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Study on Energy Conservation and Emission Reduction Evaluation Index System of Container Terminal Loading and Unloading Process

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Abstract

In recent years, as China's container throughput volume growth for years, in loading and unloading process of container terminal, a large number of transportation, loading and unloading equipment and yard equipment in operation process, not only consumes a lot of energy, but also emit large amounts of gas pollution substance pollution, solid and liquid pollutants. These problems not only cause the environmental deterioration in the port, but also pose a serious threat to the health of residents around the port. Therefore, the research on energy saving and emission reduction of container port handling technology is of practical significance and extremely necessary.

Keywords

Container terminal; Handling technology; Energy conservation and emission reduction; Analysis of influencing factors.

1. Introduction

With the rapid development of China's economy, my country's demand for energy has also grown tremendously. Although my country's current annual energy production is among the highest in the world, the demand for energy is still less than demand. Moreover, in the international arena, the problems of energy consumption and pollution emissions are becoming more and more serious. The goals of all countries are to reduce energy consumption and pollutant emissions as much as possible. The status of container ports both at home and abroad is as a distribution center for foreign trade goods, but they are also the main source of energy consumption and pollutant emissions. Therefore, energy-saving and emission reduction activities in container ports are not only the responsibility of port companies, but also the government's guidance to the public. A necessary link to cultivate energy conservation awareness. This is not only conducive to the realization of the overall goal of energy conservation and emission reduction, but also conducive to improving their own economic benefits.

Foreign scholars focus on environmental protection and sustainable development for energy conservation and emission reduction in container ports, and they pay less attention to the combination of modern information technology and port energy conservation and emission reduction. Thomas. A. ghgalunas and Meifengluo, after investigating the surrounding environment in the container port, based on the theoretical basis of energy conservation and emission reduction, put forward a large number of suggestions for energy conservation and emission reduction in the investigation port [1]. In order to study the sources and solutions of pollutants in ports, PerH.O.Ison analyzed different types of waste and put forward recommendations for sustainable reuse of pollutant emissions from port transportation [2]. ALM.Goulielmos (2000) through field investigation of ports and analysis of factors affecting energy conservation and emission reduction, the author believes that environmental costs should be regarded as part of port costs, and has made an in-depth study on this [3].

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At present, domestic scholars mainly focus on the analysis of influencing factors for energy conservation and emission reduction of container ports, and they have in-depth research on the construction of energy conservation and emission reduction index systems. Huang Guoqing (2014) put forward an energy-saving evaluation system for port loading and unloading machinery based on the research on the energy-saving status of port loading and unloading machinery, which is helpful to the implementation of energy conservation and emission reduction work of port enterprises and lays the foundation for the formulation of further related energy-saving standards . Ling Qiang (2010) took Shanghai Port as an example to introduce the guiding ideology, design principles, index composition and application methods of establishing an evaluation index system . Li Hongbo (2012) established an evaluation index system for the soft power of Jinzhou Port through the analysis of the status quo of the soft power of Jinzhou Port, including 4 first-level indicators and 22 second-level indicators, and put forward suggestions for improvement and improvement.

This article is based on the above background, using the analytic hierarchy process and the fuzzy comprehensive evaluation method to carry out a detailed study and discussion on the energy saving and emission reduction evaluation system of the container terminal handling process.

2. Analysis of Factors Influencing Energy Conservation and Emission Reduction of my country's Container Terminal Handling Technology

As there are many factors affecting energy saving and emission reduction benefits in the loading and unloading process of port terminals, this article will analyze the influencing factors of energy conservation and emission reduction in container terminal loading and unloading processes from the structural, technical and management levels.

2.1 Structural level

2.1.1 Infrastructure construction

In the working process of container terminal loading and unloading, the construction of infrastructure is directly related to the berth utilization rate of the terminal, the condition of the navigation route, and the state of use of the loading and unloading equipment. At present, most ports have a combination of infrastructure construction and energy-saving networking. The level is low, and the front-end collection and distribution capacity of the terminal is not high, which makes the intensive and large-scale development of port cargo handling and transportation slow. The construction of a series of good infrastructure for transportation can make the berths of the wharf better maintained in daily use, save berthing time when ships berth, and avoid unnecessary berthing risks; and it will improve the condition of the waterway and make the waterway more stable. The applicability is enhanced, the channel environment is improved, and unnecessary pollution emissions are reduced; it can also facilitate loading and unloading when loading and unloading equipment is used, improving loading and unloading efficiency, saving loading and unloading time, and reducing unnecessary energy consumption.

2.1.2 Loading and unloading equipment configuration

In the working process of container terminal loading and unloading, the structural configuration of loading and unloading equipment is very important for energy saving and emission reduction. Unreasonable configuration of loading and unloading equipment will lead to oversupply of various equipment participating in the loading and unloading process. Most of the transportation equipment is not It is applicable to the requirements of the trend of specialization and large-scale, and the elimination cycle of transportation equipment is too long, making the development of supporting service facilities of transportation equipment lagging behind. As long as it has a series of good structural configurations, it can maximize the utilization of machinery and equipment. In addition, through reasonable configuration, unnecessary shutdown of mechanical equipment can be reduced, and various loading and unloading facilities of the terminal can be used to the best use, thereby

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increasing the utilization rate of loading and unloading equipment and reducing the unit energy consumption of loading and unloading equipment.

2.1.3 Yard equipment configuration

In the working process of container terminal loading and unloading, the rationality of the configuration of the yard equipment will not only restrict the loading and unloading volume of the port loading and unloading goods, but also have a great impact on the storage quality of the goods and the applicability of the types of goods. In the process of yard equipment structure configuration, the actual demand for energy saving and emission reduction of the port should be followed, with the goal of reducing equipment unit energy consumption, improving operation efficiency as the goal, and reducing pollution emissions as the standard.

2.2 Technical level

2.2.1 Energy-saving technology R&D investment

The essence of reducing the unit energy consumption and pollution emissions of loading and unloading equipment is to upgrade the performance of loading and unloading equipment and improve the efficiency of loading and unloading equipment. Many ports have insufficient investment in energy-saving technology research and development, which makes the research and development of energy-saving technologies and products insufficient, leading to slow development of energy-saving and emission-reduction work in ports. However, the necessary prerequisite for upgrading the performance of loading and unloading equipment is the large investment in energy-saving technology research and development, in order to develop the use of clean energy to replace fuel and some key technologies for environmentally friendly vehicles.

2.2.2 Modern Information Technology Application

With the rapid development of modern information technology, port automation has become the development trend of major ports. However, with the exception of some extra-large ports, the degree of modern informatization in the industry still needs to be further improved. In the port loading and unloading process, the automatic control of loading and unloading equipment, dispatching facilities, and yard handling equipment has a significant positive impact on the development of port energy saving and emission reduction.

2.3 Management level

2.3.1 Energy saving laws and regulations and standards

For a country or port organization, energy-saving laws and regulations and energy-saving standards and regulations are the embodiment of its will to energy-saving emission reduction requirements. During the "Twelfth Five-Year Plan" period, my country's total pollution emissions have dropped significantly. For example, major pollutants such as sulfur dioxide, nitrogen oxides, and ammonia nitrogen have been reduced by 18%, 13%, and 18.6% respectively; and my country's energy consumption per unit of GDP It has also been reduced by 18.4%, and the expected energy-saving and emission-reduction targets have been successfully completed. This shows that the formulation of a practical and effective standard is of positive significance to the development of energy conservation and emission reduction work.

2.3.2 Energy-saving monitoring and assessment system

It is very necessary to establish a scientific, complete and unified assessment system to count and monitor the progress of energy conservation and emission reduction. Only by ensuring the authenticity, accuracy and real-timeness of the statistical data of energy conservation and emission reduction, can we analyze the benefits of energy conservation and emission reduction work, discover problems in energy conservation and emission reduction work, and accurately grasp the follow-up of energy conservation and emission reduction work. Development and goal setting.

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3. Establish an evaluation system model for energy saving and emission reduction of container port handling technology

3.1 Establish an evaluation index system for energy saving and emission reduction of container terminal handling technology

Based on the analysis of influencing factors that affect energy conservation and emission reduction of container terminal handling technology introduced in the previous section, this article combines the current status of energy conservation and emission reduction of my country's container terminal handling technology, and finally determines pollution emissions, energy-saving technologies and measures, energy consumption, and energy saving. Regulations, standards, organizations and systems, as well as six first-level indicators of technological innovation, and 17 indicator levels such as unit energy consumption of loading and unloading production equipment, are shown in Table 1.

Table 1. Evaluation Index System for Energy Conservation and Emission Reduction of Container Terminal Handling Technology

Target layer	Criterion layer	Index layer
Evaluation Index System for Energy Conservation and Emission Reduction of Container Terminal Handling TechnologyA	pollution discharge B_1	Water pollution discharge C_{11}
		Air pollution emissions C_{12}
		Solid waste discharge C_{13}
	energy-saving technologies and measures B_2	Energy saving elimination and improvement plan C_{21}
		Comprehensive utilization of new energy C_{22}
		Energy-saving publicity and technical training C_{23}
	energy consumption B_3	Comprehensive unit energy consumption of container production C_{31}
		Unit energy consumption of loading and unloading production equipment C_{32}
		Unit energy consumption of yard operation equipment C_{33}
	energy-saving regulations and standards B_4	Implement relevant laws and regulations C_{41}
		Implement energy consumption quota standards for high energy consumption products C_{42}
	organization and system B_5	Energy saving special system, plan and evaluation C_{51}
		Implement energy consumption review and monitoring system C_{52}
		Equipped with energy consumption meters and regular inspection standards in accordance with the law C_{53}
		New purchases and renovation projects are designed according to energy saving C_{54}
	technological innovation B_6	Clean energy consumption as a percentage of energy consumption C_{61}
		Number of new technology and new products C_{62}

3.2 Establish a comprehensive evaluation system model

The evaluation method used in this article is the AHP-fuzzy comprehensive evaluation method, which is composed of the analytic hierarchy process and the model comprehensive evaluation method. The Analytic Hierarchy Process (AHP) was developed by the American operations researcher TLSaaty and others in the 1970s. What was first proposed is a combination of qualitative and quantitative decision analysis method. Fuzzy Comprehensive Evaluation (FCE), which is a comprehensive bid evaluation method based on fuzzy mathematics.

The basic steps of AHP are as follows.

Establish a hierarchical structure model, distinguish the target layer, the first target layer and the second target layer, and establish different hierarchical structures.

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Construct a matrix that can be compared in pairs. After scoring and comparing each element, bring the result into this matrix to form a judgment matrix. And assign the value of the element's importance on the scale of 1-9, as shown in Figure 1.

$$a_{ij} > 0, \quad a_{ji} = 1/a_{ij}, \quad a_{ii} = 0$$

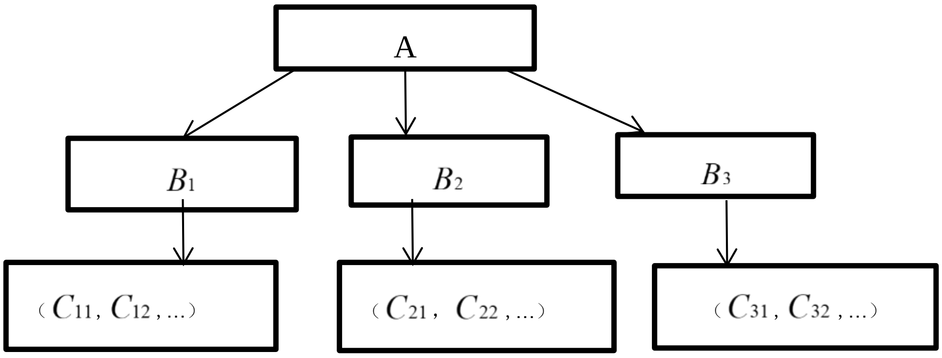

Figure 1. Two or more references

A represents the target layer, Bi represents the first-level indicator layer, and Ci represents the second-level indicator layer, which is the proportional scale of the element and the importance relative to B, are shown in Table 2.

Table 2. Proportional scale

Relative ratio (scale a_{ij})	meaning
1	Indicates that two elements are equally important
3	Indicates that the former is slightly more important than the latter compared to the two elements
5	Indicates that compared with two elements, the former is obviously more important than the latter
7	Indicates that compared to two elements, the former is more important than the latter
9	Indicates that compared to two elements, the former is extremely important than the latter
2, 4, 6, 8	Indicates the intermediate value of the appeal adjacent judgment

Through expert scoring, each element in the hierarchical structure can be compared with the elements of the previous level in turn to construct a judgment matrix. Table 3 shows the importance of the elements of the B layer relative to the elements of the A layer to form an A-B judgment matrix.

Table 3. A-B judgment matrix

A	B_1	B_2	B_3	…	B_{n-1}	B_n
B_1	1	—	—	—	—	—
B_2	a_{21}	1	—	—	—	—
B_3	a_{31}	a_{32}	1	—	—	—
…	…	…	…	1	—	—
B_{n-1}	a_{n-11}	a_{n-12}	a_{n-13}	…	1	—
B_n	a_{n1}	a_{n2}	a_{n3}	…	a_{nn-1}	1

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For the judgment matrix A, the calculation satisfies

$$AW=\lambda_{max} W \tag{1}$$

Among them is the largest feature root of A, W corresponds to the normalized feature vector, and the component of W is the weight value of the corresponding element single order. This paper uses an approximate calculation method to calculate the weight vector, the formula is as follows.

$$W_i = \sum_{j=1}^{n} a_{ij} \div n \sum_{k=1}^{n}\sum_{j=1}^{n} a_{kj} \text{ ,i=1,2,…,n} \tag{2}$$

$$\lambda_{max} = \sum_{i=1}^{n} ((AW)_i \div nW_i) \text{ ,i=1,2,…,n} \tag{3}$$

Among them, refers to the relative ratio of the i element to the j element. After the above calculation, the sorting weight vector of the comparison element required by the single criterion is obtained, and then the obtained W vector is normalized separately to obtain the matrix vector.

$$w = (w_1, w_2, \cdots, w_n) \tag{4}$$

In order to satisfy the consistency of the judgment matrix, it is necessary to check the consistency of the judgment matrix. The following formula can be used to calculate the consistency index:

$$C.I. = (\lambda_{max} - n) \div (n-1) \tag{5}$$

In the above formula, C.I. represents the degree of consistency of the matrix. The farther C.I. is from 0, the worse the consistency of the judgment matrix. Compare with the corresponding average random consistency index R.I. When C.R.= (C.I.R.I)0.10, the consistency of the matrix is very good. When C.R.= (C.I.R.I)>0.10, the elements in the matrix need to be adjusted until the conditions are met.

The specific steps of the fuzzy comprehensive evaluation method are as follows:

Establish an evaluation factor set. The factor set is a set composed of various factors affecting the evaluation object, denoted by U, namely:

$$U = \{u_1, u_2, \cdots, u_n\} \tag{6}$$

Among them are evaluation factors, and n is the number of individual factors at the same level. The evaluation factors in this article are the evaluation indicators of each level obtained by the analytic hierarchy process in the previous section. The rating comment set is a set of possible evaluation results made by the evaluation object, which can be expressed as:

$$V = (V_1, V_2, \cdots, V_n) \tag{7}$$

Among them is the evaluation grade standard, and n is the number of elements, that is, the number of grade reviews. It stipulates the selection range of the evaluation results of a certain evaluation factor,

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and these evaluation factors can be qualitative or quantitative, and generally can be divided into four grades: good, good, medium, and poor.

Let A be an ordinary subset of the universe of X, x absolutely belongs to A, that is, the degree to which x belongs to A is 1; x absolutely does not belong to A, that is, the degree to which x belongs to A is 0. Generally, if x is between the two, a value between (0,1) is used to indicate the degree to which x belongs to A. This number is called the degree of membership, and the set formed is called a fuzzy set. Let X be the domain of discourse, then:

$$U_A : X \to [0,1] \tag{8}$$

The above formula is called a fuzzy subset A of X, which is the membership function of A, and is called the membership degree of x to A.

In the fuzzy comprehensive evaluation, the evaluation starts from one factor in the factor set U to determine the degree of membership of the evaluation object to the elements of the evaluation set. This process is called single-factor fuzzy evaluation. Suppose the membership degree of the i-th evaluation factor to the j-th element in the comment set is $r_{ij}(j = 1,2,\cdots,m)$. According to the evaluation structure of the i-th factor, the fuzzy set can be expressed as:

$$Ri = (r_{i1}, r_{i2}, \cdots, r_{im}), i = 1,2,\cdots,n \tag{9}$$

If you evaluate n elements, the result is a matrix with n rows and m columns, which is called membership R. R is a single-factor evaluation set, a fuzzy matrix, and a fuzzy subset of the evaluation set V, namely:

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \cdots \\ R_n \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \tag{10}$$

When the weight set W and the single factor evaluation matrix R are known, the fuzzy transformation can be used for comprehensive evaluation to obtain the fuzzy comprehensive evaluation calculation model:

$$B = W * R = (w_1, w_2, \cdots, w_n) * \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} = (b_1, b_2, \cdots, b_n) \tag{11}$$

The "*" in formula 3.10 represents a certain synthetic operation; it is called a fuzzy comprehensive evaluation index, or evaluation index for short. The meaning of is the degree of membership of the evaluation object to the j elements of the comment set when all factors are considered comprehensively.

4. Case Analysis

First, through the data collection and processing of Qingdao Port, the original data of the required quantitative indicators are obtained, as shown in Table 4 below.

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Table 4. Raw data of quantitative indicators

index	data	grade
Clean energy consumption as a percentage of energy consumption C_{61}	46.36	better
Number of new technology and new products C_{62}	8	good

Then, through the distribution of expert questionnaires and online consultation, relevant experts were consulted to vote on 15 qualitative indicators and gave suggestions. The statistical evaluation results are shown in Table 5.

Table 5. Qualitative indicator voting statistics

index	good	better	ordinary	Poor
Water pollution discharge C_{11}	4	1	0	0
Air pollution emissions C_{12}	3	1	1	0
Solid waste discharge C_{13}	3	2	0	0
Energy saving elimination and improvement plan C_{21}	4	1	0	0
Comprehensive utilization of new energy C_{22}	3	1	1	0
Energy-saving publicity and technical training C_{23}	2	2	1	0
Comprehensive unit energy consumption of container production C_{31}	2	3	0	0
Unit energy consumption of loading and unloading production equipment C_{32}	0	2	2	1
Unit energy consumption of yard operation equipment C_{33}	2	1	2	0
Implement relevant laws and regulations C_{41}	4	1	0	0
Implement energy consumption quota standards for high energy consumption products C_{42}	3	2	0	0
Energy saving special system, plan and evaluation C_{51}	4	1	0	0
Implement energy consumption review and monitoring system C_{52}	3	1	1	0
Equipped with energy consumption meters and regular inspection standards in accordance with the law C_{53}	4	0	1	0
New purchases and renovation projects are designed according to energy saving C_{54}	3	2	0	0

According to the determination method of the membership degree of qualitative index and quantitative index, normalization is carried out, and the fuzzy matrix R of evaluation index is obtained.

$$R_1 = \begin{bmatrix} 0.8 & 0.2 & 0 & 0 \\ 0.6 & 0.2 & 0.2 & 0 \\ 0.6 & 0.4 & 0 & 0 \\ 0.8 & 0.2 & 0 & 0 \\ 0.6 & 0.2 & 0.2 & 0 \\ 0.4 & 0.4 & 0.2 & 0 \\ 0.4 & 0.6 & 0 & 0 \\ 0 & 0.4 & 0.4 & 0.2 \\ 0.4 & 0.2 & 0.4 & 0 \\ 0.8 & 0.2 & 0 & 0 \\ 0.6 & 0.4 & 0 & 0 \\ 0.8 & 0.2 & 0 & 0 \\ 0.6 & 0.2 & 0.2 & 0 \\ 0.8 & 0 & 0.2 & 0 \\ 0.6 & 0.4 & 0 & 0 \end{bmatrix}, \quad R_2 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

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Combined with the weight of the indicator system, the table 6 is as follows.

Table 6. Fuzzy matrix of evaluation indicators

index	R				W
Water pollution discharge C_{11}	0.8	0.2	0	0	0.041
Air pollution emissions C_{12}	0.6	0.2	0.2	0	0.067
Solid waste discharge C_{13}	0.6	0.4	0	0	0.125
Energy saving elimination and improvement plan C_{21}	0.8	0.2	0	0	0.021
Comprehensive utilization of new energy C_{22}	0.6	0.2	0.2	0	0.008
Energy-saving publicity and technical training C_{23}	0.4	0.4	0.2	0	0.039
Comprehensive unit energy consumption of container production C_{31}	0.4	0.6	0	0	0.222
Unit energy consumption of loading and unloading production equipment C_{32}	0	0.4	0.4	0.2	0.063
Unit energy consumption of yard operation equipment C_{33}	0.4	0.2	0.4	0	0.056
Implement relevant laws and regulations C_{41}	0.8	0.2	0	0	0.054
Implement energy consumption quota standards for high energy consumption products C_{42}	0.6	0.4	0	0	0.046
Energy saving special system, plan and evaluation C_{51}	0.8	0.2	0	0	0.075
Implement energy consumption review and monitoring system C_{52}	0.6	0.2	0.2	0	0.050
Equipped with energy consumption meters and regular inspection standards in accordance with the law C_{53}	0.8	0	0.2	0	0.017
New purchases and renovation projects are designed according to energy saving C_{54}	0.6	0.4	0	0	0.016
Clean energy consumption as a percentage of energy consumption C_{61}	0	1	0	0	0.058
Number of new technology and new products C_{62}	1	0	0	0	0.042

Bring the evaluation matrix and weight into the calculation model for calculation, and get the result:

$$\mathrm{B}=W*\mathrm{R}=(w_1,w_2,\cdots,w_n)*\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}=(0.5224,0.3812,0.0838,0.0126)$$

From the above evaluation results, it can be seen that the performance of Qingdao Port’s energy-saving and emission-reduction work corresponds to the “good” level of 0.5224, and the performance of Qingdao Port’s energy-saving and emission reduction work corresponds to the “good” level of 0.3812. The energy-saving and emission-reduction performance of Qingdao Port corresponds to the "medium" level of 0.0838, and the energy-saving and emission reduction performance of Qingdao Port corresponds to the "poor" level of 0.0126. According to the principle of maximum degree of membership, the evaluation value of Qingdao Port's energy saving and emission reduction is 0.5224.

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