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Research on Sustainable Port: Evaluation of Green Port Policies on China's Coasts

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Abstract: Increasing port pollution has forced governments to enact policies related to green ports to maintain the sustainability of maritime transportation. In this article, we established a policy evaluation system based on the PMC (policy modeling consistency) index model to evaluate 17 green port-related policies currently enacted on coastal China, providing a new perspective on existing maritime policy evaluations. The results show that the average overall consistency of the policies is 7.16 with "good" performance, and no policy is "low" consistency. While this suggests that the existing policy design is sound, some deficiencies exist, such as insufficient cooperation between governments and insufficient emphasis on incentives. We provide recommendations for improvement based on these deficiencies and analyzed and optimized every policy in detail. Meanwhile, we found that policy texts from southern ports perform better, contrary to the previous view. The discovery could be a good entry point for future research. We also offer some suggestions for the development of green ships in China. The research makes these contributions and may provide some insights for policymakers.

Keywords: green port; maritime transportation; policy evaluation; coasts; shipping; sustainable development

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1. Introduction

The sustainability of ports is a significant research area. With the continuous development of maritime transportation, intensive port operations have consumed a large amount of fossil energy, which has a negative environmental impact on the coastal port, and ship fuel combustion produces particles and emission gases, making port pollution increasingly severe [1]. According to relevant statistics, the annual carbon emissions from shipping activities have exceeded 2.7% of global emissions and are trending to grow [2–4]. In addition to carbon emissions, pollution also involves the production and emission of SO_X and NO_X. Only in 2011, a total of 18 million tons of CO_2, 0.4 million tons of NO_X, 0.2 million tons of SO_X, and 0.03 million tons of PM_{10} were emitted from ports [5]. Port pollutants can seriously jeopardize the human respiratory system and affect the ecological environment around ports, especially for people living in port cities [6]. Continuing greenhouse gas (GHG) emissions have had a massive impact on the environment of ports. Clearly, ports face increasing social and environmental pressures and challenges.

With the recognition of the necessity of marine environmental protection, the need for green environmental activities, and the fact that ports significantly impact the environment in which they are situated, the term "green port" has gained relative importance [7]. "Green port" indicates a sustainable and environmentally friendly port [8]. The direction focuses on treating port pollution and protecting port ecology, rational use of resources, low-energy operation, and other green development behaviors. The aim is to achieve rational resource use and promote ecologically sound investments and ecological orientation of technologies [9]. The concept of "green port" development is to combine port activities, operations, and management in an environmentally friendly way [8], for example, developing and applying various emission reduction technologies and restoring the port's ecological environment. One of the main measures for the application of the concept of "green port" development is the incorporation of the term "green" growth into the further development of the port system and the establishment of environmental planning in the said region [8]. Basically, the concept of green ports can be realized in every port in the world. Possible differences (including problems) arise mainly from geographical location, technological development, and degree of industrialization [10]. Therefore, to realize the "green port", scholars have provided advice and a theoretical basis in the fields of operation, policy, marketing, and other related areas [11–13]. In reality, numerous ports have embarked on greening efforts, using solar power as an alternative energy source [14]. Many port administrators have used AMP (alternative maritime power), a green and energy-efficient technology that involves the use of land-based power sources to supply the main onboard systems of a ship during berthing, thereby replacing the ship's auxiliary generators to control port pollution [15].

More and more governments have chosen to guide the sustainable development of ports by issuing appropriate green port policies. However, there are few evaluations of green port policy texts in previous studies. This raised the question regarding whether the relevant policies formulated by the government are reasonable. Have the policies played a qualifying guiding role? If the policies are flawed, how should the government improve them? From the perspective of policy optimization, there is a great need to conduct a comprehensive and systematic assessment of current green port policy texts. After all, the consistency and completeness of policy texts are essential factors affecting the extent to which policy objectives are achieved [16]. Analyzing existing green port policies from a textual perspective would benefit the governance and improvement of sustainable maritime transportation. Therefore, we introduced the PMC index model and designed an evaluation system specifically for evaluating green port policies to address the aforementioned research questions and fill the gaps in the perspectives and content of sustainable maritime transportation.

1.1. Literature Review

A comprehensive review of the existing literature concerning "green port policies and regulations" and "port policies evaluation" can better provide a context and theoretical basis for our research.

1.1.1. Green Port Policies and Regulations

Port policies are a primary governance tool for implementing green goals and standardizing the port operations of the various actors involved [17]. The general target audience is maritime enterprises and employees. The content of a green port policy should include the following aspects: conservation of nature, pollution reduction, promotion of cleaner energy, resource recovery, and utilization [18]. These are now standard elements of green port policies. However, from the perspective of the sustainable development of maritime transportation, the policy content of green ports should include more than just environmental protection and energy substitution. It should also include elements of economic value or port efficiency growth. Port industrial development areas and maritime clusters may be areas where the environment offers new economic opportunities [19]. Tourism revenue can also be generated by improving the port environment.

Governments and international organizations are actively developing policies and regulations to promote the greening of ports. The Port of Rotterdam and 11 other major world ports joined forces in 2018 to launch the "World Ports Climate Action Program" to accelerate the ports' green transformation [20]. The IMO 2018 passed a preliminary GHG emission reduction strategy for ships on international voyages, specifying emission reduction targets for 2030–2050 to promote the greening of ports and shipping [21]. Changes were made in 2023 to strive for net-zero GHG emissions from maritime transportation by 2050 [22]. The European Sea Ports Organization (ESPO) has been working to help members' ports achieve sustainable development since its formulation in 1993 [23]. For example, the "ESPO Green Guide 2021—a Manual for European Ports Towards a Green Future" has constraints or plans regarding air quality management, noise management, waste management in ports and ships, the blue economy, etc. [24]. The International Association of Ports and Harbors (IAPH) launched the environmental ship index (ESI) in 2011 to measure carbon emissions from ships [25]. The policy was set up whereby ships that emit less can receive a reduction in port fees based on criteria set by each port. Nearly 7000 ships are currently participating in the program [25]. However, some scholars have compared the ESI and clean shipping index (CSI) and found that ESI can produce high scores in some cases without reducing actual emissions and that CSI is a more reliable measurement of environmental impacts [26]. This fact has the potential to make scores unreliable.

Green port policies in the U.S. got off to an early start. In 2005, the Port of Long Beach implemented the Green Port Policy, which established a basic framework for environmentally friendly port operations in some areas: Protection of the marine environment, reduction of harmful emissions from port activities, improvement of water quality in the harbor, and sustainable development [27]. The Emission Control Area (ECA) policies for North America were officially launched on 1 August 2012. The policy limits SO_X and NO_X emissions from ships to achieve emission reductions in ports and shipping. However, Xiao et al. [28] found through their evaluation that the ECA policies effectively reduced the emission of pollutants from ships, particularly sulfur dioxide (SO_2), but did not affect NO_X. This suggests that ECA policies also have limitations and need to be improved. The Maritime and Port Authority of Singapore (MPA) launched the "Maritime Singapore Green Initiative" in 2011, which proposes to reduce CO_2, SO_X, and NO_X emissions from shipping lines, terminals, shipping companies, and port vessel operators through the Green Ship program, Green Port program, and Green Energy and Technology program [29]. In 2022, the agency also released "Maritime Singapore Decarbonization Blueprint: Working Towards 2050", systematically proposing a pathway to peak carbon neutrality in the maritime sector. The blueprint involves cutting-edge elements such as the development of a port-centered ecosystem and the development of the world's first ammonia-fueled tanker [30].

In recent years, the growth of Chinese ports has been very rapid. China's ports accomplished 15.68 billion tons of cargo throughput and 300 million TEUs of container throughput in 2022, up 33% and 56%, respectively [31]. The Chinese government has also introduced a series of policies to realize green transformation of maritime transportation. For example, "The Guiding Opinions on Promoting the Transformation and Upgrading of Ports", issued in 2014, mentioned promoting the green transformation process of ports, strengthening port environmental protection, and actively encouraging ports to carry out ecological protection and restoration projects [32]. "The Guiding Opinions on Building World-Class Ports", released in 2019, clearly emphasizes the need to build a clean and low-carbon port energy use system to reduce pollution emissions in port operation areas [33]. However, there are very few evaluations related to China's green port policies nowadays for the country as an active maritime transportation country. It is an essential driving factor for this research to target the relevant policies in China's coastal areas.

1.1.2. Port Policies Evaluation

Policy evaluation is a complex and systematic exercise in measuring policy plans by selecting scientific standards and methods and conducting comprehensive examinations of policy systems and processes [34]. Scientific policy evaluation results help people better understand the strengths and weaknesses of the policy to adjust and make the policy play a better guiding role. Relevant scholars have utilized quantitative or qualitative methods to evaluate port policies. Utami [35] analyzed and evaluated the policies enacted by Indonesian governmental departments, aiming to promote the development of fishing ports through qualitative methods such as interviews, documentation, and questionnaires and found that the policies did not contribute generously to the development of local fishery activities; as a result, they provided recommendations to the relevant governmental departments. However, the qualitative appraisal method requires fewer data, and the appraisal results are susceptible to the influence of subjective factors, the level of theory, and practical experience. Some scholars have also used qualitative methods to evaluate port policies. Jiang et al. [36] developed a supply chain model sensitive to demand and consumer behavior. They compared the fluctuations of the Hainan bonded port and Hong Kong bonded port, exploring related factors in conjunction with the local port tax policies. Chang et al. [37] evaluated how effective pollutant reduction policies are in port areas based on a newly developed emissions calculation and evaluation model. They found that reducing ship speed to 12 knots was most effective in reducing fuel consumption, costs, and emissions. Recommendations are also made for future policy approaches. Wan et al. [38] established a policy evaluation framework that can be used to facilitate the formulation, implementation and review of trade facilitation policies, and explained the effects of central port-oriented trade facilitation measures by analyzing relevant port policies in Shenzhen and Hong Kong. Tian et al. [39] used empirical analysis to investigate the pricing strategies of Hainan travel agencies in the context of the free trade port initiative, providing new perspectives and strategic directions for Hainan's tourism industry.

However, there are some deficiencies in the previous research on port policies. Previous studies have evaluated from a single perspective limited to the effects of policies on port effects or performance [13,37,40,41]. The current policy evaluation methods also have certain limitations. For example, the FAHP method is computationally complex. Some scholars believe the technique is limited: The local fuzzy weight normalization process needs to be revised, or assigning zero weights to items may lead to wrong decisions. [13,42,43]. To fill the gaps in the previous studies, we adopted the PMC index model to carry out a study of policies in related areas.

1.2. Research Contributions

The theoretical and practical contributions of our research are summarized as follows.

- Theoretical contributions. Our study fills a research gap because the existing literature does not assess green port policies from the perspective of policy texts. The PMC index model is for the first time introduced and applied to the quantitative evaluation of green port policies to enrich the knowledge system of port policy evaluation;
- Practical contributions. The research provides valuable insights and a basis for the Chinese government to supplement and improve existing policies. The findings have practical implications for the sustainable development of maritime transportation. The proposed evaluation model and system can be used as a tool for other governments to improve their policies.

The organization of the full paper is listed as follows. Section 2 presents the PMC index model and selects representative green port policies in China. Section 3 builds the PMC index model and quantitatively evaluates the policies studied. Section 4 concludes and provides further discussion of policy elements in the context of the current situation.

2. Materials and Methods

2.1. PMC Index Model

The PMC (policy modeling consistency, definition from Dr. Mario Arturo Ruiz Estrada) index model is a policy text analytical model based on the idea of the "Omnia Mobilis" hypothesis, which emphasizes that everything in the world is constantly evolving and interconnected [44]. It is based on the policy itself, analyzing the internal consistency of the policy. It assumes that the individual variables are equally important and that the relevant weak variables should not be ignored in the modeling process.

The PMC index model as a quantitative method differs from other evaluation methods focusing on policy impact detection. In addition to evaluating a single policy, it allows for coherent comparisons by considering different policy elements based on contents [44]. The advantages and disadvantages of each policy can also be visualized by creating a PMC surface chart. The PMC surface presents the scores of each policy from a three-dimensional point of view, and by observing the ups and downs of the surface, one can intuitively judge the strengths and weaknesses of each dimension's policy features and indicators. Moreover, the PMC model is more comprehensive in terms of indicator dimensions. To a certain extent, this has enriched the research on policies regarding ex ante assessment and the reliability and validity of indicator sets. The methodology applies to ex ante, in-process, and ex post evaluations, and the quantitative results are timely. In recent years, the PMC index model has become an effective policy evaluation method and has been used in a wide range of academic fields. For example, Dai et al. [45] scientifically explored and evaluated 18 policy texts in China's Yangtze River Economic Belt with the theme of green development using the PMC index model and establishing a multi-input-output strategy table. Wang et al. [46] used the model to quantitatively evaluate 66 wind power industry policies in China from 2010–2021. They found that the general population has policy acceptance in a few policy texts, and there are problems such as insufficient technical support and talent building. Thus, we chose the PMC index model to evaluate China's green port policy. The modeling steps of the PMC index model are as follows:

(1) Setting of variables. A system of policy evaluation indicators is established, including main variables and sub-variables, and the indicators are usually set to reflect key policy elements;
(2) Determining parameters and creating the multiple input–output table. We set the parameters of the sub-variables to binary (i.e., 0 and 1). Then, based on the policy analysis, if a sub-variable meets the assignment rule, it will be set to 1; conversely, it will be set to 0. However, this is one of the limitations of PMC index model because all sub-variables have equal status. In some cases, the sub-variables do not have equal status, and some significantly impact what is being studied;
(3) Measurement of PMC index. The PMC index value is equal to the sum of all the main-variables:

$$\mathrm{PMC} = \sum_{i=1}^{m} X_i \tag{1}$$

$$X_i = \frac{\sum_{j=1}^{n} X_{i,j}}{n} \tag{2}$$

X_i is the value of the main variable i, and $X_{i,j}$ denotes the values of the sub-variables j belonging to the main variable i. m is the upper limit of i, and n is the upper limit of j. The range of m is from 1 to the number of main variables, and the range of n is from 1 to the number of sub-variables belonging to the same main variable;

(4) Construction of PMC surface. The PMC surface is a tool that shows the evaluation effect of policies in the form of images. Establishing a PMC matrix is the basis for constructing a PMC surface. We enter all main-variable scores for a single policy into the data analysis software in a 3 × 3 matrix format and then generate surface charts based on the appropriate code. The nine variables on the PMC matrix correspond to the nine points on the PMC surface chart. In particular, convex sections indicate high scores on specific policies, while concave sections indicate low scores. This approach allows us to see the strengths and weaknesses of the policy more clearly.

$$\text{PMC surface} = \begin{pmatrix} X_1 & X_2 & X_3 \\ X_4 & X_5 & X_6 \\ X_7 & X_8 & X_9 \end{pmatrix} \tag{3}$$

2.2. Areas of Study

After discussion, we considered that representative policies should be selected from the guidelines issued by the Ministry of Transport of P.R. China (MOT) and the local governments in the regions where China's five major port coastal clusters are located for analysis. The reason is that these publishing organizations are authoritative administrative agencies. The five port clusters are also the Chinese government's plans for future development and coastal management [47]. The five major port clusters are the Bohai Rim port cluster, the Yangtze River Delta port cluster, the Pearl River Delta port cluster, the southwest coastal port cluster, and the southeast coastal port cluster. These port clusters' geographic locations cover China's coastal areas (Figure 1).

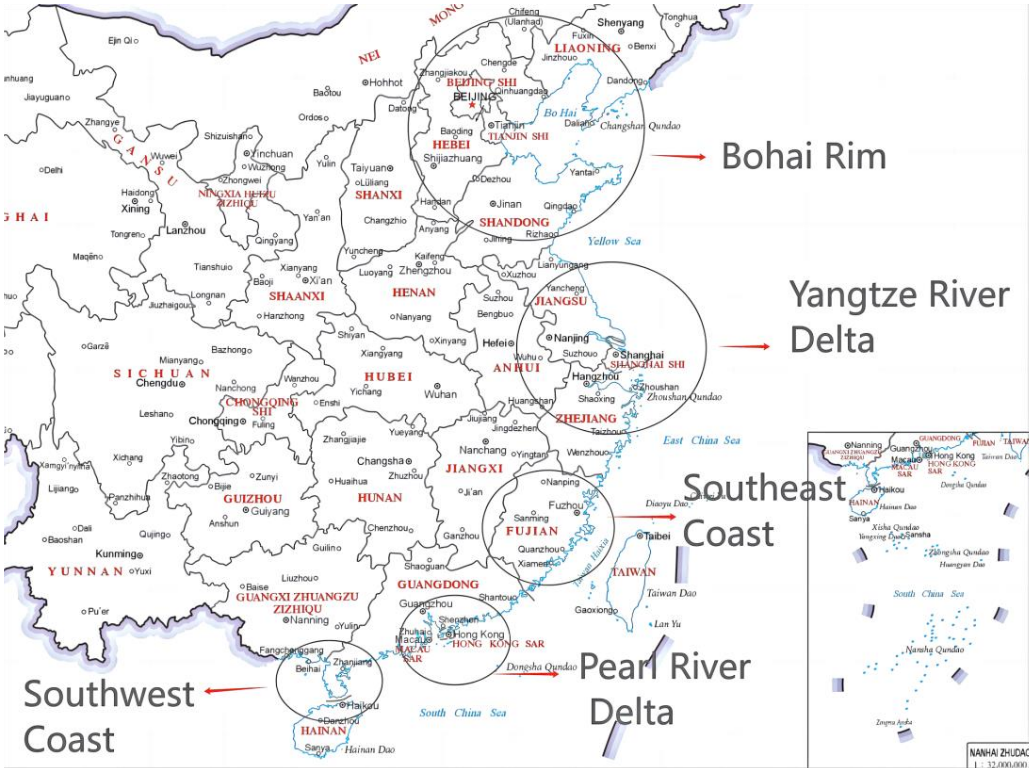

Figure 1. Sketch map of the five major port clusters in China.

2.3. Policy Samples

To find the relevant Chinese green port policies more accurately, we also set the following selection principles:

(1) The policy must be released during China's 14th Five-Year Plan period (2021–2025). The five-year plan is a long-term plan that the Chinese government mainly uses to plan major projects and propose goals for development. Comparative evaluation would be more convincing if the selected representative policies were released in the same period. The selection of recent policies can avoid the problems caused by the timeliness of the policies. Furthermore, now is the later stage of the 14th Five-Year Plan. Examining and evaluating policies now will be more conducive to the government's corresponding adjustments in the next plan;

(2) The policy topic must be related to green transportation, port and shipping, or environmental protection because of the high relevance of these themes to green ports.

After determining the selection principles, we searched for policies on the official website of the MOT or the governments of provinces or municipalities. Finally, after the collective analysis and discussion of the team, we selected the following 17 representative policies on green ports in China. The reasons they were considered representative are as follows: Besides being very consistent with our selection principles, these policies are more specific about green ports than others and were issued by authoritative Chinese government agencies or departments. This includes 2 policies at the national level and 15 at the regional level (Table 1).

Table 1. Representative policies for green port in China.

Item	Policy Name	Categorization	Policy Issuing Agency	Policy Source
P1	Green Transportation 14th Five-Year Plan Development Plan (2021)	Nation	MOT	[48]
P2	Water Transportation 14th Five-Year Plan Development Plan (2021)	Nation	MOT	[49]
P3	Tianjin Green Transportation 14th Five-Year Development Plan (2022)	Bohai Rim	Tianjin Transportation Commission	[50]
P4	14th Five-Year Plan for Coastal Port Development in Hebei Province (2021)	Bohai Rim	Hebei Provincial People's Government	[51]
P5	Shandong Province Transportation Energy Saving and Environmental Protection 14th Five-Year Development Plan (2022)	Bohai Rim	Shandong Provincial Transportation Department	[52]
P6	14th Five-Year Plan for the Development of Northeast Asia International Shipping Center in Dalian (2021)	Bohai Rim	Dalian Municipal Transportation Bureau	[53]
P7	Shanghai Green Transportation 14th Five-Year Plan (2023)	Yangtze River Delta	Shanghai Municipal Transportation Commission	[54]
P8	Jiangsu Province 14th Five-Year Green Transportation Development Plan (2021)	Yangtze River Delta	Jiangsu Provincial Department of Transportation	[55]
P9	Zhejiang Province Water Transportation Development 14th Five-Year Plan (2021)	Yangtze River Delta	Zhejiang Provincial Department of Transportation	[56]
P10	Guangdong Province Green Port Action Plan (2023–2025) * (2023)	Pearl River Delta	Guangdong Provincial Department of Transportation	[57]
P11	Shenzhen Port and Shipping Development 14th Five-Year Plan (2022)	Pearl River Delta	Shenzhen Municipal Bureau of Transportation	[58]
P12	Guangzhou Port and Shipping 14th Five-Year Development Plan (2021)	Pearl River Delta	Guangzhou Port Authority	[59]
P13	Guangxi Green Transportation 14th Five-Year Development Plan (2022)	Southwest Coastal	Department of Transportation of Guangxi Zhuang Autonomous Region	[60]
P14	Hainan's 14th Five-Year Plan for Ecological Environmental Protection (2021)	Southwest Coastal	Hainan Provincial Government	[61]
P15	Xiamen Port 14th Five-Year Development Plan (2021)	Southeast Coastal	Xiamen Port Authority	[62]
P16	Fuzhou City 14th Five-Year Plan for Ecological Environmental Protection Plan (2021)	Southeast Coastal	Fuzhou Municipal Government	[63]
P17	Quanzhou City 14th Five-Year Plan for Ecological Environmental Protection Plan (2021)	Southeast Coastal	Quanzhou Municipal Government	[64]

* Most of the ports and shipping operations in Guangdong Province are concentrated in the PRD (Pearl River Delta). We therefore consider that the policy can be attributed to the region.

2.4. Setting of Variables

To evaluate the policies in a targeted manner, we used the ROST-CM6 software(ROST Content Mining System Version 6.0) to partition the words and analyze the word frequency statistics of the selected 17 representative policies for China's green ports. We eliminated words such as "promote", "strengthen", "development", and so on, which are redundant and interferential phrasing, and combined words with similar meanings; then, we found the top 60 high-frequency words in Table 2. The top 60 high-frequency words are listed in descending order.

Table 2. China's green port policy text keywords frequency statistics table.

Serial Number	Keywords	Frequency	Serial Number	Keywords	Frequency
1	construct	2059	31	conservation	322
2	ecology	1810	32	transform	320
3	environment	1691	33	area	318
4	green	1390	34	railway	314
5	traffic	1332	35	low-carbon	313
6	port	1291	36	highway	290
7	energy	1019	37	combined-transport	287
8	protection	977	38	encourage	285
9	transport	954	39	clean	277
10	pollution	890	40	optimize	277
11	facility	802	41	innovate	274
12	ship	798	42	repair	274
13	shipping	696	43	guarantee	272
14	emission	630	44	preventive-treatment	269
15	management	596	45	sewage	267
16	enterprise	595	46	inland-river	260
17	engineering	590	47	standard	260
18	service	586	48	structure	251
19	wharf	571	49	field	246
20	technology	535	50	research	243
21	resource	439	51	function	240
22	monitor	432	52	explore	239
23	supervise	385	53	coordination	238
24	channel	373	54	pivot	231
25	logistics	362	55	intelligence	218
26	security	358	56	policy	217
27	container	358	57	action	210
28	port-district	353	58	strict	208
29	quality	336	59	renovate	202
30	country	323	60	vehicle	198

Based on the modeling principles of the PMC index model, we combined the content of the keyword's frequency analysis and the team members' understanding of the development of the port and shipping frontiers. After referring to the research literature of Estrada [44], Dai et al. [45], and Wang et al. [46], we then determined the evaluation of the policies in China's green port indicator system. It contains 9 main variables and 49 sub-variables. Each of the main variables consists of several corresponding sub-variables and the sub-variables reflect policy elements closely related to the main variables. Among them, the main variables are Policy Nature X1, Policy Timeliness X2, Publishing Organization X3, Policy Field X4, Policy Content X5, Incentive Mode X6, Policy Guarantee X7, Policy Evaluation X8, and Policy Audience X9 (Table 3).

Table 3. The setting of variables for China's green port policies.

Main-Variables	Sub-Variable Variables	Criteria for Evaluation of Sub-Variables
Policy Nature (X1)	Predictions (X1.1) Supervise (X1.2) Suggestion (X1.3) Guidance (X1.4)	The policy is predictive in nature The policy is supervisory in nature The policy is suggestive in nature The policy is guided in nature
Policy Timeliness (X2)	Short term (X2.1) Middle term (X2.2) Long term (X2.3)	Fewer than three years of policy planning More than 3 years and less than 5 years of policy planning More than 5 years of policy planning
Policy Subject (X3)	The state council (X3.1) The MOT (X3.2) The local government (X3.3) Others (X3.4)	The state council issued the policy The MOT issued the policy The local government issued the policy Other sectors issued the policy
Policy Area (X4)	Economics (X4.1) Societal (X4.2) Politics (X4.3) Environment (X4.4) Technology (X4.5)	The policy includes the economy, industry, etc. The policy includes services, employment, etc. The policy includes administrative, institutional, etc. The policy includes environmental protection, etc. The policy includes science, technology, etc.
Policy Content (X5)	Treatment of water pollution (X5.1) Treatment of dust pollution (X5.2) Treatment of noise pollution (X5.3) Promotion of clean energy facilities (X5.4) Ecological restoration (X5.5) Improvements in the reception and disposal of pollutants from ships (X5.6) Energy optimization for ships (X5.7) Research of emission reduction technologies (X5.8) Advocacy for environmental protection (X5.9) Enhancement of international cooperation (X5.10) Incentives for innovation (X5.11) Emphasis on economical use of resources (X5.12) Emphasis on resource recycling (X5.13)	The policy contains elements to treat port water pollution The policy contains elements to treat port dust pollution The policy contains elements to treat port noise pollution The policy contains the promotion of clean energy facilities in ports The policy contains restoration of port ecology The policy includes enhancement of reception and disposal of pollutants from ships The policy includes the optimization of ship energy The policy includes research and development of low-carbon technologies The policy includes research to promote environmental protection The policy includes advocacy for international cooperation The policy includes enhancing international cooperation The policy contains incentives for innovation The policy contains elements that emphasize the economic use of resources The policy includes an emphasis on resource recycling
Incentive Mode (X6)	Financial support (X6.1) Tax benefits (X6.2) Talent cultivation (X6.3) Fee remission (X6.4) Green finance (X6.5) Digital support (X6.6) Improvements in the shipping carbon mechanism (X6.7)	The incentive of the policy includes financial support The incentive of the policy includes tax benefits The incentive of the policy includes talent cultivation The incentive of the policy includes fee remission The incentive of the policy includes green finance The incentive of the policy includes digital support The incentive of the policy includes improvements in the shipping carbon mechanism

Table 3. *Cont.*

Main-Variables	Sub-Variable Variables	Criteria for Evaluation of Sub-Variables
Policy Guarantee (X7)	Intersectoral collaboration (X7.1)	The guarantees of the policy include intersectoral collaboration
	Assessing effectiveness (X7.2)	The guarantees of the policy include effectiveness assessment
	Penalties (X7.3)	The guarantees of the policy include penalties
	Monitoring of pollution (X7.4)	The guarantees of the policy include
	Improvements in legislation (X7.5)	The guarantees of the policy include improvements in legislation
Content Evaluation (X8)	Adequate basis (X8.1)	Adequate basis for policy formulation
	Specific objectives (X8.2)	Specific objectives in policy formulation
	Detailed plan (X8.4)	Detailed planning in policy formulation
Policy Object (X9)	Governments (X9.1)	There is planning for the governments
	Port or shipping enterprises (X9.2)	There is planning for the port or shipping enterprises
	Universities (X9.3)	There is planning for the universities
	Individuals (X9.4)	There is planning for the individuals

2.5. Construction of Multi-Input–Output Tables

Multi-input–output tables are an optional database analysis framework for storing large amounts of data to measure a single variable [44]. The final multi-input–output table for the sample of item policies was constructed based on the system of evaluation criteria set out in 2.1 and the results of the assignment of sub-variables (Table 4).

Table 4. The multi-input–output table for China's green port policies.

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
X1	X1.1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
	X1.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X1.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X1.4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X2	X2.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X2.2	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
	X2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X3	X3.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	X3.2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	X3.3	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X3.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X4	X4.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X4.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X4.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X4.4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X4.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X5	X5.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X5.2	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1
	X5.3	0	0	0	1	1	0	0	0	1	1	0	0	1	1	1	1	1
	X5.4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X5.5	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1
	X5.6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X5.7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X5.8	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1
	X5.9	1	0	1	0	1	1	1	1	1	0	1	0	1	1	0	1	1
	X5.10	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	0
	X5.11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X5.12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X5.13	1	0	1	1	1	0	1	1	0	1	0	1	1	1	1	1	1

Table 4. *Cont.*

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
X6	X6.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X6.2	0	0	0	0	0	1	0	1	1	0	1	0	0	1	1	1	1
	X6.3	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
	X6.4	0	0	1	0	1	0	0	1	1	1	1	1	1	0	1	1	1
	X6.5	1	0	1	0	0	0	0	1	0	1	1	0	1	1	0	1	1
	X6.6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X6.7	1	0	1	0	1	1	1	1	0	0	0	0	1	1	0	1	1
X7	X7.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X7.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X7.3	0	1	0	1	0	0	0	0	1	0	0	0	0	1	1	1	1
	X7.4	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1
	X7.5	1	1	1	1	0	1	1	0	1	0	1	1	0	1	1	1	1
X8	X8.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X8.2	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
	X8.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X9	X9.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X9.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X9.3	0	0	0	0	0	1	0	1	1	1	1	0	1	1	1	1	1
	X9.4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

2.6. Calculation of PMC Index

We summarized the scores for each main variable based on the multi-input–output table (Table 4) created in 2.5. Establishing a hierarchy of evaluations is critical for policy evaluation. We set the PMC index evaluation level of China's green port policies based on the scores and the evaluation criteria in studies (Tables 5 and 6).

Table 5. PMC index of the evaluated policies.

Main-Variable	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	Average Score
X1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
X2	0.67	0.67	0.67	0.67	0.67	0.67	0.33	0.67	0.67	0.33	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.63
X3	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
X4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
X5	0.92	0.69	0.77	0.92	1.00	0.77	0.92	0.92	0.85	0.85	0.69	0.69	1.00	0.92	0.92	1.00	0.92	0.87
X6	0.71	0.29	0.86	0.43	0.71	0.71	0.43	1.00	0.71	0.71	0.86	0.57	0.86	0.86	0.71	1.00	1.00	0.73
X7	0.80	1.00	0.80	1.00	0.60	0.60	0.80	0.60	1.00	0.80	0.60	0.80	0.60	1.00	1.00	1.00	1.00	0.82
X8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.67	1.00	1.00	1.00	1.00	1.00	0.98
X9	0.75	0.75	0.75	0.75	0.75	1.00	0.75	1.00	1.00	1.00	1.00	0.75	1.00	1.00	1.00	1.00	1.00	0.90
PMC index	7.10	6.64	7.09	7.02	6.98	7.00	6.48	7.44	7.48	6.69	7.07	6.40	7.37	7.70	7.55	7.92	7.84	7.16
Rank	8	15	9	11	13	12	16	6	5	14	10	17	7	3	4	1	2	_

Table 6. Evaluation criteria for policy consistency based on PMC index scores.

PMC Index	0–3.99	4–5.99	6–7.99	8–9
Evaluation	Low consistency	Acceptable consistency	Good consistency	Perfect consistency

The PMC index model can be calculated in three steps according to Formulas (1) and (2). Firstly, with reference to (4) and (5), the multi-input–output table is entered separately to assign a value to each sub-variable. Then, the values of the main variables are calculated by merging the assigned values of the sub-variables using (6). j denotes the main variable, and i denotes the secondary variables. Finally, the data are imported into (7) to generate the PMC index value of the strategy to be evaluated, which is the summation score of all the primary-variable variables in (6).

$$X \sim N[0-1] \tag{4}$$

$$X = \{XR : [0-1]\} \tag{5}$$

$$X_i\left(\sum_{j=1}^{n} = \frac{X_{ij}}{T(X_{ij})}\right) i = 1, 2, 3, \ldots, 9 \tag{6}$$

$$PMC = \begin{bmatrix} X_1\left(\sum_{k=1}^{4}\frac{X_{1k}}{4}\right) + X_2\left(\sum_{l=1}^{3}\frac{X_{2l}}{3}\right) + X_3\left(\sum_{m=1}^{4}\frac{X_{3m}}{4}\right) + \\ X_4\left(\sum_{n=1}^{5}\frac{X_{4n}}{5}\right) + X_5\left(\sum_{o=1}^{13}\frac{X_{5o}}{13}\right) + X_6\left(\sum_{p=1}^{7}\frac{X_{6p}}{7}\right) + \\ X_7\left(\sum_{q=1}^{5}\frac{X_{7q}}{5}\right) + X_8\left(\sum_{r=1}^{3}\frac{X_{8r}}{3}\right) + X_9\left(\sum_{s=1}^{4}\frac{X_{9s}}{4}\right) \end{bmatrix} \tag{7}$$

2.7. Construction of PMC Surface Charts

The values of the main variables calculated in Section 2.6 are brought into Formula (3). Then, we plot PMC surface charts with code and **MATLAB** software (MATLAB 2018a).

3. Quantitative Results and Discussion

3.1. Analysis

According to the calculations, the average PMC score of the selected representative policies is 7.16, showing "good" consistency overall. However, there is regional variability in the level of PMC. Calculations based on categorization show that average PMC levels in descending order are southeast coast, southwest coast, Yangtze River Delta, Bohai Rim, and Pearl River Delta (Figure 2. Average PMC scores for five port clusters). Examined from a regional perspective, the average PMC index is highest for the representative policies of the southeast coastal port cluster at 7.70. The Pearl River Delta port cluster has the lowest average PMC index for usual policies, with a score of 6.72. The rank also reflects the regional government's importance to green port projects.

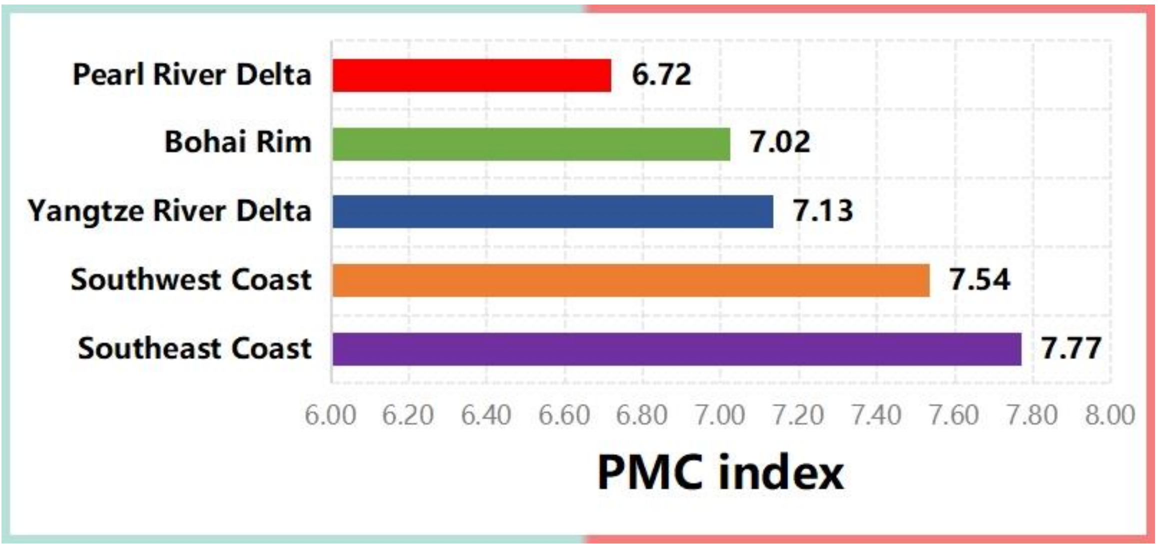

Figure 2. Average PMC scores for five port clusters.

Based on our results, we conclude that there are several characteristics of the current green port policies along China's coasts:

Firstly, the policy coverage is very complete. The 17 representative policies all achieved a perfect score of 1.00 on the X4 Policy Area. It means that the policies can theoretically provide a stable and reliable environment and a good direction and support for the development of the industry and relevant stakeholders.

Secondly, the Chinese government attaches great significance to developing a clean energy industry in maritime transportation among the various elements, as evidenced by the fact that each policy scored a perfect score in X5.4 and X5.7.

Thirdly, the Chinese government has paid insufficient attention to incentives by. More than half of the policies do not include tax benefits, and 8 of the 17 policies need to mention green finance or carbon trade systems. Governments need to diversify incentives. Existing green port policies focus mainly on financial subsidies and digital support while neglecting the role of tax incentives, green finance, and carbon trading mechanisms in achieving this goal. Therefore, the creation of multiple incentives in the future will be crucial to strengthening our green ports. Implementing port-based green incentives can reduce emissions, and significant greenhouse gas emission reductions can also lead to social benefits [65]. Thus, we propose that the governing authorities enrich the incentives as much as possible to support port and shipping enterprises more.

Fourth, there is insufficient cooperation among Chinese government sectors. The X3 Policy Subject is the indicator with the lowest average score in the evaluation system. During the 14th Five-Year Plan, China's green port policy was limited to a single subject, namely the MOT and Local Government, resulting in a need for more communication and cooperation between multiple disciplines. Therefore, the development and implementation of cross-sectoral policies should be strengthened in the future. Through effective intersectoral communication, a rational sectoral coordination mechanism can be established, and policy conflicts can be reduced.

Fifth, the emphasis on penalties in policy guarantees is also insufficient, with half of the 17 policies not mentioning penalties. Penalties are an effective means of safeguarding the public interest and the order of the industry and can effectively curb the emergence of corruption in the industry and play a good monitoring and safeguarding role. The relevant governments should pay more attention to this aspect in their subsequent policies.

We compared and analyzed the indicators for each policy and suggested improvements for policymakers. While the PMC surface charts provide a visual representation of the strengths and weaknesses of the policies, it is necessary to define the policy optimization path further. The choice of the optimization path depends on the gap between the values of the main variables of each policy and the mean; the more significant the gap, the more forward the optimization path. Figures 3–8 were plotted by importing the data into **MATLAB** software, similar to the steps we followed in 3.3.4. The vertical axis in the picture is the PMC score for each variable.

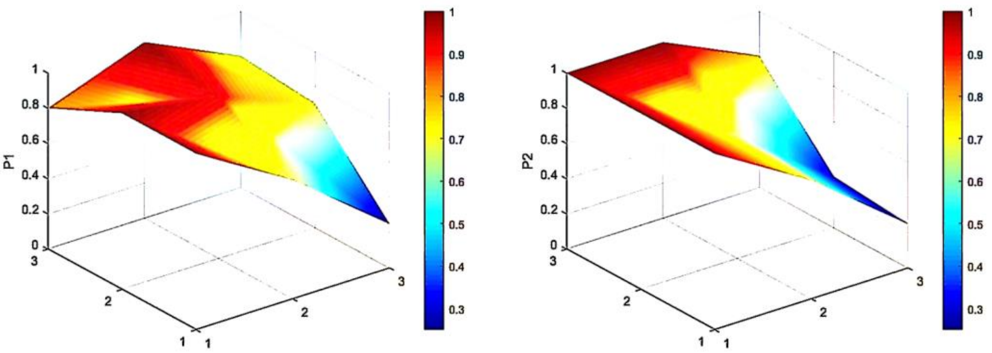

Figure 3. The policies P1 and P2 of PMC surface charts.

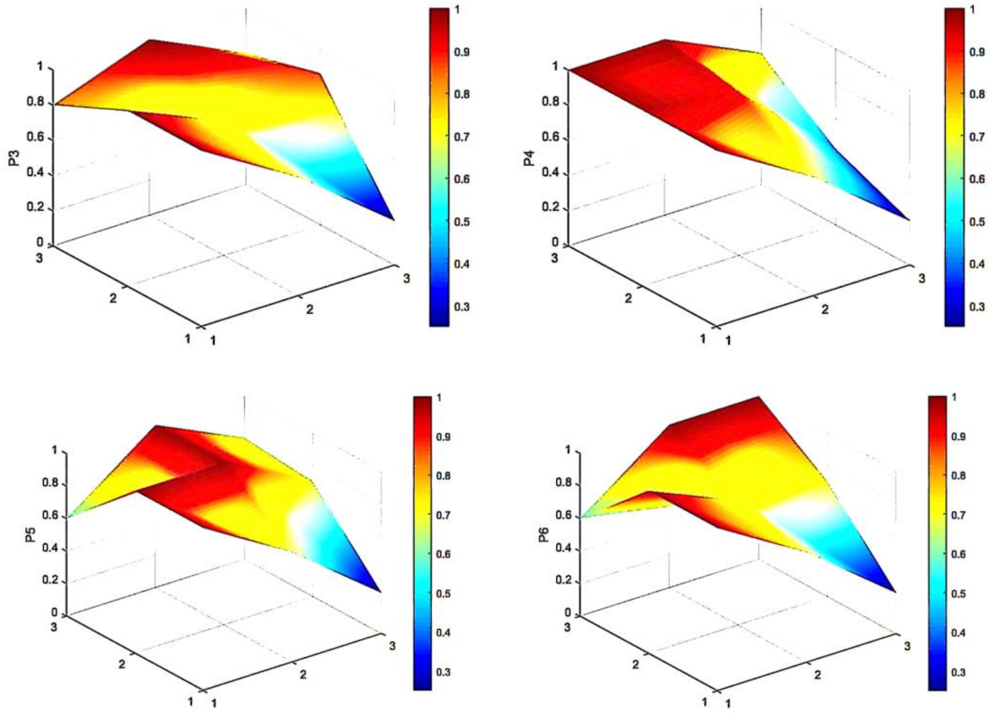

Figure 4. The policies P3–P6 of PMC surface charts.

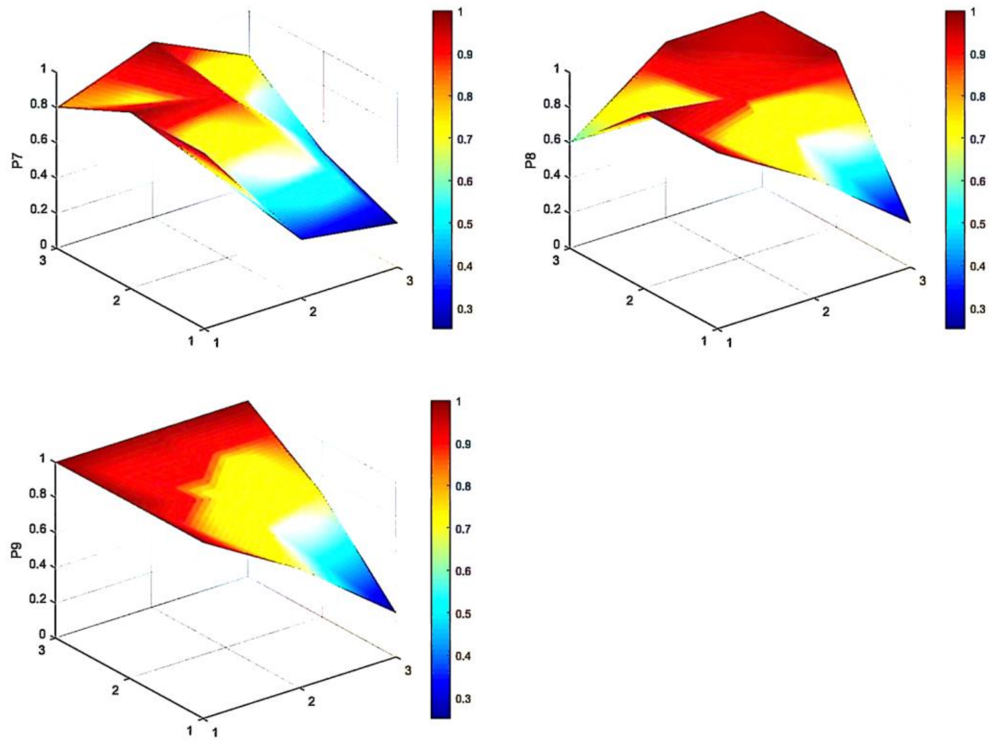

Figure 5. The policies P7–P9 of PMC surface charts.

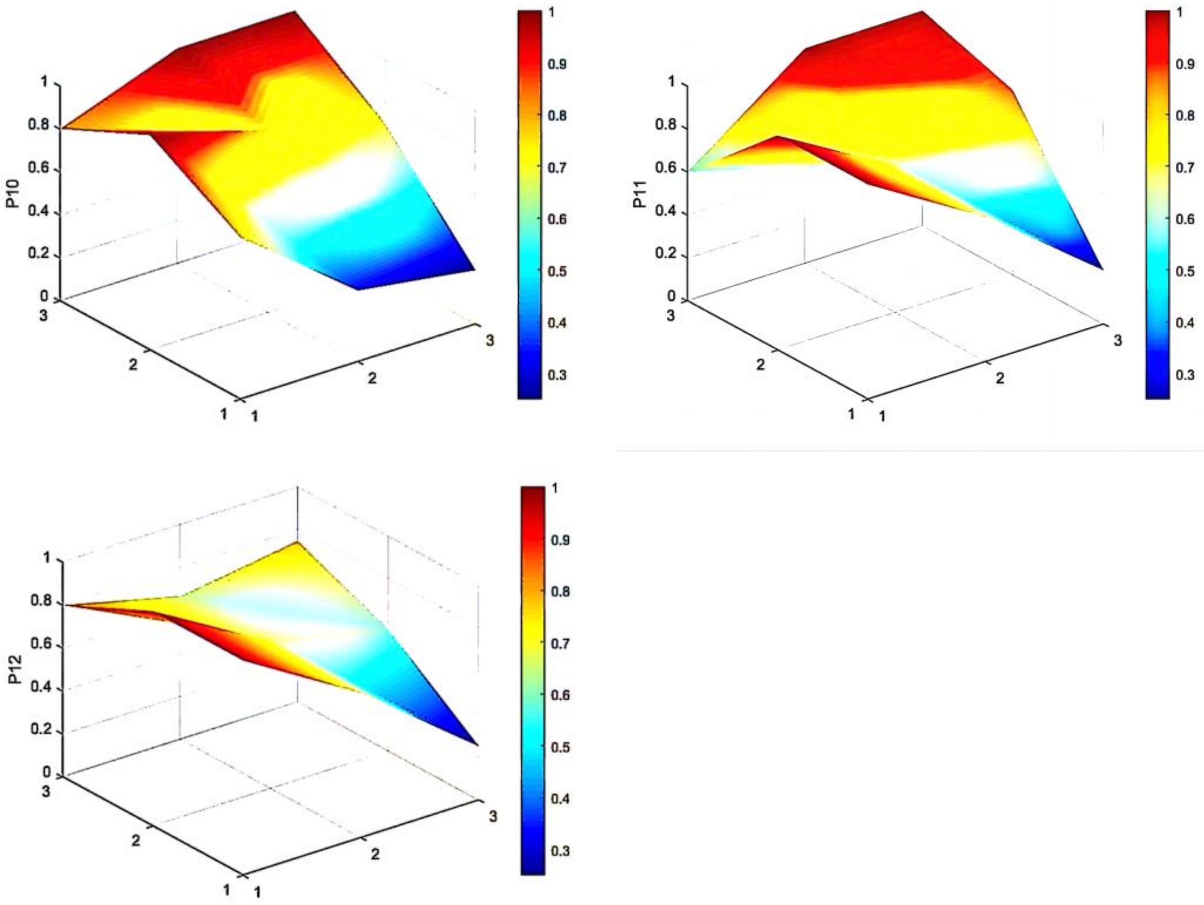

Figure 6. The policies P10–P12 of PMC surface charts.

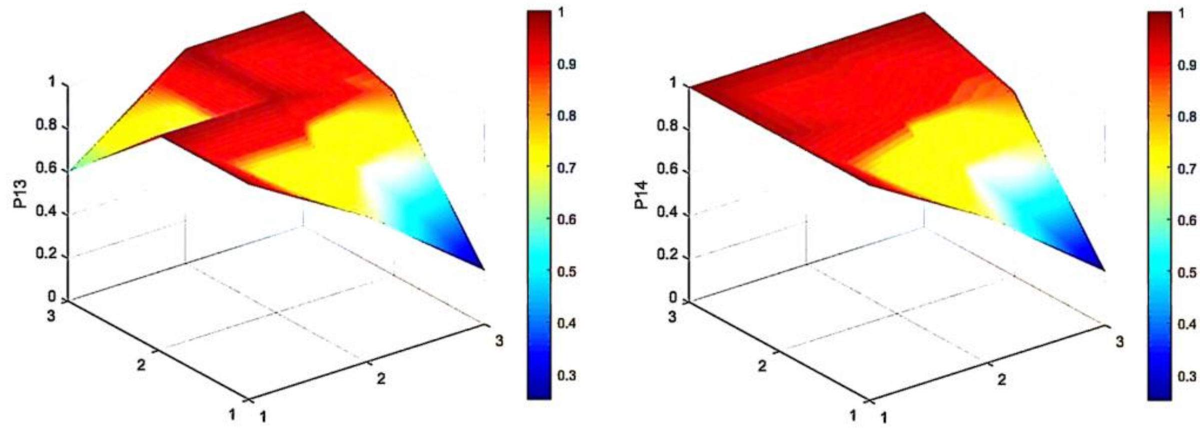

Figure 7. The policies P13–P14 of PMC surface charts.

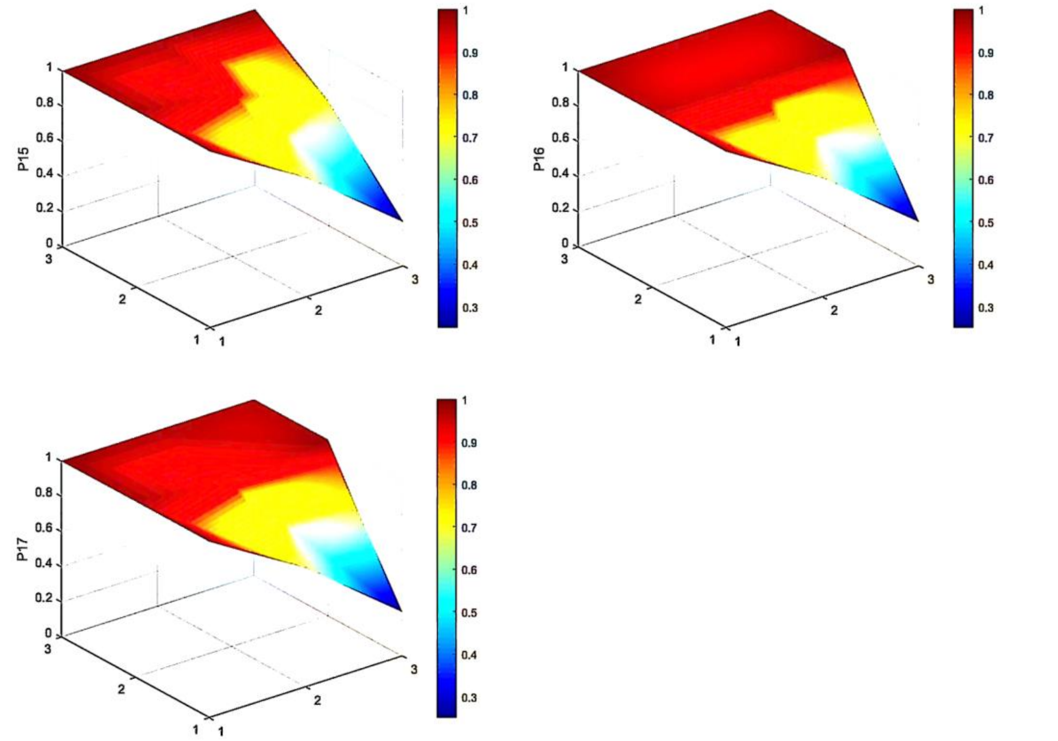

Figure 8. The policies P15–17 of PMC surface charts.

3.1.1. Nation

Figure 3 corresponds to policies P1 and P2. P1 scored 7.10. The theme is to accelerate the formation of a low-carbon transportation system in China and promote the greening of the transition to economic and social development. It also emphasizes desulfurization and nitrogen reduction in the port and shipping sector. The other aspects, such as X5 Policy Content, X6 Incentive Mode, and X7 Policy Guarantee, scored high on the PMC index. The policy is a good lead. Somewhat regrettably, however, there is no mention of green tax incentives or the treatment of noise pollution in ports. The optimization path for P1 is X9–X6–X7.

P2 scored 6.64. Another policy issued by the MOT aims to build a modern water transportation system that is safe, convenient, efficient, green, and economical. Compared with P1, the policy focuses on the greening of ports and proposes corresponding management measures for trade and intelligence of ports. We can observe that P3 scored 0.29 on X6 Incentive Mode, which is at a significant disadvantage compared to other policies, indicating that the policy has less reference to incentives. For example, there are no corresponding tax benefits or fee remission measures. Notably, the policy received a perfect score of 1.00 on the X7 Policy Guarantee, indicating the importance that policymakers place on safeguarding. Subsequent policies could consider incorporating more incentives in their development. The optimization path for P2 is X6–X5–X9.

Despite the limitations of P1 and P2, the two policies provide a degree of guidance by providing examples of green port policy texts for coastal areas.

3.1.2. Bohai Rim

P3–P6 (Figure 4) represent those policies selected from the Bohai Rim cluster. The area's ports and cities are located across the sea from South Korea, making it a gateway for maritime trade between China and South Korea.

P3 scored 7.09 and ranks 9th out of 17 evaluated policies, which is a medium level. According to the evaluation, there are no apparent shortcomings in the policy. The Tianjin Transportation Commission issued the policy to turn Tianjin into a green demonstration city and make the Port of Tianjin a world-class green port. The optimization path for P3 is X9–X7–X5.

P4 scored 7.02. It is a policy that aims to improve the layout of coastal ports in Hebei Province. This policy scored 0.57 on X6 Incentive Mode, which places it at the bottom of the list of representative policies selected from the Bohai Rim region, suggesting policymakers need to pay more attention to incentives. And there is still room for improvement. The optimization path for P1 is X6–X9.

P5 scored 6.98. It ranks 13th out of 17 policies. Although the policy has the lowest score in the Bohai Rim region regarding green port construction, there are some highlights. With a perfect score of 1.00 on the X5 Policy Content, the policy combines various elements of port pollution prevention, ecological restoration, and energy optimization. Compared to the other three policies, the policymaker should have made improved legislation on the X7 Policy Guarantee, a policy optimization path that can be achieved in the future. The optimization path for P5 is X7–X9–X6.

P6 scored 7.00. This planning document issued by the Dalian Municipal Transportation Bureau aims to build Dalian into a world-class international shipping center. As with P4, there are no obvious shortcomings in this policy. Notably, P7, compared with the other three policies, pays more attention to education content, calling on the Dalian Maritime University and other colleges and universities to support and actively improve the training systems of port and shipping personnel. Meanwhile, this policy is also the only one of the four policies in the Bohai Rim that mentions green tax incentives, reflecting strong foresight. The optimization path for P6 is X7–X5–X6.

3.1.3. Yangtze River Delta

Policies P7, P8, and P9 (Figure 5) are representative policies selected from the Yangtze River Delta cluster. It is the most densely distributed port group with the most significant throughput along China's coast and excellent development potential [66].

P7 scored 6.48 and ranks 16th out of 17 policies as "acceptable consistency". The policy is one of the special plans underpinning the 14th Five-Year Plan for Shanghai Comprehensive Transportation to guide the development and construction of green transportation in Shanghai during the 14th Five-Year Plan period. It scored 0.33 on X2 Policy Timeliness, significantly lower than the average. The policy was published in 2023, and the 14th Five-Year Plan will end in 2025, which needs longer to be effective. With a score of just 0.43 in the X6 Incentive Mode, it lacks elements such as tax benefits and green finance. As a super first-tier city in China, Shanghai is endowed with rich social resources. Therefore, it is necessary to provide more incentive support in policy formulation. Meanwhile, the policy for Shanghai, one of the wealthiest places in China regarding university resources, made no mention of cooperation with universities in X9 Policy Audience, which is also one of its disadvantages. The optimization path for P7 is X6–X2–X9–X7.

P8 scores 7.44 and ranks 6th out of 17 policies with "good consistency". It is a policy issued by the Jiangsu Provincial Department of Transportation. Notably, the policy scored 1.00 on the X6 Incentive Mode. Its incentives are in place to fully stimulate the companies involved. The score on the X7 Policy Guarantee is significantly lower than the average, indicating that the government needs to consider the protection of the policy, which is one of the optimization points for the future. The optimization path for P8 is X7.

P9 scored 7.48 and ranks 5th out of 17 policies, which is an excellent ranking. The policy originates from Zhejiang Province. The policy has no significant disadvantage on X1–X9, and the overall design of the policy is more reasonable. The optimization path for P8 is X5–X6.

3.1.4. Pearl River Delta

P10, P11, and P12 (Figure 6) correspond to the Pearl River Delta (PRD) port clusters. The PRD region is located along the southern coast of China, close to Hong Kong and Macao, and is strategically located to facilitate maritime trade with China and abroad. The port cluster was formed with the ports of Guangzhou and Shenzhen as the core, and several ports complement and supplement each other.

P10 scored 6.69 and ranks 14th out of 17 policies. It is one of the few policies focusing on "green port construction". The policy mentions that by 2025, ports' green and low-carbon production modes should be initially formed. The policy is a better guide for constructing green ports in Guangdong Province, with no apparent disadvantages except that it is only a short-term plan, resulting in a lower score on X2 Policy Timeliness. Subsequent policymakers may propose relevant measures to optimize the tax incentives for the port industry and improve the carbon trading mechanism to make the policy design more reasonable. The optimization path for P10 is X2–X1–X5–X6–X7.

P11 scored 7.07 and ranks 10th out of 17 policies, achieving a moderate level. The PMC score of P11 is higher than that of P12, which indicates that the policy design of P12 is more reasonable, reflecting that Shenzhen port receives better support from the government than Guangzhou port. This result is consistent with the findings of previous studies [67]. However, P11 on the X7 Policy Guarantee scored lower than the other two, meaning the policy's protection is a disadvantage. The government can propose appropriate management measures for testing pollutants and pursuing penalties in the future. The optimization path for P11 is X7–X5.

P12 scored 6.40, ranking last out of 17 policies. The policy has a significant disadvantage in terms of design for the construction of green ports compared to other policies. P12 scored significantly lower than average on X5 Policy Content, X6 Incentive Mode, X8 Content Evaluation, and X9 Policy Object, and the local government needs to increase its support in these areas and consider more policy elements. The optimization path for P12 is X8–X6–X5–X9–X7.

3.1.5. Southwest Coast

P13 and P14 (Figure 7) are from the southwest coastal region. The southwest coastal port cluster is an essential strategic pivot connecting China and Southeast Asia. Although the overall development of the southwest coastal port cluster started late, it has developed particularly rapidly in recent years. The PMC indicator calculation results show that these two policies scored 7.37 and 7.70 points, respectively; the overall evaluation is good. This result suggests that the region strongly focuses on greening its ports and developing related shipping. The optimization path for P13 is X7, and P14 values for all variables are above average, so there is no recommendation to optimize the pathway.

3.1.6. Southeast Coast

Policies P15, P16, and P17 (Figure 8) are representative policies selected from the southeast coastal region, corresponding to the three coastal cities of Xiamen, Fuzhou, and Quanzhou. These 3 policies have outstanding scores out of the 17, ranking in the top five. The indicator scores show that the usual policies were formulated with full consideration and complete elements. Regarding X5 Policy Content, these three policies involve the indicator variables we proposed. And all of the X7 Policy Guarantees yielded a good score of 1.0. It should be mentioned here that Policy P16 (i.e., "Xiamen Port's 14th Five-Year Development Plan") was issued by the Xiamen Port Authority in April 2021, and there is no mention of improving the carbon market or green finance in the policy. However, issued in October 2022, "Xiamen Port Authority issued the Xiamen Port Low Carbon Development Action Plan", was the first low-carbon development action plan in China's port and shipping sector to be officially issued and implemented by a local industry authority, which not only focuses on the content of the section but also provides a more detailed layout for the greening of Xiamen Port. For example, constructing a "distributed energy + storage + micro-grid" self-consistent energy system promotes the application of BIM (building information modeling, a data management tool for engineering design, engineering construction, and engineering management) technology in port construction projects. It can be seen that the local rulers attach great importance to promoting the greening of the port and shipping projects [68]. P15 is the only one of these three policies that has an optimization path that can be suggested: X7.

3.2. Discussion

3.2.1. Comparison of Policies in North and South Ports

We also achieved results that differed from previous studies. Traditionally, ports from the north of China are more robust, while ports from the south are weaker, such as regarding green efficiency [69]. But, in some fields, this may have changed with the times, with northern ports being less competitive than southern ports [70]. By comparing the average value, which reflects the general level of the phenomenon as a whole, the PMC indexes of the policy samples from northern ports (P3–P6) and southern ports (P7–P17) were found to be not very different (Figure 9). They are even lower in their PMC index. This is in contrast to the traditional view. It shows that green port policies in the South have more complete policy elements closely related to policymakers. The reasons for this change are closely associated with the level of economic development in the North and the South and their natural geographic location. The financial situation in the South of China is better than in the North, which gives local governments more leeway to consider trade development and the greening of industries. Due to the Sino–U.S. trade friction, Southeast Asia has become the key strategic shift objective between the two countries [71–74]. Southern ports have an inherent advantage in this regard. They are closer to Southeast Asia than ports in the north and are more accessible for international cooperation and transportation of processed products. Obtaining government support to develop maritime transportation for trade and greening is also easier. Perhaps, it means that green port projects in the South have more significant potential for development. At least in terms of policy samples, the green port policies of southern ports have demonstrated a certain degree of sophistication. Future researchers can move toward more in-depth studies and discussions in related areas.

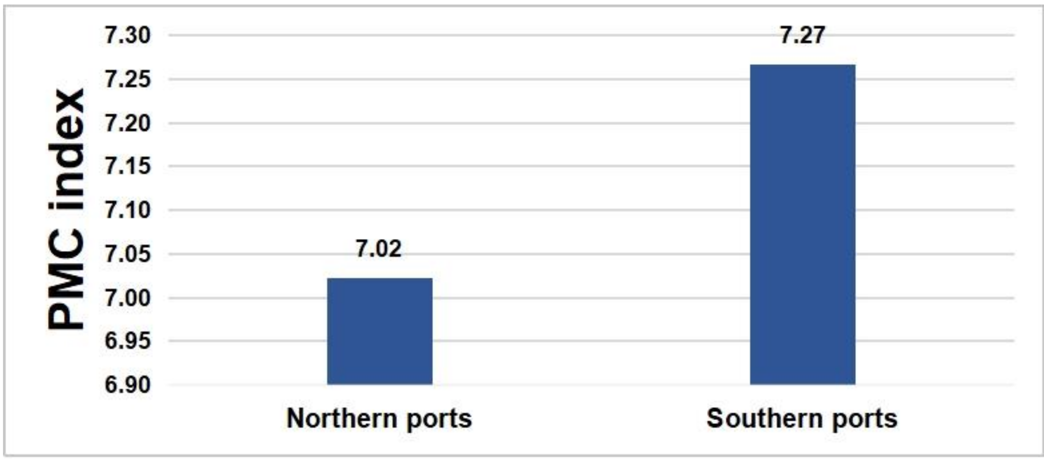

Figure 9. Comparison of PMC index Average Values of Green Port Policies in China's Northern and Southern Ports.

3.2.2. Green Ships and Green Shipping Corridors

In reviewing these policies, we also found that most of the 17 representative policies referred to the need to actively explore the application of green energy on ships, such as liquefied natural gas (LNG), hydrogen fuel, and methanol. It shows the importance that the Chinese government attaches to this field. The Chinese government has strongly advocated the development and construction of new energy vessels in many policies from 2013 to 2022, including exemptions from vehicle and vessel taxes, subsidies or fee reductions for new energy vessels, and so on [75–79]. Motivated by these policies, the green ship market in China is very active. In 2022, China's full-year new orders for green-powered ships accounted for 49.1% of total orders, the highest level ever. International market share of new green ship orders reached 57.0% by 2023 [80,81]. The IMO is advocating for an accelerated global push towards the use of new and alternative sources of energy for ships. Against this backdrop, the Chinese government must support shipping and ports in building capacity to produce, use, and supply zero-emission fuels and technologies, which is an important measure to advance the adaptation of its shipping to the international response to climate change. It should be noted that LNG fuel technology has disadvantages in emission reduction compared to other clean energy technologies. The government should guide enterprises or research institutions to develop other clean energy technologies as much as possible [82]. Meanwhile, the Chinese government is actively promoting the development of green shipping corridors, although China is not a signatory to the Clydebank Declaration. In January 2022, Shanghai Port and Los Angeles Port jointly initiated the construction of a green shipping corridor. This is the first green shipping corridor across the Pacific Ocean. In the same year, relevant cooperation agreements were also reached between the ports of Guangzhou, Los Angeles, Shenzhen, and Gothenburg. Green shipping corridors are zero-emission routes between two or more ports. Zero-emission fuels are readily available to ships along their routes and are subsidized for shipowners. As green corridors are both environmentally friendly and economical, ports will cooperate with more shipping companies through green corridors, gather more shipping elements, enhance ports' international status and competitiveness, and promote the development of China's green ship industry. Wang et al. [83] designed an ammonia-based global network of green corridors, a model that captures potential synergies between different routes and geographic regions. This is a good source of inspiration for governments in China and other countries on route selection for green shipping corridors.

But how should the Chinese government achieve a more significant breakthrough in international competition in green energy ships in today's increasingly complex global environment? In particular, in April 2023, the European Union (EU) formally adopted the agreement on the European Carbon Boundary Adjustment Mechanism (CBAM), which establishes a transition period from 2023–2025, with carbon tariffs to be formally introduced from 2026 onwards. From 2024, the shipping industry will be included in the EU Carbon Emissions Trading System (ETS). Decarbonization requirements in ship operations have become one of the critical trends in the development of the shipping industry, and the market demand for green-energy ships will further expand. This is both an opportunity and a challenge for the Chinese government. In such a background, China's policymakers should increase the mechanism to ensure that the construction of green ships is a standard policy system and that it connects well with the EU and other international carbon markets. The government should also guide the bank capital, financial credit, and leasing support; encourage the participation of private capital; broaden financing channels; introduce relevant support policies; and improve the enthusiasm of the prominent participants.

4. Conclusions

To better promote the sustainable development of maritime transportation, we designed an evaluation system based on the PMC index model to evaluate 17 current green port-related policies in China and summarized their characteristics. Unlike previous evaluation systems that focused on whether the implementation of policies impacted port emissions or environment, the system evaluates green port policies, for the first time, from the perspective of the policy text. It fully considers critical factors such as policy content, incentives, and guarantees. The results showed that the average PMC score of the evaluated policies was 7.25, presenting "good consistency". Overall, China's current green port policies are sound. Still, there is much room for improvement, including but not limited to enriching the content of the policy, supplementing it with additional incentives, and strengthening the means of safeguarding the policy. These elements can be improved in the subsequent policies. When comparing the PMC scores of policies in the North and South of China, we also found a difference from previous studies: Namely, the policy samples in the South, which have more policy elements, outperform those in the North. This is one of the directions that can be expanded in the future. While reviewing a sample of policies, we offered insights into the current situation facing China's green ship industry and green shipping corridors.

Limitations

The evaluation system we proposed can also provide a theoretical basis for evaluating green port policies in other countries and providing suggestions for improvement. We believe that the target of the evaluation system should not be limited to the generalized theme of green port policies. In the future, scholars can take the system as a basis to consider more relevant variables, making the research targets more specific, such as carbon emission control policies, sulfur emission control policies, and others, to make a greater contribution to sustainable maritime transportation. There are also some limitations to this study. Firstly, we set the variables based on text mining and our understanding of the maritime industry. Strictly speaking, it is somewhat subjective. Secondly, the limited number of indicators makes it difficult for our policy assessment system to cover all aspects of green port construction. In the future, scholars can utilize other methods to select more objective variables. Alternatively, a more in-depth segmentation of green ports could be explored.

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