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The low-carbon development of shipping industry in China

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THE LOW-CARBON DEVELOPMENT OF SHIPPING INDUSTRY IN CHINA

By

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Shipping industry is the fundamental industry of national economy, and is the important industry relating to the national security and national economy. Since the reform and open policy, the development of shipping industry in China is rapid, but the shipping industry has great potential and development space in saving energy and reducing carbon emissions. Furthermore, low-carbon green shipping industry is the unavoidable demand of transportation development.

China’s shipping industry has not established a complete evaluation system of low-carbon green development currently, so how to comprehensively, objectively and scientifically evaluate the effect of China's shipping industry low-carbon green development, is a urgent problem. According to the objective situation of the development of shipping industry in China, this paper build a perfect evaluation index system of low carbon green shipping industry, and provide some recommendations and measures for energy saving and emission reduction in shipping industry.

Based on the analysis on development situation of energy-saving and emission reduction in domestic and international shipping industry, this paper analyzes the impact of low-carbon green development of shipping industry to ecological environmental, and studies the mechanism of shipping industry low carbon green development. And the evaluation index system for low-carbon green development of China's shipping industry is constructed based on the AHP and fuzzy comprehensive evaluation method. Using the research on DPSIR model, it also provides practical basis for related countermeasures, proposes the scientific, innovative, operability strategy of the shipping industry green development.

KEYWORDS: Low-carbon green development, index system, DPSIR model, AHP

CONTENTS

LIST OF FIGURE

LIST OF TABLES

LIST OF ABBREVIATIONS

MSA	Maritime Safety Administration
IMO	International Maritime Administration
AHP	Analytic Hierarchy Process
FCEM	Fuzzy Comprehensive Evaluation Method
WTO	The World Trade Organization
EEOI	Energy Efficiency Operation Indicator
GDP	Gross Domestic Product
DPSIR	Driving force - Pressure – Condition - Impact - Response
TEU	Twentyfoot Equivalent Unit
COSCO	China Ocean Shipping Company

Part 1
Introduction

1.1 the background and significance of this research

With the deepening of the globalization of world trade, the trend of change also led to the steady development of shipping industry; however, after recent years of high-speed development period, the speed of the development of the shipping industry reduced markedly after the outbreak of the global financial crisis, and has not rebound yet. But on the other hand, the global dry bulk fleet, container fleet, oil and other liquid bulk fleet, rolling fleet etc. have already obtained the full development and growth.

According to the research on the energy consumption and carbon emissions of global shipping industry in recent years from the United Nations, on the basis of estimates, carbon dioxide emissions of global commercial shipping in recent years three times higher than the previous estimation numerical. According to incomplete statistics, at present, global shipping activities discharge carbon dioxide about 11.2 million tons annual, accounting for approximately 4.5% of global carbon dioxide emissions, but the previous number was about 4 million tons estimated by the International Maritime Organization (Yang,2011,p.11). Recently, a survey on world merchant fleet is conducted by International Council for Clean Transportation. This report says that: Global oceangoing merchant fleet discharges three main oxygen compounds which can cause greenhouse effect: carbon dioxide, nitrogen dioxide, sulfur dioxide, accounted for 2.1%, 4.9%, 14.2% respectively of the total emission of global transportation system (Yang,2011,p.12). However, many shipping companies refused to use a clean marine fuel, because the prices of environmentally friendly fuel are relatively expensive, and it will greatly increase the fuel cost for shipping companies. Some shipping company even choose to be affiliated to developing countries and regional port whose environmental protection system is not perfect and implementation force of environmental protection laws and regulations is weak, and evade United States and Europe and other national and regional port which strictly enforce clean air law, in order to escape the scope of the harsh environmental protection laws and regulations, so that the number of waste gas and water discharged by ships in the process of shipping can not be effective supervised and controlled in this situation. According to reckoning, if this situation fails to improve, is expected that by 2020, the global shipping industry will need 4 million tons of fuel (Ye,2010, p.17), and the total emissions of global oceangoing merchant fleet will increase approximately 75% more than the current amount in 2020 (Zhang, 2011,p.19).

Many countries and regions have constituted or are constituting very oppressive laws and regulations, to compel the ships to save the fuel oil consumption and reduce greenhouse gas emissions, forcibly demand shipping enterprises to use the marine clean fuel, and this kind of fuel belongs to environmental protection type; it's greenhouse gas emissions in the process of combustion are relatively low. But the price is more costly compared with other ordinary ship fuel. As a result, this measure can effectively improve the level of exhaust gas emissions

of shipping, but also will sharply increase the ship operating cost of shipping companies.

The "Green Industrial Revolution" which was induced by the global climate change is accelerated in the global scope, low carbon green development becomes a global economic development trend, and the change of development type has become a new trend and direction. China is the largest developing country in the world, so "Green Industrial Revolution" is the biggest challenge for China, and if is also the biggest opportunities. The core of the green revolution is the disengagement between economic growth and the emissions of carbon dioxide, China needs to seize the opportunity and find a way of green development. In November 2009, Wen Jiabao, the premier of China, clearly pointed out that China will speed up the construction of green transportation system which has the characteristics of low carbon in the State Council executive meeting, and he also put forward a total target that the carbon emissions of unit GDP will decline about 40% to 45% in 2020 than the figure in 2005. The meeting stressed that the transportation is a big energy and resource consumption industry, the greenhouse gases discharged by all kinds of transport vehicle are the main cause of global warming. Therefore the transportation industry should expedite the establishment of green transportation system with the characteristics of low carbon to meet the requirements of green and sustainable development.

The shipping industry is the basic industry of national economy, and is the lifeline of the national security and the national economy. Since the Chinese economic reform, the development of China's shipping industry is relatively rapid. According to the statistics end to July 2011, it is notable that China has miscellaneous commercial shipping 17.8 million, 1.8 million deadweight tons, deadweight tons grow approximately 77% compared to 2005, the size of shipping fleet leapt to third in the world (People’s daily, 2011, p.1). Thus, with the growth of China's transportation fleet, the development of low carbon green shipping industry has a profound significance for the development of low carbon green transportation in China.

The goal of low carbon green development of shipping industry in China is "constructing a unimpeded, efficient, safe and green transportation system", a wide cross-section of society in China has begun to attach great importance to the development of this objectives at present. The establishment and continuous development and improvement of green shipping system, have features like dynamic variability, systematicness and cooperativity, these features left a huge space for development for the theory and practice research on the green and low carbon development of shipping industry.

1.2 Literature Review

1.2.1 Studies in other countries

(1) policy research:

At present, the most representative foreign green transport policy is "the

American Transportation Strategic Planning (2000-2005) ", "the American Transportation Development Strategy of science and technology " formulated by the U. S. Department of transportation, and the white paper of European Union " the common transport policy to 2010: be up to the moment of decision ", "new comprehensive logistics policy outline" in Japan and so on, these are the programmatic document for the development of green transport, have guiding significance for the development of green transport all over the world.

(2) theoretical research:
Paul R. MurphyJr (Contemporary logistics, 2010) successively inquired into the impact of environmental problems to the decision-making of logistics through the value chain in 2008, and deem that green logistics can not only expand the scope of logistics, but also can affect and change the work mode of logistics manager in 2009; Pilar L. Gonza-Torre etc. (Cycle logistics system, 2010) studied environmental policy of cycle logistics in European; Asha Weinstein Agrawal etc. (The transportation tax option, 2010) have made a study on the taxes and incentives of green transportation; moreover, some academics have made a research on other aspects, such as influencing factor of green transportation, the implementation motivation of green transportation, green transport behavior, coping measures, environmental awareness, social responsibility and so on.

Massoli etc. (Massoli, 2008) proposed a project to effectively reduce and absorb the carbon emissions of merchant fleets from the point of the operation of the ship; Peter J and B Williams (Peter, 2010) elaborate the basic principle of reducing greenhouse gases and discharging pollutants from the view of combining marine natural environment and shipping; Windson B (Windson B, 2010) put forward the index system of sustainable development shipping, and combined with the system model to forecast the green economic developing trend of future shipping route; ErikHaites (ErikHaites, 2009) analyzed the problem of development planning of shipping industry under the background of global carbon emissions trading; IanYoung (IanYoung,2008) has made an exhaustive study of green shipping and the problem of how to transform the sustainable development of the shipping industry into reality, and puts forward related suggestions; Matti Turtiainen (Matti Turtiainen, 2005) is detail analyzed guidelines of the shipping industry from the angle of shipping policy, emphasized the significance and importance of global environment to reduce emissions of the shipping, and also put forward relevant protective measures; Thomas. A. Grigalunas (Thomas. A. Grigalunas, 2007) forecast the future development of energy saving and emission reduction of the shipping industry, and advocated comprehensive management from the macro and micro aspects.

1.2.2 Studies in China

Zhuo Dongming (Zhuo, 2010) also discuss related issues in the "accelerating green shipping ". In addition, Sang Shiliang (Sang, 2010) advocate green shipping industry, and points out that China should accelerate the renovating process of shipping energy saving and emission reduction; Zheng Rongmin (Zheng, 2010) argues the economic significance of green, low-carbon shipping process to the marine environment; Huang Zheting (Huang,2010) analyzes the

current green development situation of the shipping industry from the view of shipping environmental regulations and environmental protection technology, and looks forward to the future development trend, puts forward the corresponding improvement scheme combined with the actual; Li Zhenghong (Li, 2009) makes a research on shipping industry in different aspects, illustrates the improvement needs of green shipping development on the ship system, route system, power system, management system respectively; Lv Anqin (Lv, 2010) analyzes and summarized the existing management problems of shipping energy-saving and emission reduction as well as the existing mode of environmental management from the view of maritime function; Yang Yiping (Yang, 2008) analyzes of the shortcomings of current construction of green low-carbon shipping industry; Lv Zuohan (Lv, 2008) expounds the measures of the shipping in the production process to reduce emissions from the perspective of shipping enterprises' management; Kong Wenxuan (Kong, 2009) proposes to build green shipping and promote modern logistics of shipping industry have a coordinated development; Teng Chunyan (Teng, 2007) introduces current work on shipping energy saving and emission reduction; Gan Aiping (Gan, 2010) discusses the financial services of low carbon shipping in China; Li Gang (Li, 2010) analyzes the economic significance of low carbon development of shipping industry; Tang Guanjun (Tang, 2010) introduces the progress of energy saving and emission reduction work of shipping industry in China; Duan Xueyan (Duan, 2011) explores financial development strategy of low carbon shipping industry in China.

1.2.3 summary

Through analysis and research on the domestic and foreign scholars' relevant literature about low carbon green shipping and its index system of evaluation, we can know that the development of shipping industry and ecological environment are interactional, and the basic theory on the low carbon development of shipping industry have been studied.

This paper adopts the DPSIR model (driving force - pressure – condition - impact - response), takes into account the requirements of low carbon development in China in the index selection, provide an evaluation index of low carbon development which is appropriate for the current development status of shipping industry, also this paper adds a certain number of quantitative index in order to fully establish low carbon green development index system of shipping industry in China, overcomes the one-sidedness of the previous studies in a certain extent, and takes the reference standard of index evaluation given by the Twelfth Five Year Plan as the base, settles on the evaluation reference standard of low carbon development index for shipping industry combined with actual needs. Finally, this paper uses the AHP fuzzy comprehensive evaluation method to carry out the demonstration analysis on the basis of the index system, so as to reflect the development situation of low-carbon green shipping industry in China, and puts forward the countermeasures.

1.3 main contents and methods of this study

(1) Through the studies on the development situation of low carbon green shipping industry and the impact of ecological environmental, this paper summarize and compare domestic and foreign development situation of low carbon green shipping industry, find out and deeply analyze development constraints factors of low carbon green shipping industry in China; the paper discusses interaction between the low carbon green development of shipping industry and ecological environment, analyze the symbiotic relation between them.

(2) Through the research of the internal mechanism of low-carbon green development in shipping industry, this paper discuss the component ingredient and coordination development of low-carbon green shipping industry, and build the development system of low-carbon green shipping industry.

(3) Through the analysis of the system and mechanism of shipping industry, the influence of the low-carbon green development from the traditional system and mechanism of shipping industry is studied.

(4) Based on the theory on the intrinsic mechanism research, this paper adopt DPSIR model to structure the evaluation index system of low carbon green development for China's shipping industry, and detailed explain and describe each evaluation index and evaluation reference standard.

(5) Using AHP analysis method to obtain comprehensive evaluation for low carbon green development of shipping industry in China, and taking a shipping company as an example to analyze scientific and reasonable results of the evaluation index system and evaluation method are reduced.

(6) according to the results of theoretical and empirical analysis, the low carbon green development countermeasure of shipping industry is studied based on principles as resource conservation, recycling, coordinated development, overall maximum benefit etc. The paper also propose related suggestions and measures of the transformation of China's shipping industry to become green and low carbon refer to shipping industry, shipping enterprises, the national government relevant management departments respectively.

This paper adopt the methods of the combination of theoretical research and case studies as well as the combination of qualitative and quantitative research, through evaluation methods like field investigation, expert consultation, longitudinal method, transverse method and so on to discuss the connotation of low carbon green development of shipping industry, construct the evaluation index system of green development of shipping industry, and evaluate it by AHP and DPSIR model.

(1) Theoretical studies. Though the comprehensive using the research results of sustainable development theory, system theory, green economics, transport economics, regional economics, environmental engineering and other disciplines, the concept, theory and method of this subject are deeply

studied based on the full collection and analysis of the domestic and international relevant data and research results.

(2) Algorithm research. the problems are located by using the analytic hierarchy process and other evaluation methods to calculate the quantitative index in the green development evaluation index system of the shipping industry.

(3) Case studies. Firstly, related factors which affect the low carbon green development of shipping industry are comprehended through the field investigation; secondly, related model is established by a comprehensive analysis; finally, a large number of empirical data is accessed by case study.

Part 2
The present situation of Low-carbon green development of shipping industry and its influence on the ecological environment

2.1 Present situation of low carbon development in domestic and international shipping industry

2.1.1 low-carbon green development status of foreign shipping industry

With the spreading of "Green Industrial Revolution" induced by the current global climate change within the scope of the world, more and more countries or regions are increasingly aware of the closely related the development of shipping industry and the protection of global ecological environment, government agencies of some developed countries have developed strict laws and regulations to forcibly reduce energy consumption of shipping, and emissions of greenhouse gas. But at the same time, this has resulted in the increase of short-term operational costs of the shipping company fleet.

(1) United States

Environmental laws formulated by Long Beach Harbor at California state of America stipulate that all cargo ships whichever enter or leave the port of Long Beach, including ocean-going and near-sea container liners, dry bulk cargo and liquid bulk cargo ships and so on. The ships must obey the following environmental regulations during the period of port: ships must use clean ship fuel in the scope of 40 nautical miles distant from Long Beach Harbor. The prices of this clean ship fuel oil are very expensive; at the same time it requires that the ship speed of entering and leaving the port must not exceed 12 knot, ships must use shore power and stop the use of marine diesel engine power during docking at the shipping pier.

It is noteworthy that the implementation of the shipping industry clean air regulations is a comprehensive management project with huge investment. Transportation Department of United States has made in-depth investigations and studies for this project. The report shows that if shipping industry throughout the United States puts into effect the clean air law, about 200 billion dollars are needed to execute this act to 2020; the annual cost is approximately 1.5 billion dollars. The federal and state governments will provide a portion of that money, but the majority rest of the money needs to be supplied by the shipping industry and the shippers. Factors such as the protection of the ecological environment, the reducing of global greenhouse gas emissions and the high volatile market price of fuel oil are the main reason for the great revolution of global trade, the new reform of shipping industry and the upgrading of the global ocean shipping supply chain. However, the current situation of weak recovery of global shipping industry makes the recovery of shipping industry level more difficult. Currently, some environmental protection organizations of the United States actively advocate to draw up and carry out related clean air law of shipping industry which come up to the global shipping industry

environmental standards through the International Maritime Organization, the basis for the implementation of these shipping industry clean air law is the specific provisions of fuel oil standards used by ocean going vessels, because most of the merchant fleet still uses the fuel oil with the feature of cheap price, poor quality, seriously exceeding emissions in the voyage at present.

(2) Europe

Some governments and environmental organizations of the EU have formulated or are formulating laws and regulations to reduce carbon emissions of shipping industry, require shipping fleet of European Union to reduce total emissions of carbon dioxide and nitrogen oxides and other greenhouse gas, reach a reduction of 20% - 40% based on the figure in 2005 until 2020, the data will be reduced by 50% to 2050. This kind of environmental protection laws and regulations formulated by the European Union is extremely stringent, particularly in the current environment of weak recovery of global shipping industry, it undoubtedly arrests the development of the shipping industry, but at the same time European shipping company indicates that, according to the current construction technology of ships and power system design, it is probably attained to achieve the above specific targets of carbon emissions reduction of shipping fleet demanded in the environmental law. But the shipping company needs to face a considerable degree of pressure from ship operating costs rising. The main task of the shipping enterprise is to improve the availability efficiency of the ship energy, and furthest reduce the emissions of the waste gas in shipping process. The EU countries generally realize that, as an important link in the global supply chain, the development of shipping industry should achieve the transformation and carry out innovation as soon as possible.

2.1.2 low-carbon green development of domestic shipping industry

Ocean Development Strategy Research Institute of China's National Marine Bureau released “the ocean development report of China” which aims at development situation investigation of national near-sea, according to the report, a section of bay and shipping water in China is faced with serious pollution, and the pollution range of near-sea water expanded nearly twice in the past decade, already more than 16 million square kilometers. At the same time, marine oil spill accidents caused by crude oil transportation and offshore oil exploitation activities constantly occurred, bringing considerable damage to the ecosystem of incident area, and could not recover within 10 years.

Since the present situation of the marine environment is very severe, all levels of government in China have already started the establishment of environmental protection laws and regulations for the shipping industry. From the aspect of shipping company, COSCO bloc express that it will positively observe and implement a series of basic principles and measures of "Green Industrial Revolution" advocated by the government in response to global climate change, reduce carbon emission in the shipping process, and devote itself to become a "green services" provider.

2.1.3 The obstructive factor of the low-carbon green development in China

For a long time, since national policy decision-making departments and business managers lacked a clear perception of shipping green low-carbon development concept, the awareness of marine environmental protection and ecological environment improvement were dim. There was no overall development sense of green shipping, and the influence of many factors seriously restrict the development of green low carbon shipping industry in China.

(1) Vague concept of low-carbon green shipping

Since the Chinese economic reform, the development of shipping industry in China has been rapid; it greatly promotes the healthy development of the national economy. But the familiar degree of ocean is still insufficient, and the impact of ship emissions on the ocean environment and atmospheric environment during the shipping process were ignored in a fairly long period. The country chose the old path of treatment after the development. Our country began to pay attention to the development of low carbon green shipping industry in recent years, and some developed countries have formulated relevant laws and regulations to reduce marine shipping emissions of greenhouse gases. However, with the acceleration of global climate change and the deepened degree of marine pollution, the scholars in our country begin to change idea and pay attention to the low carbon green development of shipping industry.

(2) Lack of relevant law and regulations

Since the 1990s of the 20th century, although China has legislated many related policies and laws for the control of environmental pollution, these policies and laws rarely involve low carbon green development for the shipping industry, such as the aspects of the responsibility distinction of reducing emissions between the owner and the Charter Party and so on. In the matter of function structure, each process included in shipping has been supervised under the corresponding functional departments. But multi joint management actually more likely to cause confusion of shipping industry development; this is not conducive to the healthy and harmonious development of the shipping industry. Meanwhile each level of government in China only takes into account the interests of their own area when the overall development planning of the shipping industry is formulated, and simply considers the short-term interests, which resulted in the negligence of the long-term development benefit and sustainable development of shipping industry, and it is the main reason that shipping industry in China did not have a harmonious orderly development.

(3) The lower level of shipping technology

The development of low-carbon green shipping industry is closely related to the application of low-carbon green technology. the general trend of the global development is the transition from "high carbon economy" to the "low carbon economy", the design, development and manufacture "green ship" which have high safety standards, low exhaust emissions, few environmental pollution even no pollution is currently a major trend. But at present the research ability and application range of shipping technology in China are far lower than the specific

requirements of low carbon green shipping, such as the energy utilization efficiency of shipping in China and the degree of intelligentization, automatization and informatization of shipping activities are all low, the use conditions of environmentally friendly materials, coating materials and fuel do not meet the requirements of recycling and degradation advocated by low carbon green shipping and so on.

(4) The delayed development of the shipping industry

As a large shipping country in the world, China has a wide gap with the development of shipping powerful nation, and its comprehensive competitiveness of the shipping industry is weak. The main performance is the modernization degree of shipping infrastructure in China which is relatively low, and management and operations ideas of shipping companies are still outdated. The basis of the development of shipping industry is the construction and improvement of a series of basic facilities, including route, information, shipping terminal, warehousing logistics, etc. This is a gradual long-term process. Besides, the scale benefit exist in the shipping industry that the ship enlargement and the sharing shipping terminal can entirely improve the scale merit, and can improve the operation benefit of the shipping enterprise.

(5) Lack of professional management personnel in the shipping industry

China should also continue to increase investment in shipping talent training. Multi-level, diversification shipping education system is the decisive factor to ensure the shipping industry to form a reasonable talent structure and to improve the shipping management level.

Developing green low carbon shipping industry has become the trend of China's social economic development, and also conforms to the needs of the development of the times. It organically united the overall coordinated development of shipping industry and ecological environment protection, realized harmony and coordinated development of shipping activities and ecological environment.

2.2 The impact of the development of the shipping industry and the ecological environment

2.2.1 The impact of the shipping industry on the ecological environment

During shipping, ship sailing will inevitably produce some operating pollutants, including: domestic sewage, solid waste, chemical material emission, ballast water pollution and harmful microorganisms, toxic liquid, etc. These pollutants will cause varying degrees of destruction of atmospheric and oceanic environments. The pollution of the shipping industry can be divided into the following categories:

(1) Waste gas pollution

During the ocean transport processes, ships discharge a large amount of waste

gas, causing pollution of the atmosphere and ocean environment, these harmful gases mainly include: carbon dioxide, sulfur dioxide, nitrogen oxides and particulate soot etc. In recent years, the shipbuilding technology is constantly improving, so that large ship oil engine also can use low quality fuel oil, and many shipping companies commonly choose low quality fuel oil to reduce ship operating costs and increase economic efficiency. These low quality fuels can not be fully burned, and with higher sulfur content, will discharge large amounts of sulfur dioxide, nitrogen oxides and harmful smoke, leading to acidification of the marine environment and pollution of atmospheric environment.

(2) Oil pollution

Oil pollution caused by sailing ship mainly includes: First, oil discharge from normal operation, including tankers ballast water, tank washings, sewage from organic cabin etc. Second, oil spill caused by all kinds of accidents, including oil spills from oil bunker and oil cargo tank, oil spill caused by connection pipeline broken or misoperation during the period of oil tanker handling process or the installation of fuel. Pollution caused by the tanker leaks is most serious among these accidents, resulting in huge economic losses, and at the same time causing serious damage to the marine environment.

(3) Other toxic liquid pollution

Such contamination may occur in liquid chemical transport ships, including discharg from the ship ballast water and water washings, bilge water accumulated in the engine sink when handling machinery with poisonous liquid is installed in it, liquid cargo emergency discharged at the situation of clearing the ship leaking liquid sawdust, rags and other materials, occurring collision fire disaster and so on.

(4) Hazardous substances pollution in marine packaging

Such contamination may occur in ships transporting hazardous material container when the packing breakage, leakage, overflow shining at the bottom of the ship deck and cabin. Washing solution and washing water used to clean up toxic substances will cause marine pollution.

(5) Sewage pollution

Such pollution includes the ship toilet discharge, other waste, bath water discharged from medical room (pharmacy, ward), the discharge from ship loading living animals, and other waste water etc.

2.2.2 The impact of the ecological environment on the development of the shipping industry

The global shipping activities have caused huge destruction to the atmospheric environment and the marine environment and bad influence on the entire ecosystem environment that is difficult to restore. This leads to large changes in the global ecological environment, but changes in the global ecological system

under the influence of human will react to the shipping activity of human beings, and then engender an adverse effect on the overall harmonious development of shipping industry.

According to the current situation, the greenhouse effect caused by the greenhouse gas emission from shipping industry is the main factor that affects the human shipping activity. Because of the influence of global warming affecting the atmosphere environment and the marine environment, the severe weather has obviously increased and the situation of seawater acidification is serious, which has greatly affected the navigation safety of the shipping.

2.2.3 Symbiotic relationship between shipping industry and ecological environment

In most of the writings of modern biology, biological scholars accepted the Debary interpretation of "symbiosis is living together, is biotrophic of mutual contact together, or from the general sense said, symbiosis refers to the symbiosis between unit in a symbiotic environment according to a certain mode form the relationship between certain, it implies that the organism to some degree of permanent physical contact." In this concept, there are three symbiotic elements: symbiosis unit, symbiosis mode and symbiotic environment, and there is an interreaction relationship between these three elements(Zhang, 2004, p.5).

Broadly speaking, the relationship between shipping industry and ecological environment is symbiotic relationship. Shipping system and ecological environment system are two symbiotic units; the way of mutual effect is the symbiotic model. The external environments (such as economic, trade situation and technical conditions, etc) are symbiotic environment which influence their symbiosis relationship(Chen, 2006, p.12). The symbiotic relationship between shipping industry and ecological environment is created and developed in the symbiotic environment, and it is achieved through the function of a series of symbiotic environment variables, such as domestic and foreign total economy situation, technical conditions and related policy measures, etc. In symbiosis theory, symbiotic mode also known to be a symbiotic relationship, refers to the interaction or the combination form between the symbiosis unit, it reflects the way and the strength of the effect between the symbiosis unit, and also reflects material and energy exchange relationship and information exchange relationship between them. The development of shipping industry is inseparable from the support of ecological environment, and also has a certain influence on the ecological environment; on the contrary, the change of ecological environment will promote or hinder the development of shipping industry. The symbiotic mode is not fixed, and it changes with the changes of symbiotic unit characters and the changes of symbiotic environment. It is worth noting that the development of shipping industry and ecological environment is not a relation of replacement. If the development of shipping industry and ecological environment can have both benefits, joint evolution and coordinate development, it will be able to produce great symbiosis energy to mutually promote development. Based on symbiotic relationship between them, the shipping industry development and ecological environment are interdependent and mutually symbiotic, there are inseparable and closely linked, so that the development of low carbon green

shipping industry is very necessary.

2.3 Summary

This chapter analyzes and reviews the development status of domestic and foreign low carbon green shipping industry, sums up the important factors which hinder low carbon green development of China's shipping industry. At the same time, the paper analyzes the interaction between the development of shipping industry and ecological environment, expounds the symbiosis relationship between them.

Part 3
The research on the inner mechanism of low-carbon green development in shipping industry

3.1 Overview of basic green economics theory

3.1.1 Resource scarcity theory

During the period of civilization development, there are three major issues waiting to be solved: resources shortage, ecological deficit, the loss of resource relative advantage. In view of the above three questions, the solution is the limited development, the paid use and the knowledge substitution theory.

The first is limited development. From the perspective of space-time, the total resources on the earth can be used by human quantity is limited; resource regeneration needs a long period. At the same time, the nature digestion ability of waste and the technological capabilities in a certain period are also limited; it is difficult to thoroughly digest the waste. So to a great extent, humans can only develop resources in accordance with the reality technology capability and waste digestion ability. To avoid the collapse of society, humans can only make full use of renewable resources of the earth to ensure earth resources sustained output. Limited development should avoid pollution to ensure the sustainable development of social economy.

The second is paid use. The analysis shows that mankind has entered the era of ecological deficit and economic prosperity depends on the huge ecological deficit to sustain; mankind has not calculated ecological cost in the corresponding accounting system. There are no price signals regulating people's behavior, and the use of resources in the Free State in a large extent. This will inevitably worsen the ecological deficit. Since the ecological deficit is not accounted, the environment resources are in priceless state, people will exchange for the immediate economic interests at the expense of the environment cost. People must confront the problem of ecological deficit, reevaluate the value of environmental resources, and put the ecological deficit into the global accounts system.

The third is knowledge substitution. The development of knowledge economy provides the key methods and ways to solve the problem of human resource scarcity, and a new kind of capital is playing a more and more important role. The full play of the function of knowledge capital will make up for the disappearance of the relative advantage of resources to a certain extent. Humans will gradually exert center advantage of knowledge capital in human resources, from production mode of natural resources as the center in the past shift to production mode of human resources as the center in green economy times, fundamentally change the production mode based on material capital. Although resources are limited, technological advances are unlimited. Relying on science and technology can not only find new sources of energy but also can better use resources under the existing conditions, eliminating the pollution in the

process of production and consumption, and forming cycle production mode coordinated with ecological system(Zhang, 2005, p.23).

3.1.2 Basic theory of ecological capital

As a basic capital, ecological capital has obvious public product characteristics, and can hardly be replaced in general. The loss of the ecological capital will lead to the loss of the overall basis of other capital, and thus lose the development space. The viewpoint of green economics shows that: if economic development wants to achieve the goal of sustainable development, it must adopt the scientific, effective and orderly systematic method, and pay more attention to the basic of ecological capital.

All economic activities of the mankind must follow the balance of the ecosystem, and they must follow the regeneration law of the ecological resources; otherwise the development will fall into stagnation or even backward. This requires that the basic core of the economic, political, scientific and technological, cultural and other social activities of the human society is firstly taking into account the ecological capital. When the market principle, the scientific and technological principle, the policy system principle collide with the basic position of the ecological capital, the priority of ecological capital should be subordinated. Liu Sihua, an eco-economist in China, emphasizes the principle of "ecological rationality priority", that is, the ecological and rational of human economic activity gives priority to the rationality of economy and technology. In many cases, human activities are always for the short-term behavior and pursuit for short-term interests, and ecological capital bring long-term interests for human, and the long-term interests is the premise of sustainable development of human society. So it is necessary to use the basic position of ecological capital to regulate all economic activities of mankind, turn the whole human society to the direction of green(Dai, 1998, p.32).

3.1.3 External theory

In the traditional economics theory, externality problem is one of the performances of market failures. When an economic activity of a behavioral agent will benefit the other members of the society, but he himself does not obtain compensation thereby, which means personal income of behavioral agent obtained in this activity is less than the social benefits brought by the activity, and thus the external economy is produced, namely external positive effect. In contrast, when an economic activity of a behavioral agent makes other members of the society pay the price, but he has not given the corresponding compensation, then private costs of behavioral agent paid for this activity is less than social cost created by this activity to society, thus the external diseconomy is produced, namely the external negative effects. The problem of ecological environment is a typical external diseconomy. When the external diseconomy appears, because the commonality of ecological capital and the property rights of the ecological capital cannot clearly define and ignore the value of ecological capital, ecological capital will inevitably be infringed.

3.2 The inner mechanism of the low-carbon green shipping system

3.2.1 The connotation of low-carbon green shipping

The connotation of green shipping receives attention to pursue the close link between economic interests and the protection of the ecological environment in business(Feng, 2011, p.52). These two parts are combined and coordinated in the process of business, to achieve coordinated and sustainable development of shipping industry, and further lay stress on the principle of mutual coordination between navigation benefit and ecological environment. They should not take the old road of "treatment after pollution", but do not deprive development space of posterity because of the short-term economic interests of contemporary people. Shipping management system of environmental symbiosis is built up from the view of environment and sustainable development, and its essence is green development model of shipping industry combined with the connotation of sustainable development and environmental protection. The main research on the green shipping theory includes the ship economic speed, the low carbon operating strategy, the shipbuilding system turn to the environment friendly and so on. Green shipping does not only requires a proper slow ship sailing speed, but further more emphasizes the cooperation with advanced supply chain system. For example, if a container ship arrives at port terminals ten hours later compared to original plan, at this time if the unloading or transshipment flight is timely, it can ensure economic benefit not to be affected, and it also can save the pierage created by ship docked at the pier, this measure can both achieve low carbon green goals and reach the target of reducing the economic cost. At the time of paying attention to shipping and environmental problems, the problem of shipping and resource consumption cannot be ignored. Also the research on problems of shipping and social development cannot be ignored. Current research on this problem most aim at the analysis of resources and environment as an exogenous variable, to explore relevant measures and methods to ease contradictions between shipping and environmental, but not analyze and research the resources, environment, shipping and the development of the economy as a whole system. The concept of the green shipping, starting from the point of sustainable development, considers the modern shipping industry as a circular logistics system. It is an integrated system composed of the forward logistics and reverse logistics, and the analysis and research for the modern shipping should consider shipping, economy, resources and environment factors, and carry out in-depth analysis and research aim at the operation mechanism, development strategy and mode of modern shipping system on this basis. The connotation of developing low carbon green shipping industry has been updated and improved with the continuous improvement of social values and science technology, the formation of low carbon green shipping system is a step-by-step process of system development and function improvement.

3.2.2 Basic theory research on the development of low-carbon green shipping industry

(1) The guiding role of green economics theory to the development of low-carbon green shipping

The basic theory of green economics has great guidance for the development of

low-carbon green shipping industry. In the shipping industry, the development of shipbuilding industry needs to consume a large amount of natural resources; and these natural resources are often limited and nonrenewable. When the consumption of resources more than the "natural interest" of resources, a series of ecological environment problems will inevitably appear. The development of low-carbon green shipping industry should follow the principles such as the limited exploitation of resources, paid use and knowledge substitution suggested by green economics. At the same time, when the development of the shipping industry is contradicting the fundamental position of the ecological environment, the priority of ecological environment capital should be obeyed.

The main cause of the destruction of the ecological environment caused by the development of shipping industry is not regarded ecosystem as a type of capital and has not given the reasonable value which causes the external economy. People usually pursue economic efficiency such as speed, rate of profit, added value in shipping process and mainly follow economic rules, but ignore the ecological rules in this process. So the consequences are ultimately bad ecological environment. Green economics propose to consider the ecological environment as the elements of human life and production, value ecosystem and capitalize ecological value. As long as the pricing of ecological capital is reasonable, employees in shipping industry will be initiative to take sustainable development action of protecting the ecological environment and saving resources under the control of the cost-benefit principle. This has a great guide for the establishment of low-carbon green shipping system.

(2) The guiding role of low-carbon development theory for the development of low-carbon green shipping industry

In order to deal with the global climate change, the pollution of the ecological environment, the shortage of energy resources, etc., the UK actively promotes the global low-carbon economy(Wu, 2009, p.7). In 2003, the British government first published the energy white paper entitled "our energy future: creating a low carbon economy", the white paper first proposed the concept of "low carbon economy", so this concept began to get extensive attention all over the world. China, as a developing country, has a low level of per capita income, so the pressing matter of the moment is to maintain stable and rapid economic growth, "low carbon development" conforms to the requirement of economic development and carbon emission reduction in China. According to the experience statistical analysis of 45 years of data from 1960 to 2004 in 38 countries, the obtained figure shows that the correlations between carbon emissions and total economic growth present an inverted U-shaped curve, namely the rapid growth of economic development will inevitably lead to higher levels of carbon total quantity emissions, when the speed of economic growth is slowing down or stopping, the carbon emissions will gradually decline(Edwards, 2011, p.483). The turning point of the carbon emissions in developing countries, namely the turning point of carbon emissions from increasing to decreasing, is $23000 average annual per capital income, at present China's statistical data are still apart very far from this value. Therefore, the development of economy, anti-poverty and increasing the per capital income of nationals are still the top priority of China. The shipping industry plays a vital role in promoting the

economic development in China, so we need to keep the development of shipping industry, and make the shipping industry contribute to the economic development of our country(Zhang, 2009, p.28).

In order to cope with the deterioration of the ecological environment caused by global warming, we should implement the relevant specific measures to reduce the total emissions of greenhouse gases during the course of human activities. Current with the deepening of the severity level of issues such as the energy crisis, the ecological environment destruction, and global climate change and so on, the concept of green low carbon development has been paid more and more attention, and it is an effective measure to deal with the above related issues. The shipping industry occupies a large proportion in the energy consumption, so low carbon development application should be applied to the development of the shipping industry.

3.2.3 The overall objectives and basic principles of low-carbon green development of shipping

(1) Overall objectives

The overall objectives of the shipping industry low carbon green development are paying attention to the combination of economic benefits and ecological environment protection, emphasizing the coordinated role between shipping benefit and ecological environment and achieving sustainable development ability of the shipping industry, and making the shipping industry to meet the requirements of sustainable development in the process of modernization, actualizing mutual promotion and joint improvement of the shipping economic benefits, social benefit and ecological environment benefit.

(2) Basic principles

The low-carbon development of shipping industry should follow the principle of sustainable development and low-carbon development.

The sustainable development is based on the sustainable utilization of resources and good ecological environment, so it must follow the basic principles of ecology and embody the systematicness and coordination. Also it is necessary to maintain the harmony between economic, social development and ecological environment protection, and follow the economic law and ecological law.

At present, the development of shipping industry in China has the characteristics of high energy consumption, so it has great potential in energy saving and emission reduction. Shipping industry must adhere to the principle of low-carbon development, energy saving and emission reduction, so that the growth of economic performance as the shipping profit can unhook connection with the growth of carbon emissions.

3.3 Economic value analysis of low-carbon green development in shipping industry

(1) The low-carbon green development of shipping industry can increase the core competitiveness of shipping enterprises

According to the contents of the articles published by Nazli.Choucr, a professor of Harvard University, the competition of global economic market is very intense now(Nazli.Choucr, 2011, p.3). If the enterprise wants to obtain the effective development and maintain sustainable development, it must transform thought and began to pay attention to ecological environmental, otherwise the enterprise will face increasingly severe of additional cost pressures caused by ecological environment. The reason is that governments and environmental organizations claim the requirements of low carbon and emission reduction for the current industrial development to encourage enterprises to reduce energy and resource materials consumption, and effectively reduce the relevant operation cost, thus enhancing the competitiveness of enterprises. Good ecological environment will greatly promote the development of enterprises. The core of shipping industry low carbon green development is achieving mutual coordination development of shipping enterprise production activities and social benefits and ecological benefits, in order to obtain better development trend in the fierce competition.

(2) The low-carbon green development of shipping industry can improve the brand value of shipping enterprise

Brand value is an important sign of brand to pick out from other competing brands; it is determined by factors such as the market share rate of products, profitability of brand, the development potential of brand, etc. The low-carbon green development of shipping industry requires shipping companies to consider the ecological environment from the design and manufacturing of ship, the entire procedures of transport operation, to the relevant management methods. Establishing a perfect low-carbon green shipping industry can not only reduce energy consumption and emissions, but also raise the image of shipping enterprise, which is helpful for shipping enterprise to increase market share, raise brand value of shipping enterprises, especially when shipping market has not yet been restored.

(3) The low-carbon green development of shipping industry can get rid of the green trade barriers

Along with the increasing economic globalization, the role of the traditional trade barriers in the international environment is gradually diluted, and replaced by the emerging green barriers. China formally entered WTO in 2001, foreign shipping enterprises gradually enter the domestic market, and bring huge challenge to domestic shipping enterprises, and the competition of shipping industry is more intensified. Only by speeding up the development of low carbon green shipping industry, it can get rid of the green trade barriers of all countries, and achieves more competitiveness, thus domestic shipping companies will occupy the more market share in the international market and produce more profit.

3.4 Summary

This chapter first discusses the connotation of the shipping industry low carbon green development, followed by the introduction of the green economics basic theory and the analysis of the intrinsic mechanism of low carbon green shipping industry, and provides a theoretical basis for the shipping industry low carbon green development, finally has analyzed economic value brought by the green low-carbon development of shipping industry.

Part 4
The evaluation index system construction and evaluation methods research of low-carbon green development in shipping industry

4.1 The research theory of evaluation index system for low-carbon green development of shipping industry

4.1.1 Theoretical introduction to the DPSIR model

DPSIR is the model of drivingforces — pressure — state — impact — response proposed by the European Environment Agency and EU statistics bureau, this index framework has been widely adopted in the field of environmental protection and sustainable development related issues in the world(Hanne Svarstada etc. 2008, p.117).

(1) The drivingforces are the potential cause of the environmental change, mainly refers to the operating activities of shipping production and the development trend of shipping industry in this paper.

(2) The pressure is the influence of shipping activity on the surrounding environment and natural resources, is the immediate pressure factor on ecological environment, mainly showing as the degree of environmental destruction and resource consumption.

(3) The state is the dynamic changes of ecological environment under the pressure and the changes on function of low carbon green development, mainly showing as the pollution level of ecological environment, such as water pollution, deterioration of air quality, noise pollution and other.

(4) The impact is the impact of the ecological environment on social and economic, including four indexes: socio-economic, environmental risks, ecological environment, and social evaluation.

(5) The response is the adopted countermeasure and constituted active policy in the process of low-carbon green development of shipping industry.

Overall, the DPSIR model is a framework based on causality organization information and related index, the inner has causal connection, as shown in Figure 4.1. Apart from the rough interactions between the situation of social economy and ecological environment, it also shows that the ecological environment has some response to the economic and social; these responses include the environmental goals and measures adopted by social to cope with malignant change and adverse effects of the environment(David&Rudolf, 2008, p.93).

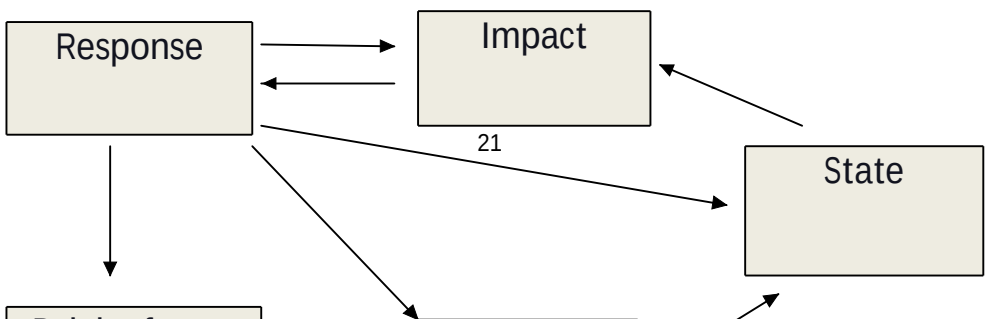

Fig.4.1 causal connection of DPSIR model
Source: David Niemeijer, Rudolf S de Groot. (2008). Frameing environmental indicators: moving from causal chains to causal networks. *Environ Dev Sustain* .

Generally, the selection of indexes is usually the selection of the state index of core object. Selecting the core object state will be impacted by some other factors. If we neglect the influence of these factors and only consider the concerned core object, the prediction accuracy of concerned core object state will decrease(Talley, 1994, p.343).

The DPSIR model addresses this problem. The biggest advantage of this model is containing a causal relationship of "what has happened (state index and impact index), why (pressure index, drivingforce index), how to deal with (response index)", it usually not only pay attention to the "what happened" but also extend thought to seek "why" and "how to deal with"; and it includes not only the state of the concerned core object, but also the factors which may make the state index unfavorable change become favorable change(He, 2008, p.21).

The prominent advantage of the DPSIR model is that it provides a state index as the core, rather than rigidly fix the category of certain index (which is pressure or response). This model will think fully and the causes of problem and coping strategies are integrated into the chain of index system, which can avoid the omission of important information.

4.1.2 Construction principles of shipping low-carbon green development index system
The construction of low-carbon green development evaluation index system of shipping industry in China should adhere to the following principles:

(1) The principle of scientificalness

The index system construction of low carbon green development of shipping industry in China based on the scientificalness and rationality of theory and method; evaluation index and method are the key content of low carbon green development index system of shipping industry. Therefore, during the process of determining the indexes the concept must be clear, scientific connotation should be decisive, statistical and computing method are normative and the methods of measure is standardized.

(2) The principle of pertinence

In the evaluation index system, the construction of indexes should be should be targeted. Selected index should fully reflect the connotation and specific requirements of shipping industry low carbon green development, the information contained in the selected index should be able to objectively reflect the development and change of the system, which is conducive to the adjustment and control of development strategy and specific planning.

(3) The principle of operability

The selected index should combine with the specific situation of the shipping industry; we should strictly select the key and representative index as well as consider the availability of data from the reality. In addition, the connotation of the evaluation index should be clear, the proportion of the subjective index and objective index should be careful, and the factors that affect the operability of the evaluation index system are reduced.

4.1.3 The construction step of low-carbon green development index system for the shipping industry

(1) Theoretical analysis and research

The construction of low carbon green development index system of shipping industry is the refinement of related research in the field, which is the inheritance and development of previous studies; through the study and research of the relevant literature, it will provide a theoretical basis for the construction of the index system.

(2) Identification of shipping environmental problem

The development of shipping industry has a significant impact on the society, environment, ecology and resources. Aiming at these impacts, the identification of these problems caused by the development of the shipping industry provide the basis for the construction of the index system.

(3) Establishment of index system

The research of the relative theory and the identification of the shipping environmental problems provide the theoretical basis for the construction of the index system. The index system establishment of low carbon green development which conforms to the characteristic of domestic shipping can refer to the related research on the index system and combine with the actual situation of the shipping industry, and consult the experts on screening indexes.

Figure 4.2 shows the basic step of establishing the index system of low-carbon green shipping industry in China:

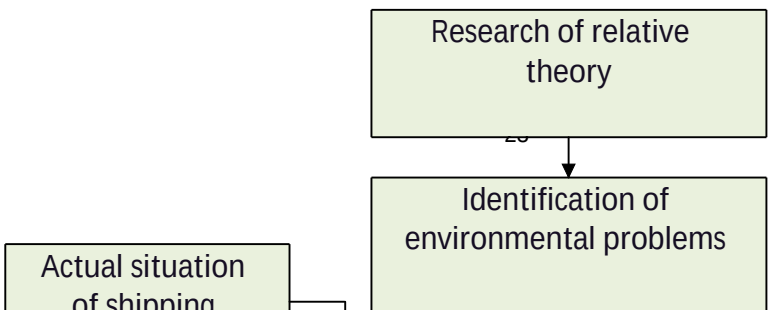

Figure.4.2 the step of establishing the index system
Source: Completed by the author.

4.2 The construction of the low-carbon green development evaluation index system based on the DPSIR model for shipping industry

Through the study on the relevant theory and the reference from existing system, the following index system is determined according to the actual situation of shipping industry in China. This index system includes 22 indexes, as shown in table.4.1.

Table.4.1 Low-carbon green development evaluation index system

Low-carbon green development evaluation index system of shipping industry in China	drivingforces	Per capita GDP
		Per capita GDP growth rate
		Transport turnover of ship cargo
		The unit energy consumption of the ship
	pressure	The energy efficiency operational indicator of ship
		Nitrogen oxide emission index
		Sulfide emission index
		Unit fuel consumption quota
	state	Carbon emission intensity
		Nitrogen oxide emission intensity
		Sulfide emission intensity
		Air quality
		Biodiversity
	impact	GDP contribution rate of shipping industry
		Benefit of environmental investment
		Customer satisfaction of shipping enterprise
		Public satisfaction to the environment
	response	The unilization ratio of marine clean fuel
		The setting of the low carbon emissions institution
		Implementation of low-carbon emission policy
		Adjustment of transport organization structure
		The input ratio of low carbon emissions funds

Source: Completed by the author.

1. Drivingforce index

(1) Per capita gross domestic product (GDP, RMB / person): per capita GDP is generally used as macroeconomic index to measure the state of economic development, per capita GDP=GDP / total population.

(2) Per capita GDP growth rate: (this year per capita GDP—last year per capita GDP) * 100%/ last year per capita GDP.

(3) Transport turnover of ship cargo: the index is one of the important indexes for the shipping department to draw up plans and examine economic, specifically refers to the product of cargo tonnage and transportation distance actually transported by shipping department in a certain period of time, using ton miles as unit.

(4) The unit energy consumption of the ship: it refers to the amount of fuel consumed by the unit turnover in the course of the ship transportation. This index is an important index of the economic benefit of energy utilization of the shipping enterprise.

2. Pressure index

(5) The energy efficiency operational indicator of ship: this indicator is used to measure the carbon dioxide emissions during the voyage. According to the "voluntary application of the energy efficiency operation indicator (EEOI)" proposed by IMO in the fifty-ninth marine environment protection committee, the calculation method of this indicator is as follows(IMO, 2005):

$$EEOI=\frac{\sum_i FC_i \times CF_i}{m_{cargo} \times D} \tag{4.1}$$

i: fuel type;

FC_i: the amount of ship fuel consumption, the total amount of fuel consumed by the marine main engine, auxiliary engine, boiler and incinerator during in port and navigation. Unit: t;

CF_i: CO_2 emission factor, refers to CO_2 quality discharged by per 1 tons of i fuel. Unit: t (CO_2) /t (fuel);

D: navigation mileage, refers to the actual voyage distance of ship in the transportation, the mileage does not refer to the shortest distance or the distance plotted on the chart from A to B, but usually refers to the real voyage distance recorded in the log. Unit: nm;

m_{cargo}: cargo dead weight, EEOI can be used in all cargo transport ships, the type of cargo are varied, so the measurement units are different.

(6) Nitrogen oxide emission index: this index is used to assess the total nitrogen oxide emissions during the voyage of a ship(Japanese ship machinery society, 2008, p.5). The formula is:

$$index_{NO_x}=\frac{N}{\sum_i m_{cargo} \times D_i} \tag{4.2}$$

N: nitrogen oxide emissions (t/year)

D: navigation mileage, refers to the actual voyage distance of ship in the transportation, the mileage does not refer to the shortest distance or the distance plotted on the chart from A to B, but usually refers to the real voyage distance recorded in the log. Unit: nm;

m_{cargo}: cargo dead weight, EEOI can be used in all cargo transport ships, the type of cargo are varied, so the measurement units are different.

(7) Sulfide emission index: this index is used to investigate the sulfide emissions during the operation of a ship, and the calculation method is:

$$index_{SO_x} = \frac{S}{\sum_i m_{cargo} \times D_i} \tag{4.3}$$

S: sulfide emissions (t/year)

D: navigation mileage, refers to the actual voyage distance of ship in the transportation, the mileage does not refer to the shortest distance or the distance plotted on the chart from A to B, but usually refers to the real voyage distance recorded in the log. Unit: nm;

m_{cargo}: cargo dead weight, EEOI can be used in all cargo transport ships, the type of cargo are varied, so the measurement units are different.

(8) Unit fuel consumption quota: table 4.1 gives all kinds of ship unit fuel consumption quota.

Table.4.2 All kinds of ship unit fuel consumption quota

Ship type	Rated load X	Unit fuel consumption quota (kg/kton横 n)		
		In 2010	In 2012	In 2020
Container ship X (TEU)	X≤500	31.04	30.11	27.31
	X＞500	30.07	29.17	26.46
	X≤1000	19.40	18.82	16.67
	1000＜X≤3000	16.01	15.52	14.09
	3000＜X≤10000	13.29	12.89	11.70
Dry bulk carrier X (ton)	10000＜X≤30000	9.22	8.94	8.11
	30000＜X≤60000	5.43	5.27	4.78
	60000＜X≤80000	2.43	2.35	2.14
	X＞80000	2.13	2.07	1.87
	X≤3000	16.01	15.52	14.10
Break-bulk cargo ship X (ton)	3000＜X≤10000	13.29	12.89	11.70
	X＞10000	11.64	11.29	10.24
Liquid bulk carrier		8.73	8.47	7.68
Ro-ro ship		49.47	47.99	43.53

Source: IMO, 2005.

3. State index

(9) Carbon emission intensity: the index generally refers to the CO_2 emissions /GDP value.

(10) Nitrogen oxide emission intensity: the index generally refers to NO_x emissions /GDP value.

(11) Sulfide emission intensity: this index generally refers to SO_x emissions /GDP value.

(12) Air quality: refers to the number of days or year which air quality better than or equal to grade 2. The reference standards in the “Index of ecological city construction" of the national Environmental Protection Administration are ≥280, this paper use this value as the reference standards.

(13) Biodiversity: the index is qualitative index. The biodiversity mainly includes the species diversity of animals, plants, microorganisms, etc, the diversity of the genetic and variation of the species and the diversity of the ecosystem.

4. Impact index

(14) GDP contribution rate of shipping industry: this index is qualitative index. The rapid development of the national economy is the basis of the growth level of shipping industry, it provides protection for social development, environmental governance, improvement of resource utilization rate; conversely the development of shipping industry will promote the development of regional economy.

(15) Benefit of environmental investment: this index is qualitative index. The direct and indirect benefits of the investment brought by the investment of the environment protection should be considered in the assessment of shipping industry.

(16) Customer satisfaction of shipping enterprise: investigating the major clients of shipping enterprises and inspecting the quality of service and so on, the index refers to the proportion of basically satisfied clients of shipping industry to the total survey population. This paper consults the reference standards of public satisfaction to the environment, and takes >90 as the standard value.

(17) Public satisfaction to the environment: the degree of public satisfaction to the work of environment protection and the quality of the environment. At present, this paper consults the reference standards of public environmental satisfaction rate in the "Index of ecological city construction" of the national Environmental Protection Administration, and takes >90 as the standard value.

5. Response index

(18) The unilization ratio of marine clean fuel: the ratio of the amount of marine clean fuel consumption to the total amount of fuel consumed in the whole shipping.

(19) The setting of the low carbon emissions institution: this index mainly assesses the setting of the carbon emission organization and the integrity of its function in the shipping enterprise.

(20) Implementation of low-carbon emission policy: the index mainly assesses the implementation situation of carbon emissions policy.

(21) Adjustment of transport organization structure: this index is used for the assessment of the transportation degree by ways of modern transportation organization.

(22) The input ratio of low carbon emissions funds: this index assesses the funds input situation of each ship on the aspect of the carbon emissions, which is the ratio of low-carbon emissions total operating costs to the total investment.

The 22 indexes constitute low carbon green development index system of China's shipping industry and the indexes of carbon emissions intensity, the unilization ratio of marine clean fuel, the setting of the low carbon emissions institution and Implementation of low-carbon emission policy are set up in accordance with the requirements of shipping industry low carbon green development, and it make the low carbon green development index system more scientific and comprehensive.

There is close correlation among these indexes in DPISR model: per capita GDP and its growth rate, ship deadweight tonnage growth rate and the shipping industry competitiveness level belongs to the socioeconomic index, which is the root cause leading to the deterioration of the ecological environment. Human activities usually focus on the pursuit of economic interests, while ignoring the adverse impact and tremendous pressure of ecological environment caused by shipping activities. The concrete performance is the destruction of the natural environment caused by the discharge of waste water, solid waste, the emission of greenhouse gas, the excessive consumption of energy.

When the shipping industry has a serious impact on the quality of the marine environment and the air quality, the customer satisfaction degree of the shipping enterprise and will the public satisfaction of environment also be influenced. The impact of biodiversity destruction on the ecological environment is also direct, and the deterioration of the ecological environment will be counterproductive to the shipping activities. The increase of the extra operating cost due to environmental protection pressure will also make the customer satisfaction of shipping industry decline.

4.3 Research on the evaluation methods of low-carbon green development of shipping industry based on AHP

4.3.1 AHP theory

At present, analytic hierarchy process is widely used in determining the weight of evaluation index. The hierarchy analysis method assumes there is a progressive structure between hierarchies. Firstly, a complex problem is decomposed into several levels according to the cause and effect, forming a hierarchical structure; then establish judgment matrix from the lowest level by

pairwise comparison, using the mathematics method to calculate the biggest characteristic value and the corresponding orthogonal eigenvector. The weight of each factor is obtained, and its consistency is tested. In the end, the combination weight of each layer is calculated, and the weight value can be sorted and evaluated.

The concrete steps of the application of analytic hierarchy process are as follows:

(1) Construct the hierarchical structure of the index system

In this paper, the hierarchical structure of the evaluation index system of low carbon green development based on DPSIR model is divided into three hierarchies. The first hierarchy is the target hierarchy, which is also the highest one. There is only one element on this hierarchy, that is, the low carbon green development level of China's shipping industry. The second hierarchy is the criterion layer, which refers to the intermediate links in order to achieve the ultimate goal, including five elements, namely, the driving dynamic index, pressure index, cerebral state index, impact index and response index; The third hierarchy is the index layer, also known as the project hierarchy or the operating hierarchy, which includes various alternative measures and the decision schemes in order to achieve the goal.

(2) Establish a judgment matrix

This is a key step in the AHP analytic hierarchy process. After constructing the hierarchical structure of index system, according to the requirements of corresponding standards on the upper level index, make pairwise comparisons of the degree of importance on the next level. Express with specified scale value, write in a matrix form and the judgment matrix is established.

Assuming that a layer has n factors and $X=\{x_1, x_2,..., x_n\}$, compare their effects on a certain criterion of the upper level, and determine the proportion of the layer. Use a_{ij} to express the comparison results between the i factor and the j factor. Judgment matrix is:

$$A=(a_{ij})_{n\times n}=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

The element a_{ij} in above judgment matrix is usually estimated by the experts according to years of academic research and work experience. But it needs a quantitative scale. A comparison between pairwise factors scales is shown in table 4.3.

Table. 4.3 Scaling list

Scale	Meaning
1	The factor i has the same influence with factor j.

3	The influence of factor i is slightly larger than that of factor j.
5	The factor i has a larger influence than factor j.
7	The influence of factor i is larger than that of factor j.
9	The influence of factor i is absolutely larger than that of factor j.
2,4,6,8	The intermediate value of the adjacent judgment.

Source: Completed by the author.

(3) Determination of hierarchy weight value

① Normalize each column of the judgment matrix

$$\overline{a}_{ij} = a_{ij} / \sum_{i=1}^{n} a_{ij} \qquad \text{(i=1, 2, … , n)} \qquad (4.4)$$

② Normalize each column of the judgment matrix, and then draw a summation according to the line.

$$\overline{\omega}_i = \sum_{j=1}^{n} \overline{a}_{ij} \qquad \text{(i=1, 2, … , n)} \qquad (4.5)$$

③Standardize the vector $\overline{\omega} = (\overline{\omega}_1, \overline{\omega}_2, ..., \overline{\omega}_n)^T$

$$\omega_i = \overline{\omega}_i / \sum_{i=1}^{n} \overline{\omega}_i \qquad \text{(i=1, 2, … , n)} \qquad (4.6)$$

④ Calculate the maximum eigenvalue. The formula is as follows:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_I}{n w_i} = \frac{1}{n} \sum_{i=1}^{n} \frac{\sum_{j=1}^{n} a_{ij} w_j}{w_i} \qquad (4.7)$$

(4) Conformance testing

Determining whether the matrix is a consistent matrix can be tested by whether $\lambda_{\max}$ equals to n. The larger $\lambda_{\max}$ is than n, the less likely the matrix is a consistent matrix and the harder it is for the standardized feature vector reflects the degree of importance of each factor. Therefore, in order to guarantee the rationality of the evaluation, it is necessary to test the consistency of the judgment matrix, and the process is as follows:

Index of judging matrix consistency is CI:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \qquad (4.8)$$

CR is the consistency coefficient of the judgment matrix. Thereinto, $CR = \frac{CI}{RI}$.

RI is an average random consistency index, which is related to the matrix order n. RI value of n=1-9 can be seen in Tab.4.4.

Table.4.4 Average random consistency index R.I.

Dimensionality	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.92	1.12	1.24	1.32	1.41	1.45

Source: Completed by the author.

In the case of n when CR<0.1, the matrix has passed the consistency check. If not, the matrix should be corrected.

4.3.2 Weight assignment of evaluation index system

In this paper, the weights of each element of the index system are determined by Satie's scaling law. Experts and professors or senior engineers from the Environmental Protection Bureau, Ministry of Transport, Dalian Maritime University are invited to put forward the adjustment suggestion and determine the indexes weights. Due to the limited time of writing paper, expert survey is made by telephone interviews, and the contents of questionnaires are listed specifically listed in the appendix. We issued 20 copies of questionnaires, 16 of which are actually recovered, accounting for 80%. Take the average value of each score in the questionnaire, then get the judgment matrix, and then calculate the weight of all levels of indicators. The specific process is as follows:

(1) Establish a judgment matrix

Table 4.5 The judgment matrix of target layer

S	X_D	X_P	X_S	X_I	X_R
X_D	1	0.71	0.83	1.23	0.76
X_P	--	1	1.21	1.46	0.71
X_S	--	--	1	0.97	0.69
X_I	--	--	--	1	0.65
X_R	--	--	--	--	1

Source: Completed by the author.

Table 4.6 The judgment matrix of driving forces indicators

S_1	X_1	X_2	X_3	X_4
X_1	1	0.75	0.52	1.36
X_2	--	1	0.86	2.28
X_3	--	--	1	3.12

X_4	--	--	--	1

Source: Completed by the author.

Table 4.7 The judgment matrix of pressure indicators

S_2	X_5	X_6	X_7	X_8
X_5	1	1.47	0.63	2.85
X_6	--	1	0.38	2.01
X_7	--	--	1	3.67
X_8	--	--	--	1

Source: Completed by the author.

Table 4.8 The judgment matrix of state indicators

S_3	X_9	X_{10}	X_{11}	X_{12}	X_{13}
X_9	1	1.58	1.66	2.32	0.78
X_{10}	--	1	1	2.03	0.52
X_{11}	--	--	1	1.76	0.45
X_{12}	--	--	--	1	0.33
X_{13}	--	--	--	--	1

Source: Completed by the author.

Table 4.9 The judgment matrix of impact indicators

S_4	X_{14}	X_{15}	X_{16}	X_{17}
X_{14}	1	0.86	1.29	2.03
X_{15}	--	1	2.58	3.54
X_{16}	--	--	1	0.86
X_{17}	--	--	--	1

Source: Completed by the author.

Table 4.10 The judgment matrix of response indicators

S_5	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}
X_{18}	1	2.29	1.85	0.77	0.96
X_{19}	--	1	0.87	0.52	0.64
X_{20}	--	--	1	0.65	0.76
X_{21}	--	--	--	1	1.33
X_{22}	--	--	--	--	1

Source: Completed by the author.

(2) Calculate the maximum characteristic root of every judgment matrix and its corresponding eigenvector.

Take Matrix S of the target layer as an example. The largest eigenvalue λ_{max}=5.379 of the Matrix S can be calculated from Formula 4.4 to 4.7, the corresponding eigenvalue is:

$\omega_1 = (0.312,0.273,0.070,0.142,0.203)^T$

(3) Consistency check

$$CI = \frac{\lambda_{\max} - n}{n-1} = 0.95$$

From Tab.4.1, we can see RI=1.12, which is corresponding to n=5.

Thus, consistency index CR=CI/IR=0.085<0.1. Therefore, judging whether a matrix has an acceptable consistency, the eigenvalue matrix of matrix S of the target layer needs to be examined without any logical error.

(4) Similarly, according to the above methods, the influence of driving force, pressure, state, and influence and the matrix eigenvalue and eigenvector value can be obtained. The consistency should be tested.

Driving force index evaluation judgment matrix S1:

1=(0.183,0.304,0.271,0.242,) ^{T}, λ_{max} =5.007, its CR=0.00175<0.1

Pressure index evaluation judgment matrix S2:

2=(0.386,0.135,0.203,0.276,) ^{T}, λ_{max} =4.0712, its CR=0.0245<0.1

State index evaluation judgment matrix S3:

3=(0.219,0.175,0.173,0.220,0.213) ^{T}, λ_{max} =4.2387, its CR=0.0901<0.1

Influence index evaluation judgment matrix S4:

4=(0.272,0.312,0.144,0.272,) ^{T}, λ_{max} =5.0143, its CR=0.0100<0.1

Response index evaluation judgment matrix S5:

5=(0.253,0.176,0.290,0.258,0.023) ^{T}, λ_{max} =5.2013, its CR=0.0511<0.1

In summary, the weights of every indicator are shown in the following table:

Table.4.11 Evaluation index system of low-carbon green development of shipping industry

Evaluation index system of low-carbon green development of shipping industry	Driving force 0.312	GDP (XI) 0.057
		Per capital GDP growth rate(X2)0.095
		The revolving quantity of the goods of the ship (X3) 0.083
		Unit energy consumption of ships (X4) 0.076
	Pressure 0.273	Vessel operating efficiency index (X5) 0.105
		Nitric oxide emission index (X6) 0.037
		Sulfide emission index (X7) 0.056
		Unit fuel consumption quota (X8) 0.075
	State 0.070	Carbon emission intensity (X9) 0.015
		Nitric oxide emission intensity (X10) 0.012
		Sulfide emission intensity(X11) 0.012
		Quality of air environment (X12) 0.016
		Biodiversity (X13) 0.015
	Influence 0.142	Contribution of shipping industry to GDP (X14) 0.039
		Benefits of environmental protection investment (X15) 0.044
		Satisfaction of shipping enterprise customers (XI6) 0.020
		Public satisfaction with the environment (X17) 0.039
	Response 0.203	Clean fuel utilization rate of the ship (XI8) 0.051
		Set-up of low carbon agencies (XI9) 0.036
		The implementation of low carbon policy (X20) 0.059
		Structure adjustment of transport organizations (X21) 0.052
		Low carbon investment proportion (X22) 0.005

Source: Completed by the author.

4.3.3 Fuzzy comprehensive evaluation method theory

Fuzzy comprehensive evaluation method can well solve the problems that are usually difficult to be quantified, and it is usually applied to solve all kinds of uncertainty problems.

(1) Establish fuzzy sets

Establish the factor domain U of evaluation objects. $U=(U_1,U_2,\ldots,U_N)$, $U_i(i=1,2,\ldots,n)$ is the evaluation factor and n is the index of the layer.

Set up the evaluation set $V=(V_1,V_2,\ldots,V_m)$. The number of evaluation set m is usually between 5 and 9. If m is too large, it is not easy to judge the level of the evaluation object; if m is too small, it can't meet the requirements of fuzzy

comprehensive evaluation. In this paper, n=5. V1, V2, V3, V4, V5, separately stand for 5 different comments, namely, good, better, medium, worse and poor.

(2) Determine membership matrix

If X is the domain, the mapping is as follows:

$$u_A : X \to [0,1] \tag{4.10}$$

A is a fuzzy subset of domain X. u_A is the membership function of the fuzzy subset A, $\forall_x \in X$. $u_A(x)$ is the degree of membership of X to A. Calculate the degree of membership of index i to rating order j and generate the membership function R.

$$R = \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1m} \\ r_{21} & r_{22} & \ldots & r_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ r_{n1} & r_{n2} & \ldots & r_{nm} \end{bmatrix} \tag{4.11}$$

In the matrix, r_{ij} is the membership of U_i to V_j, which forms the foundation of fuzzy comprehensive evaluation. The calculation of membership degree is divided into qualitative and quantitative indexes, and the membership degree of qualitative index is determined by using expert scoring method.

(3) Determination of the weight vector of the evaluation factors

W is the membership of every factor in U to the evaluated subject. It is mainly decided by the degree of concentration. That is, in fuzzy comprehensive evaluation, what sequence of factors people pay attention to. Every factor in U has a different importance to the evaluated subject, therefore, the corresponding weight of every factor should be in a fuzzy way. There is a fuzzy subset in U,

$$W=(w_1,w_2,\ldots,w_n), \qquad \sum_{i=1}^{n} w_i = 1, \quad w>0(i=1,2,\ldots,n) \tag{4.12}$$

(4) Result vector of Synthetic fuzzy evaluation

Integrate W with the R of every evaluated subject in certain algorithm. Result vector of Synthetic fuzzy evaluation can be obtained. That is:

$$W \circ R = (w_1, w_2, ..., w_p) \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1m} \\ r_{21} & r_{22} & \ldots & r_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ r_{p1} & r_{p2} & \ldots & r_{pm} \end{bmatrix} = (b_1, b_2, ..., b_m) = B \tag{4.13}$$

b_1 is obtained by the j column operation between W and R. It represents the degree of membership of the evaluated subject to the fuzzy subset v_j in the whole perspective.

4.4 Summary

This chapter is the key part of this paper. Firstly, the paper introduces the DPSIR (driving force - pressure - state - Impact - response) model, and

synthesizes the related low carbon green theory and the development situation of China's shipping industry to build evaluation index system of low carbon green development in China's shipping industry, as well as explains the index reference standard, improves the index system under the guidance of experts, uses the AHP method to determine the weight of each index in the evaluation index system. Secondly, the paper describes the theory of fuzzy comprehensive evaluation, and provides the evaluation method of low-carbon green development of shipping industry. Through the establishment of the evaluation index system, it is helpful to evaluate and analyze the low-carbon green development level of shipping industry in China.

Chapter 5
The countermeasure on the low-carbon green development of shipping industry

5.1 The countermeasure analysis on low-carbon green development of shipping industry

5.1.1 Countermeasure analysis on macro level

As a new type of composite industry, low carbon green shipping industry should be guided by the management of the national unified regulation. On basis of the coordination of policies and regulations, the relevant government departments should establish a unified shipping management department to establish standards for management and constraints on the sewage charges system, license system, environmental protection and low-carbon green development. That can minimize the external diseconomy of China's shipping industry(Zhang, 2009, p.41).

Government departments should attach great importance to the transformation of shipping industry to low-carbon green development, and formulate policies on low-carbon subsidies, tax support as well as loan preferential to guide the development of low carbon green.

(1) Establish and improve relevant laws and regulations

Our country has not yet introduced laws and regulations on controlling the greenhouse gas emissions, at the same time, the international convention China joined has not been changed into domestic laws and regulations(Dai, 1998, p.15). For example: according to the requirements of Annex VI, fuel supplier must register in the government sector. Meanwhile, fuel supplier and the qualification of fuel quality inspection shall be approved by the competent authorities. However, current marine laws and regulations don’t give maritime sector related rights. Relevant laws and regulations should be improved to give the maritime sector related rights. Therefore, China Maritime Bureau calls for improving the laws and regulations related to the prevention of greenhouse gas emissions from ships. This can not only promote China to effectively perform relevant convention, but also plays an essential role in promoting the emission reduction of China's shipping industry. In addition, China's domestic ships bear low level of shipbuilding and detects in the operation and management process. So they have a certain degree of difficulty in implementing relevant international conventions. Maritime sectors should introduce domestic legislation which is below the standards of international conventions but is in line with the actual domestic situation to monitor ship emissions of greenhouse gas.

(2) Formulate relevant guidelines and inspection procedures

In order to effectively monitor the emissions of greenhouse gas, the maritime sectors should work out relevant guidelines to help the ship owner and the ship

operator to be familiar with the relevant laws and regulations on the reduction of greenhouse gas emissions. Trying from the source can more effectively control greenhouse gas emissions; as to the daily supervision of maritime law enforcement officers, specific procedures should be introduced and used to guide supervision inspection such as port state control and flag state control.

(3) Control from the perspective of the ship inspection and market admittance

Every ship must pass the inspection tests before they can be put into market operation, including human level inspection, annual inspection, and interim inspection and so on. The maritime sectors should associate with ship's inspection departments and use the ship inspection opportunity to check whether a ship meets the emission reduction standard. Those that can't meet the requirements of emission reduction should be eliminated.

(4) Establish a vessel emission reduction control area

The maritime sectors shall set up a monitoring area of controlling the waste gas emission, where the emissions of greenhouse gases can be controlled. For example, assemble monitoring equipment of greenhouse gas emissions on the port, wharf, or channel to measure the amount of greenhouse gas emissions in the process of entering and leaving the port. And the data should be fed back to the relevant systems in the maritime sector.(Zhang, 2004, p.35)

5.1.2 Countermeasure analysis on medium level

In shipping industry, the traditional idea that the environmental protection will increase the cost, and low carbon will affect benefits should be abandoned. Industry development shouldn't only focus on short-term benefits. Instead, on basis of collective collaboration, energy saving and environmental protection, saving resources consumption, reducing carbon emissions as well as avoiding pollution of the environment should be treated as the long-term goal of the industry development.

5.1.3 Countermeasure analysis on micro level

Shipping enterprises are the main body of the whole market. Especially the mall and medium private shipping enterprises, whose representative is New Mileage International Shipping Company, should actively respond to the national government's laws and regulations and policies, and jointly deal with the low carbon problems(Yang, 2009, p.19). On one hand, pay attention to the concept of low carbon green development in shipping industry, take practical actions to reduce energy consumption and carbon emissions in the process of transportation, save transportation costs, not only focusing on the economic benefits of the enterprises. The enterprise's development target should contain both getting the shipping benefits and raising the strength of environmental protection. Only in this way will sustainable development be obtained in today's fierce competition of shipping enterprises. On the other hand, the mall and medium private shipping enterprises should actively introduce professional talents, speed up relevant technical development and appliance, try to shorten the

technology gap with large shipping enterprises, and effectively improve the core competitiveness of enterprises. In addition, medium and small shipping enterprises should strengthen the importance and investment intensity of environmental protection shipbuilding technology and advanced management level.

(1) Ship power

At present, the world's first oil and electricity hybrid - marine engineering supply ship Viking Lady has been announced to come into being during the United Nations Climate Conference(Jorg, 2010, p.7). This is the first time that the fuel cell has been installed on a merchant ship. The use of fuel cell on such a scale in the marine power agency is a world-class innovation. This kind of fuel cell uses natural gas, capable of producing 320 Kw auxiliary powers. If further research and popularization of this project succeed, compared with the traditional engine technology, it will greatly reduce the total amount of emissions, including carbon dioxide, nitrogen oxides and sulfides. That will greatly improve the efficiency of the fuel, and achieve zero discharge of hazardous substances. The research project may declare the future environmental innovation of the marine power system. With the introduction of a series of low carbon and environmental protection standards, the technology innovation direction of China's shipbuilding industry will be reflected in the ship design. China's shipbuilding industry needs to comply with the trend of current shipbuilding engineering technology, achieving low-carbon emission reduction, energy efficient and green development goals in the ship design efforts as soon as possible. Especially, because middle and small shipping enterprises have a not big company scale, the application of new technology in ship power is faster and more flexible than large shipping companies. They can do as the front platform for new ship’s structural dynamic test trial.

(2) Ship form

Shipping companies can achieve energy saving and emission reduction targets by the introduction of new- type ships. The resistance of the ship determines the speed and fuel consumption, which tells us that we should control the consumption of fuel by reducing the resistance of the ship so as to achieve the purpose of reducing emissions. The resistance of the ship determines the speed and fuel consumption, which tells us that we should control the consumption of fuel by reducing the resistance of the ship, so as to achieve the purpose of reducing emissions. The ship's surface resistance is determined by the size of the ship, so a good ship design can effectively reduce the ship resistance, thereby reducing fuel consumption(Qi, 2010, p.3). Ship resistance mainly comes from three aspects, namely, the frictional resistance of the hull and water, resistance of the bow’s cleaving through the waves, and air resistance. For water resistance, the streamlined design of the hull can reduce the frictional resistance of water; Installation of bulbous bow can reduce the wave resistance during the voyage. So in the design of ship, give full consideration to the scientific principle of fluid mechanics, which makes the streamlined hull design and installation of bulbous bow more scientific and effective. For air resistance, the superstructure can be arranged into a long and narrow shape so as to reduce the wind area of the hull.

(3) Scientific management

A series of scientific management mode can make the shipping companies reduce energy consumption, reduce emissions of pollutants, and thus achieve the low-carbon green development. According to statistics, there is a cubic relationship between the fuel consumption and speed. Slowing ship speed by 5% will reduce emissions by about 15%(Qi, 2011, p.14). Therefore, reducing the speed is one of the effective measures to reduce emissions. But shipping companies don't want to reduce operating efficiency due to a decrease in the speed. So there should be a balance between speed and fuel consumption through scientific research. At the same time of ensuring the speed, reduce exhaust emissions as much as possible. Also, in the ship berthing period, try to use shore power, and minimize the fuel consumption by avoiding start engine, so try to supply ship power on the shore to enable the ship docked fuel consumption, which can reduce the emission of greenhouse gases. According to the survey, in Shanghai port area, after the ship is supplied with shore power, the discharge of pollutants is reduced by more than 92%, which shows the importance of marine power. Ship shore power technology transforms shore power technology in the area of the port terminal. Meanwhile, it requires that shore power and electric power system maintain the same as much as possible; shipping companies should manage the ship power transmission mode mainly by low voltage power supply. If the majority of the shipping companies can make the use of shore power, it is believed that it will play an important role in the discharge of the ship. In addition, increase the loading efficiency to reduce the operation of the ship in port and the waiting time, which can also reduce the total amount of waste gas emissions from ships.

5.2 Summary

On basis of the analysis of earlier chapters, this chapter represents strategies on the low carbon green development of shipping industry. It analyzes specific measures of developing green low carbon shipping industry from the macro, medium and micro aspects. In view of the current development bottleneck of low carbon green of China's shipping industry and combining with the actual development situation of shipping industry, this chapter puts forward measures and strategies to speed up the low carbon green development of shipping industry.

Chapter 6
Conclusion

6.1 Main researches in this paper

Evaluation of low carbon green development in shipping industry is a comprehensive project. This paper makes a study on the evaluation index system of low carbon green development in shipping industry, the main work and innovation points are as follows:

(1) This paper summarizes the present situation of low carbon green development in domestic and foreign shipping industry and discusses the restrictive factors of low carbon green development in China's shipping industry. As well as the analysis on mutual influence of the shipping industry development and the ecological environment and the symbiotic relationship between the two.

(2) In this paper, evaluation index system of low carbon green development of China's shipping industry is established; each index has a detailed explanation and reference standard for evaluation, which is the main innovation of this paper.

(3) Using AHP, this paper analyzes the weight of the index, and takes into account the correlation between the indexes, and this is another innovation point of this paper. It is proved that the analytic method of AHP is reasonable, effective and has a strong applicability.

6.2 Inadequacies of this paper

Because my research is limited, the paper still has deficiency, the main performances are:

(1) There is still a lack of evaluation for the low-carbon green development of small and medium shipping enterprises. Due to the large number of small and medium-sized shipping enterprises in China, the development levels are different, and management modes are diverse, there is no universality. Thus it can not reflect the actual situation, causing biases of the index system in the evaluation of middle and small shipping enterprises.

(2) This paper uses the AHP analysis method, and the end result is comprehensive score. This means that it will ignore individual factors in the process of evaluation and exist subjective impact. This is the inadequacy of the paper.

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