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Construction and Evaluation of Green Logistics System in Guangzhou Port

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Abstract: In recent years, with the steady growth of the national economy, the logistics industry has developed rapidly. At the same time, the environmental pollution and waste of resources brought about by the development of port logistics have become increasingly aggravated, and green logistics is in line with the direction of social development and has become the inevitable development trend of the logistics industry in the context of energy conservation and emission reduction. Based on the basic theory of port logistics, green logistics theory and performance evaluation methods, the paper analyzes the main factors affecting green logistics, constructs the green logistics performance evaluation index system of Guangzhou port, assigns weights to the indexes through hierarchical analysis and entropy method, and uses the grey correlation model to carry out empirical research on the green logistics performance level of Guangzhou port and proposes countermeasures.

1. Logistics system based on the green development of ports

1.1 Basic elements of a port logistics system based on green development

(1) The supply capacity and development capacity of the port logistics system is in balance with the demand for port logistics from socio-economic development, i.e. the green development of port logistics is in line with the green development of the socio-economy.

(2) Green development of port logistics and resources. Optimize the limited space and time resources, emphasize the reduction of resource consumption through scientific and reasonable planning and layout of land use and logistics facilities, improve the overall efficiency of the system and maximize the value of resource utilization, and attach importance to the construction of the port logistics system while attaching importance to the improvement of the efficiency of the utilization of port logistics facilities[1].

(3) The environmental and ecological greenness of port logistics. The green development of port logistics should be based on the protection of natural resources and ecological environment, and coordinated with the carrying capacity of resources and environment.

Table 1 lists the characteristics of the green port logistics development model and the traditional port logistics development model.

Table 1. Comparison between traditional and green development models of port logistics

	Traditional development model of port logistics	Port Logistics Green Development Model
Logistics systems	Short-term supply growth Logistics demand-driven Seeing resources as systematic input Focus on growth in the number of logistics facilities	Long-term stable development Finding a balance between supply and demand See resources as limited and scarce Quality and quantity improvement of logistics facilities
Energy technology	Dominated by fossil fuels Emphasis on low cost, technology Economies of scale and technology intensity	Selective development of alternative energy sources and their full use Emphasis on conservation and renewal Technical feasibility and soundness
Environmental systems	Insufficient attention to environmental impact People control the environment Environmental influences on external economic choices	Sensitive to environmental impact Scarcity of natural resources Internalising the external costs of environmental impacts

1.2 Port logistics system architecture based on green development

The essence of a port logistics system based on green development is the coordination of the interaction between the port logistics subsystems, because the green development of the port logistics system means that the port logistics system can meet higher social demands while also ensuring that it and the port system can achieve green development, with a view to achieving a long-term dynamic coordination relationship between the internal port logistics system and its external environment. This relationship can be represented in Figure 1 as follows[2].

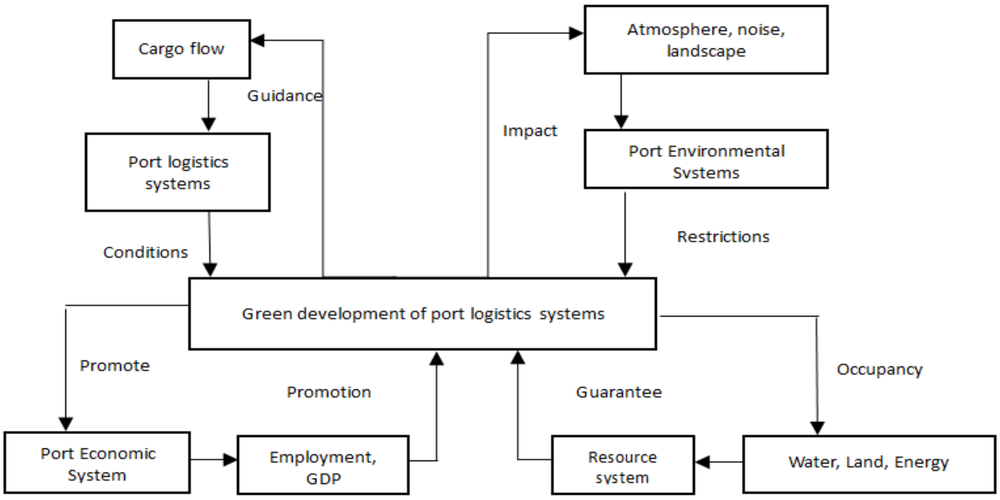

Figure 1. Operational mechanism of green development of port logistics system

2. Forms of green development model for port logistics

2.1 Relationship map of the current state of port logistics development

We frame the green development of port logistics systems as a mechanistic model that includes port logistics and the economy, society, resources and the environment. This model can be represented by a cause-effect diagram. To facilitate comparison, we first analyse the current cause-effect relationship based on the current status of port logistics development. This relationship is shown in Figure 2.

As can be seen from Figure 2, the causal relationship formed by the current status quo of port logistics development is an inferior one: traffic congestion, land resource occupation as well as environmental pollution and energy shortage will eventually lead to a lower level of socio-economic development, forming a vicious circle[3]. This is contrary to the goal of green development.

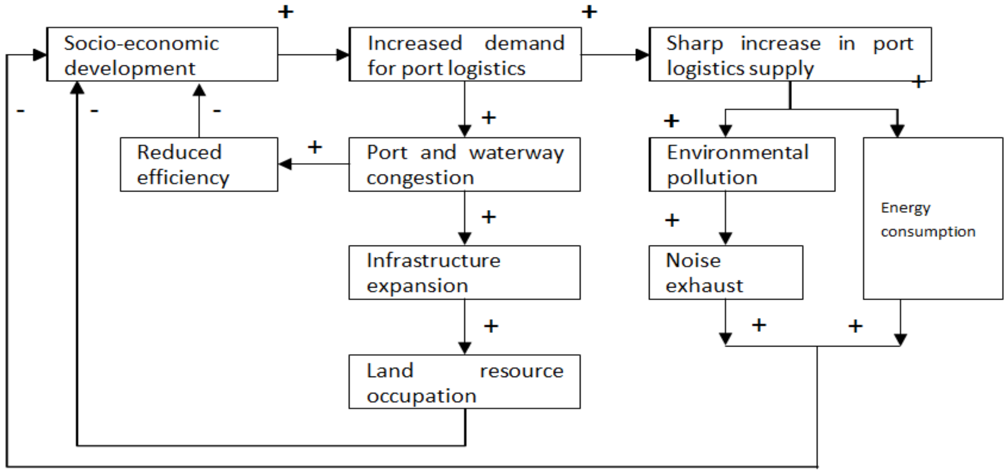

Figure 2. Relationship between the current state of port logistics development

2.2 Port Logistics Green Development Relationship Map

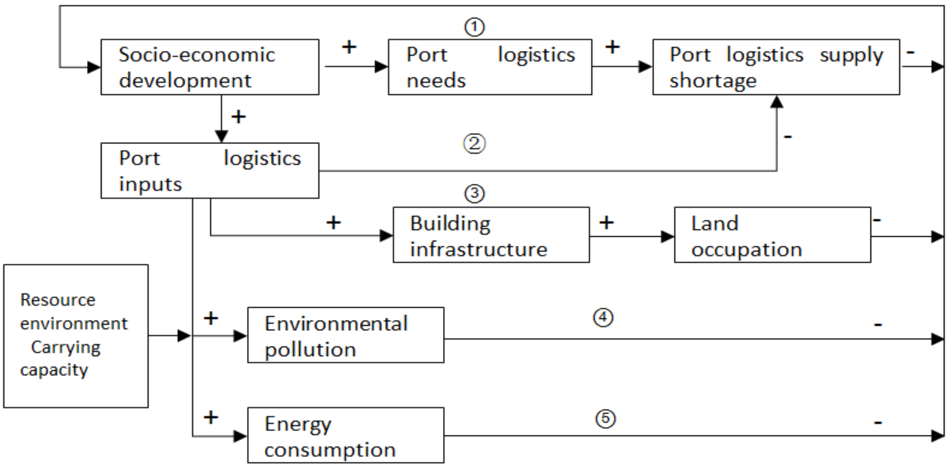

Figure 3. Port logistics green development relationship map

According to the aforementioned analysis, the main difference between the green development of port logistics and the current status quo of port logistics development is that the factors of environmental and resource carrying capacity and the coordinated development of society, economy, environment and resources are taken into account, thus forming the cause-and-effect diagram in Figure 3, which makes the whole system operate in a benign state, which is the ideal state we are pursuing[4].

3. Green logistics performance evaluation methods

3.1 Construction of the port green logistics performance evaluation index system

Based on a large amount of literature reading and related data collection and summarization, combined with the availability and relevance of actual data, it was finally determined that economic conditions, basic capacity, environmental friendliness and development potential were the four criteria layers for the evaluation of port green logistics performance, and the criteria layers were decomposed according to the theoretical basis of green logistics, and finally 8 factor layers and 22 indicator layers were obtained. The details are shown in Table 2 below.

Table 2. Port Green Logistics Performance Evaluation Index System

Target level	Guideline level	Factor layer	Indicator layer	Unit	Properties
Green Colour Things Stream Achievements Effect Comments Price (A)	Green Logistics I Economic conditions (B1)	Port Economy (C1)	Port Annual Gross Domestic Product GDP (D1)	billion	Positive
			Per capita consumption expenditure (D2)	Yuan	Positive
		Logistics economy (C2)	Logistics sector GDP (D3)	billion	Positive
			Value added in logistics (D4)	billion	Positive
			Average salary of logistics employees (D5)	Yuan	Positive
	Green Logistics Basic competencies (B2)	Infrastructure (C3)	Total transport route mileage (D6)	10,000 km	Positive
			Number of Internet users (D7)	10,000 people	Positive
		Logistics Development (C4)	Cargo volume (D8)	billion tonnes	Positive
			Cargo turnover (D9)	billion tonne kilometres	Positive
			Courier volume (D10)	10,000 pieces	Positive
	Green Logistics I Environmental Friendliness (B3)	Resource performance (C5)	Energy consumption rate in logistics (D11)	million tonnes/billion yuan	Negative
			Packaging waste environmentally sound treatment capacity (D12)	Tons/day	Positive
			Logistics Agglomeration (D13)	%	Positive
		Environmental performance (C6)	Unit Incident Waste Shipments (D14)	10,000 tonnes/start	Positive
			Unit of transport $C0_2$ Emission traffic (D15)	Billion tonnes/tonne	Positive
			Transport noise pollution (D16)	Decibels	Negative
			Investment in environmental pollution control (D17)	billion	Positive
	Green Logistics Development potential (B4)	Innovation capacity (C7)	Number of general tertiary schools (D18)	the	Positive
			Investment in logistics R&D (D19)	billion	Positive
			Number of patents for logistics inventions (D20)	Pieces	Positive
		Policy Support (C8)	Investment in fixed assets in logistics (D21)	billion	Positive
			Transport Finance Expenditure (D22)	billion	Positive

3.2 Determination of portfolio weights

Considering the complexity of the green logistics performance evaluation process, the article adopts a combination of subjective and objective methods for weight determination, namely the AHP-entropy method[5]. The pure use of the hierarchical analysis method is too influenced by the evaluator's personal influence, through the entropy value method can be amended, the evaluation value of a small difference in the weight of the appropriate adjustment, the weight of a large difference appropriate increase, so as to make the evaluation system more scientific and reasonable.

4. An Empirical Study on the Evaluation of Green Logistics Performance of Ports - Taking Guangzhou Port as an Example

4.1 Data sources

By reviewing the China Energy Statistics Yearbook, it is concluded that the energy consumption of the logistics industry is mainly 7 types of raw coal, gasoline, paraffin, diesel, fuel oil, liquefied petroleum gas and natural gas[6]. Referring to the energy conversion coefficients in the appendix of the China Energy Statistics Yearbook, see Table 3 below, the consumption of these 7 types of energy is uniformly converted into standard coal and then summed to arrive at the total energy consumption, this estimation method largely reduces the difficulty of calculation, the formula is

$$E = \sum_{i=1}^{7} E_i \times P_i \tag{1}$$

Where E_i is the consumption of energy source i, P_i is the standard coal conversion factor for energy source i and E is the total energy consumption.

For the calculation of CO_2 emissions, the estimation method with reference to existing studies was developed from the estimation factors published in the General Rules for Calculating Integrated Energy Consumption and the Guidelines for the Preparation of Provincial Greenhouse Gas Inventories, as shown in Table 3 below, with the formula

$$C = \sum_{i=1}^{7} E_i \times Q_i \tag{2}$$

where E_i is the consumption of the i energy source, Q_i is the CO_2 emission factor of the i energy source and C is the CO2 emissions.

Table 3. Table of energy conversion factors

Energy	Standard coal Conversion factor	Carbon emission factor	Energy	Standard coal Conversion factor	Standard coal Carbon emission factor
Raw Coal	0.7143 kgce/kg	1.9003 Kg-/kg	Fuel oil	1.4286 kgce/kg	3.1705 Kg-/kg
Petrol	1.4714 kgce/kg	2.9251 Kg-/kg	Liquefied Petroleum Gas	1.7143 kgce/kg	3.1013 Kg-/kg
Paraffin	1.4714 kgce/kg	3.0179 Kg-/kg	Natural gas	1.3300 kgce/m^3	2.1622 Kg-/m^3
Diesel	1.4571 kgce/kg	3.0959 Kg-/kg			

4.2 Evaluation of the Time Dimension of Green Logistics Performance in Guangzhou Port

The data of Guangzhou Port from 2008 to 2020 are collated and analysed for the already determined index evaluation system, the index weights are determined through the AHP-entropy method, and finally the green logistics performance level of Guangzhou Port from 2008 to 2020 is calculated according to the grey correlation method, so as to carry out a longitudinal comparative analysis of green logistics.

4.2.1 Determination of indicator weights

(1) Hierarchical analysis to determine the subjective weights of indicators

Based on the principle of AHP, a two-by-two comparison questionnaire was designed for the indicator system, as detailed in the appendix[7]. Ten experts, including department managers of logistics enterprises and researchers in the field of logistics, were invited to form a scoring group to score the importance of the indicators through a 1-9 scale based on their theoretical basis and practical experience. After the analysis and integration of the obtained scoring results of each indicator, the judgment matrix of each level of port green logistics performance indicators was calculated (Table 4)[8].

Table 4. Subjective weights for hierarchical analysis

Guideline level (total weighting)	Factor layer Relative weights	Factor layer Synthetic weights	Indicator layer Relative weights	Indicator layer Synthetic weights
	C1 (0.2000)	0.0466	D1 (0.6667) D2 (0.3333)	0.0312 0.0155
Bl			D3 (0.2098)	0.0391
(0.2330)	C2 (0.8000)	0.1864	D4 (0.5499)	0.1025
			D5 (0.2402)	0.0448
	C3 (0.3333)	0.0417	D6 (0.6667) D7 (0.3333)	0.0278 0.0139
B2			D8 (0.1220)	0.0102
(0.1252)	C4 (0.6667)	0.0835	D9 (0.3196) D10 (0.5584)	0.0267 0.0466
			D11 (0.6337)	0.0770
	C5 (0.3333)	0.1216	D12 (0.1919)	0.0233
			D13 (0.1743)	0.0212
B3			D14 (0.0791)	0.0192

(0.3647)	C6 (0.6667)	0.2431	D15 (0.4792) D16 (0.1722)	0.1165 0.0419 0.0655
			D17 (0.2695)	
			D18 (0.2970)	0.0274
	C7 (0.3333)	0.0924	D19 (0.5396)	0.0498
B4 (0.2771)				
			D20 (0.1634)	0.0151
	C8 (0.6667)	0.1847	D21 (0.6667)	0.1232
			D22 (0.3333)	0.0616

(2) Entropy method to determine objective weights of indicators

According to the calculation steps of the entropy value method, the following weights for each indicator can be obtained by processing and calculating the original data (Table 5)[9].

Table 5. Objective weights for the entropy method

Indicators	$\sum_{i=1}^{13} P(r_{ij}) \ln P(r_{ij})$	e_j	d_j	Entropy weights v_j
D1	-2.3121	0.9014	0.0986	0.0383
D2	-2.3360	0.9107	0.0893	0.0347
D3	-2.0812	0.8114	0.1886	0.0733
D4	-2.2929	0.8939	0.1061	0.0413
D5	-2.2907	0.8931	0.1069	0.0416
D6	-2.1111	0.8231	0.1769	0.0688
D7	-2.3527	0.9172	0.0828	0.0322
D8	-2.2993	0.8964	0.1036	0.0403
D9	-2.0810	0.8113	0.1887	0.0734
D10	-1.9790	0.7716	0.2284	0.0888
D11	-2.3245	0.9063	0.0937	0.0365
D12	-2.3715	0.9246	0.0754	0.0293
D13	-2.3369	0.9111	0.0889	0.0346
D14	-2.3412	0.9128	0.0872	0.0339
D15	-2.1810	0.8503	0.1497	0.0582
D16	-2.3303	0.9085	0.0915	0.0356
D17	-2.3125	0.9016	0.0984	0.0383
D18	-2.4750	0.9649	0.0351	0.0136
D19	-2.2488	0.8768	0.1232	0.0479
D20	-2.0600	0.8031	0.1969	0.0766
D21	-2.3420	0.9131	0.0869	0.0338
D22	-2.3734	0.9253	0.0747	0.0290

The entropy values for each factor layer can be calculated from the entropy weights of each indicator layer, as follows.

$$H_{C1} = H_{D1} + H_{D2} = 0.0383 + 0.0347 = 0.0730$$

$$H_{C2} = H_{D3} + H_{D4} + H_{D5} = 0.0733 + 0.0413 + 0.0416 = 0.1562$$

$$H_{C3} = H_{D6} + H_{D7} = 0.0688 + 0.0322 = 0.1010$$

$$H_{C4} = H_{D8} + H_{D9} + H_{D10} = 0.0403 + 0.0734 + 0.0888 = 0.2025$$

$$H_{C5} = H_{D11} + H_{D12} + H_{D13} = 0.0365 + 0.0293 + 0.0346 = 0.1004$$

$$H_{C6} = H_{D14} + H_{D15} + H_{D16} + H_{D17} = 0.0339 + 0.0582 + 0.0356 + 0.0383 = 0.1660$$

$$H_{C7} = H_{D18} + H_{D19} + H_{D20} = 0.0136 + 0.0479 + 0.0766 = 0.1381$$

$$H_{C8} = H_{D21} + H_{D22} = 0.0338 + 0.0290 = 0.0628$$

Similarly, the entropy values of each criterion layer can be obtained from the entropy values of each factor layer.

$$H_{B1} = H_{C1} + H_{C2} = 0.0730 + 0.1562 = 0.2292$$

$$H_{B2} = H_{C3} + H_{C4} = 0.1010 + 0.2025 = 0.3035$$

$$H_{B3} = H_{C5} + H_{C6} = 0.1004 + 0.1660 = 0.2664$$

$$H_{B4} = H_{C7} + H_{C8} = 0.1381 + 0.0628 = 0.2009$$

(3) Determination of portfolio weights

The following table 6 of combination weights can be obtained according to the combination assignment calculation of Eq.

Table 6. Weighting of Green Logistics Performance Evaluation Indicators for Guangzhou Port

Green stuff		Ports Economy	0.0625	Port Annual Gross Domestic Product GDP Per capita consumption expenditure	0.0374 0.0251
Flow economy	0.2374	Logistics		Logistics industry GDP	0.0579
Conditions			0.1749	Value added in the logistics sector	0.0703
		Economy		Average salary of logistics employees	0.0467
		Foundation Facilities	0.0701	Total transport route mileage	0.0472
Green stuff Basis of flow Capabilities	0.2094			Number of Internet users	0.0229
		Logistics Development		Cargo volume	0.0219
			0.1393	Cargo turnover	0.0479
				Courier volume	0.0695
		Resources Performance		Energy consumption rate in the logistics industry	0.0573
Green stuff Streaming environment Friendliness			0.1148	Packaging waste sound treatment capacity	0.0282
	0.3273			Logistics agglomeration	0.0293
				Unit accidental waste shipments	0.0276
		Environment Performance	0.2125	CO2 emissions per unit of transport	0.0890
				Transport noise pollution	0.0418
				Investment in environmental pollution control	0.0541
		Innovation Capabilities		Number of general higher education schools	0.0209
Green stuff Stream development Potential	0.2259		0.1105	Investment in logistics R&D	0.0528
				Number of patents for logistics inventions	0.0368
		Policy Support	0.1154	Investment in fixed assets in the logistics industry	0.0697
				Financial expenditure on transport	0.0457

4.2.2 Grey correlation evaluation

After normalising the raw data and assigning the combination weights in section 4.1.2, the grey correlation coefficients can be calculated by substituting the weighted normalised data into the formulae in the previous section, as shown in the table 7 below[10].

Table 7. Table of grey correlation coefficients

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
D1	0.543	0.565	0.610	0.601	0.634	0.665	0.703	0.734	0.791	0.828	0.890	0.959	1.000
D2	0.662	0.639	0.685	0.698	0.723	0.755	0.785	0.788	0.826	0.862	0.917	0.959	1.000
D3	0.435	0.456	0.516	0.571	0.639	0.704	0.732	0.772	0.902	0.934	0.965	0.997	1.000
D4	0.415	0.451	0.465	0.388	0.428	0.468	0.521	0.592	0.648	0.738	0.828	0.976	1.000
D5	0.488	0.517	0.550	0.583	0.615	0.636	0.681	0.691	0.775	0.829	0.887	0.955	1.000
D6	0.623	0.621	0.625	0.485	0.674	0.683	0.752	0.958	0.967	0.903	0.995	0.865	1.000
D7	0.738	0.703	0.660	0.781	0.822	0.760	0.760	0.767	0.787	0.869	0.917	0.969	1.000
D8	0.787	0.778	0.670	0.701	0.731	0.759	0.772	0.801	0.857	0.912	0.953	0.982	1.000
D9	0.482	0.484	0.483	0.486	0.578	0.724	0.737	0.795	0.867	0.964	0.985	1.000	0.984
D10	0.390	0.435	0.493	0.580	0.637	0.726	0.794	0.881	0.919	0.949	0.971	0.988	1.000
D11	0.437	0.449	0.472	0.487	0.525	0.508	0.525	0.732	0.639	0.763	0.934	1.000	0.759
D12	0.636	0.612	0.663	0.689	0.702	0.731	0.757	0.779	0.941	1.000	0.802	0.828	0.839
D13	0.720	0.664	0.603	0.820	0.738	0.767	0.832	0.908	0.664	0.798	1.000	0.856	0.922
D14	0.617	0.618	0.623	0.644	0.637	0.677	0.704	0.764	0.842	0.837	0.898	0.920	1.000
D15	0.333	0.360	0.410	0.464	0.520	0.602	0.646	0.654	0.785	0.824	0.871	0.933	1.000
D16	1.000	1.000	0.571	0.640	0.640	0.640	0.571	0.516	0.571	0.571	0.727	0.842	0.727
D17	0.451	0.473	0.520	0.510	0.545	0.579	0.620	0.656	0.723	0.769	0.848	0.941	1.000

D18	0.680	0.692	0.680	0.680	0.680	0.692	0.704	0.704	0.704	0.717	0.743	0.786	1.000
D19	0.457	0.498	0.536	0.574	0.624	0.684	0.727	0.770	0.803	0.833	0.896	0.929	1.000
D20	0.547	0.649	0.686	0.774	0.816	0.849	0.899	0.908	0.928	0.946	0.962	0.983	1.000
D21	0.390	0.431	0.487	0.488	0.503	0.525	0.567	0.608	0.688	0.736	0.759	0.868	1.000
D22	0.719	0.835	0.732	0.606	0.520	0.493	0.693	0.617	0.658	0.672	0.821	0.765	1.000

The grey correlation coefficients are brought into the equation to find the grey correlation and ranking for the years 2008-2020 (Table 8)[11].

Table 8. Correlation and Ranking of Green Logistics Performance Evaluation of Guangzhou Port, 2008-2020

Subject of evaluation (year)	Relevance factor	Ranking
2008	0.571	13
2009	0.588	11
2010	0.579	12
2011	0.602	10
2012	0.633	9
2013	0.665	8
2014	0.704	7
2015	0.745	6
2016	0.786	5
2017	0.830	4
2018	0.890	3
2019	0.923	2
2020	0.965	1

Similarly, grey correlations were calculated for economic conditions, basic capacity, environmental friendliness and development potential in each criterion layer of green logistics in Guangzhou port, and the results are shown in Table 9[12].

Table 9. Guangzhou Port Code Level Correlation 2008-2020

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Economic conditions	2.543	2.628	2.827	2.842	3.039	3.228	3.422	3.578	3.942	4.191	4.486	4.847	5.000
Basic competencies	3.020	3.021	2.932	3.033	3.442	3.653	3.814	4.202	4.398	4.597	4.822	4.803	4.984
Environmentally friendly	4.196	4.176	3.861	4.255	4.307	4.503	4.654	5.009	5.165	5.562	6.080	6.320	6.246
Development potential	2.794	3.105	3.122	3.124	3.143	3.244	3.589	3.607	3.781	3.904	4.181	4.331	5.000

5. Countermeasure suggestions for the construction of green logistics system in ports

5.1 Strengthen government macro guidance and optimize port green logistics policies and regulations

Firstly, guide the logistics enterprises in the port to reform and restructure according to the current development model, gradually make the logistics enterprises develop in the direction of scale, technology, intensification and greening; secondly, the taxes and fees of the logistics enterprises in the port should be reduced accordingly to attract more other enterprises and private capital to flow into the logistics industry.

5.2 Improving logistics infrastructure and promoting green development of port logistics

Secondly, taking into account the demand for port logistics and distribution, environmental policies and other factors, we should increase the number of large dump trucks, cold chain logistics equipment and other important equipment, and choose more vehicles with strong loading capacity and convenient loading and unloading operations; finally, we should gradually introduce new intelligent logistics equipment and facilities such as AGV picking trucks and three-dimensional warehouses into logistics enterprises. Finally, new intelligent logistics equipment and facilities, such as AGV picking trucks and three-dimensional warehouses, should be gradually introduced into logistics enterprises, so as to adjust the picking method from traditional logistics of "people to goods" to "goods to people" and improve logistics efficiency.

5.3 Enhancing green capabilities of logistics enterprises and public awareness of environmental protection

On the one hand, the responsibilities of various departments in the implementation of green logistics should be clarified, and green practices such as green distribution and processing, green transport, green packaging and green storage should be organised. The public should take the initiative to learn and practise green activities and advocate green consumption behaviour. Secondly, consumers should respond positively to the relevant green logistics policies and give full play to the public opinion to promote the green development of logistics.

6. Conclusions

While continuing to increase investment in ports and expanding the scale of ports, improving the efficiency of the port logistics system, making rational use of limited resources and controlling and reducing the pollution of ports to the environment are two important aspects that must be taken into account for the healthy development of China's port logistics system.

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