.000	-

crste: technical efficiency, also called comprehensive efficiency;

vrste: pure technical efficiency;

scale: scale efficiency, $\text{scale} = \text{crste} / \text{vrste}$;

drs: diminishing returns to scale;

-: the return to scale is unchanged;

irs: increasing returns to scale.

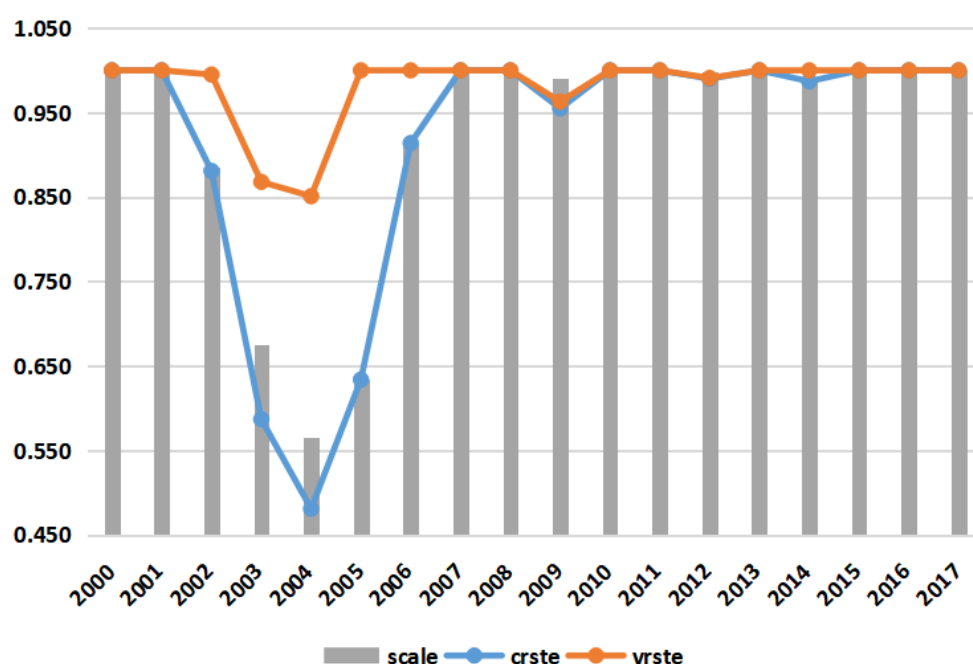


Figure 3. Crste, vrste, scale efficiency of Y port from 2000 to 2017

In 2000 and 2001, Y Port achieved the best comprehensive efficiency, pure technical efficiency and scale efficiency. In 2002-2004, the scale efficiency decreased year by year and reached its lowest level in 2004, resulting in a reduction in comprehensive efficiency to 0.481. However, in the following three years, the efficiency of the Y port gradually increased and reached its optimal level in 2007. In the decade of 2008-2017, the scale efficiency declined slightly in 2009 and 2014, and remained valid in other years, indicating that the input-output ratio is appropriate in this decade, and resource allocation, energy consumption is reasonable and utilization is high.

From the perspective of the trend of efficiency value change, the comprehensive efficiency and scale efficiency in 2000-2017 show a state of decrease, increase and stability, and the fluctuation range is relatively consistent. Meanwhile, the pure technical efficiency has been at a relatively good level, indicating that the comprehensive efficiency change of Y Port mainly comes from scale efficiency.

The scale effect of Y Port is gradually emerging. As the external environment changes or the demand increases, some of the infrastructure invested in the early stage is gradually being used.

As to changes in returns, the scale returns in 2002, 2003, 2004, 2005, 2006, 2009, and 2012 increased, indicating that the scale of operations in these seven years was small, and the scale benefit has much space to improve. The decrease in scale returns in 2014 indicates that the scale of operations in the year is large and the investment in production factors is large. In the remaining years, the scale returns are the same and the scale is effective. That is, on the basis of the original operation scale, the corresponding output can be obtained by adding a certain amount of input.

In addition, according to the "Projection" principle and DEAP operation results, a redundancy analysis for years where efficiency is not effective is made. In 2002, 2003, 2004, output of throughput and profit were insufficient, and actual output and target output were quite different. There is redundancy in mechanical utilization rate, number of 10,000-ton berths, and energy consumption, indicating that infrastructure investment, energy consumption, throughput, and profit output are unreasonable. In 2009, only throughput, profit output was insufficient, and input indicators were not redundant, which indicated less infrastructure investment and lower energy consumption during the year. In 2014, the gap between actual output and target output was further reduced. However, there is a certain degree of redundancy in terms of mechanical utilization rate, terminal length, number of 10,000-ton berths, fixed asset investment, and energy consumption, which indicated that the port efficiency was further optimized during the year, in line with the overall efficiency of 0.987.

4.3 TOPSIS Ranking and Analysis

The years with comprehensive efficiency of 1 are 2000, 2001, 2007, 2008, 2010, 2011, 2013, 2015, 2016, 2017, but it is impossible to further judge the port of this decade. TOPSIS method can be used for further analysis. Sort the results of the second evaluation of the years in which the comprehensive efficiency has been optimized, so as to achieve the final efficiency evaluation of the port within ten years. According formula (13)-(19), using objective and effective entropy weight method to obtain the weight of indicators, as follows:

$$W = [0.1148, 0.1333, 0.1271, 0.1500, 0.1328, 0.1230, 0.1188, 0.1003]$$

Then, calculate the positive and negative ideal solution, and the distance between each solution and the positive and negative ideal solution. At last, ranking the effective years according to the closeness to the ideal solution, as shown in Table 6 and Table 7.

Table 6. Positive and negative ideal solution

Indicator	Positive ideal solution	Negative ideal solution
Mechanical utilization rate	0.1148	0.0651
Berth length	0.1333	0.0461
Number of 10000-ton berth	0.1271	0.0558
Fixed asset investment	0.1500	0.0032
Energy consumption	0.1328	0.0753
Cargo throughput	0.1230	0.0146
Container throughput	0.1188	0.0011
Profit	0.1003	0.0150

Table 7. Proximity between each solution and the positive and negative ideal solution

Year	2000	2001	2007	2008	2010	2011	2013	2015	2016	2017
C	0.418	0.321	0.348	0.367	0.458	0.500	0.533	0.567	0.566	0.574
rank	7	10	9	8	6	5	4	2	3	1

The greater the proximity of the solution to the ideal solution, the better the solution. It can be seen from the ranking results that in the ten years when comprehensive efficiency is optimal, the port efficiency evaluation of Y Port still has advantages and disadvantages. Among them, the efficiency of year 2017 system evaluation is the closest to the ideal.

In summary, after combining the calculation and analysis of the two methods of DEA and TOPSIS, it is not difficult to find that the Y port indicator scheme in 2017 is the best solution in the 18-year period from 2000 to 2017, but the proximity to the positive ideal scheme is only 0.5738. There is still a big gap with the optimal solution. Lower port efficiency will not only affect the further development of port enterprises, but also cause excessive energy consumption and waste of resources. Therefore, the port needs to further improve the overall system. While pursuing high output, it also needs to pursue low investment and effectively improve the efficiency of the system to make the port develop quickly and well.

5. Conclusion

This paper first establishes the port input-output index system, then calculates and analyzes the energy consumption involved in the actual production process of the container port. Finally, construct the DEA-TOPSIS combination model to evaluate the overall efficiency of the port from 2000 to 2017.

Select port cargo throughput, container throughput, profit as output indicators, mechanical utilization rate, berth length, number of 10,000-ton berth, fixed asset investment, energy consumption as input indicators, and establish port efficiency evaluation indicator system from the perspective of energy consumption. However, the selection of indicators is based on the availability of data which lacks certain objectivity and scientificity.

The port efficiency and development level of Y Port are not ideal. The years with efficiency of 1 are 2000, 2001, 2007, 2008, 2010, 2011, 2013, 2015, 2016, 2017. In 2003, 2004 and 2005, it reached a lower level of scale efficiency. The comprehensive efficiency and scale efficiency between 2000 and 2017 shows a decreasing and rising fluctuation.

In the year when the efficiency is not effective, the port's infrastructure, financial support, energy consumption are unreasonable in terms of throughput, and profit. Input indicators have varying degrees of redundancy, which is directly related to the number of equipment and energy consumption in the port.

Even in an efficient year, the proximity of the best year 2017 in the ranking by the TOPSIS method is only 0.5738, which is still far from the optimal solution. Therefore, Y Port needs to further improve the overall system. On the one hand, it can adopt new energy or improve energy efficiency to achieve energy saving and emission reduction. On the other hand, the role of the port itself can be repositioned, and the pattern of coordinated development can be constructed by optimizing the division of labor. While attaching importance to port efficiency, the sustainable development of ports also needs to be promoted. On this basis, the existing resources will be integrated to reduce unnecessary investment, thus achieving a low-carbon port type with high output and low investment.

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