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Comparison of port climate change adaptation strategy and climate change mitigation strategy based on the case study of Shanghai port

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Comparison of Port Climate Change Adaptation Strategy and Climate Change Mitigation Strategy

Based on the Case Study of Shanghai Port

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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

Nowadays, how to deal with global climate change is receiving more and more attention. According to the dichotomy classification, climate change coping strategies can be divided into climate change adaptation strategy and climate change mitigation strategy. These two strategies are closely related, but people generally pay more attention to the mitigation strategy than the adaptation strategy. The same is true in ports. It is worth studying the reason of the bias and its rationality.

In this paper, the strategy of climate change mitigation and adaptation and their application in port are introduced in detail. The advantages and disadvantages of these two strategies and the reasons why they have not coexisted in ports are analyzed through literature analysis. In order to verify whether the climate change mitigation strategy is more suitable for the port than the climate change adaptation strategy at this stage, this paper makes an actual survey of Shanghai Port. Based on the questionnaire survey and on-the-spot interview of the grassroots employees and executives in the two main ports of Shanghai Port, the paper establishes the analytic hierarchy process (AHP) model to score the implementation of the climate change adaptation strategy and the climate

change mitigation strategy in Shanghai Port. Finally, it is found that the climate change mitigation strategy is indeed the most needed strategy of Shanghai port at the present stage. This paper makes a detailed analysis of the causes of this result and puts forward some propositions.

Keywords: Port, Climate Change Adaptation, Climate Change Mitigation, Shanghai Port, Analytic Hierarchy Process

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1. Introduction

1.1 Background of this dissertation

The existing observations and studies show that the global climate has underwent huge changes in the past century. Global warming is the main feature of climate change. The safety of human life and property is threatened heavily because of the sea level change (SLC) and extreme weather caused by global warming such as frequent storm surges, drought, heavy precipitation and so on. This issue has become one of the most important issues to be solved in human society nowadays.

Because of the geographical location, seaports have undoubtedly become one of the places that receive the most impact under the condition of global climate change. Port facilities and operations are highly vulnerable to sea level rise, frequent storm surges and other extreme weather. Nowadays, there are mainly two approaches for seaports to deal with this situation: climate change adaptation (CCA) and climate change mitigation (CCM). CCA aims to reduce vulnerability and improve response capacity, which is defined as "process of adjustment to actual or expected climate and its effects". In contrast, CCM focus on the drivers of climate change and is defined as "process of reducing pollution sources or reducing greenhouse gas emissions through human intervention." The definitions of CCM and CCA show that they are separate, but they share a common ultimate goal: to minimize the adverse effects of climate change. CCM is committed to reducing the risk of climate change through long-term efforts, and the goal of CCA is to minimize the loss of climate change because of the failure of CCM. It is said that CCM and CCA are not mutually independent. Scholars have done a lot of research on CCM and CCA, but the research is mainly on agriculture and urban planning and other fields. The research on the aspect of seaports is still a relatively new field. Therefore, this paper hopes to study this field and research on the

issues such as the attitude of some specific ports towards these two climate change policies.

In China, due to geographical location, China's coastal areas in South China and East China are very vulnerable to extreme weather, such as storm surges. China's government attaches great importance to the work of coping with climate change, and has issued many relevant policies and documents. However, it seems that the authorities are more inclined to implement the mitigation strategy than the adaptation strategy. This paper hopes to study the reasons for this phenomenon, and analyze whether this practice of the Chinese port authorities is reasonable through the study of Shanghai Port in related aspects.

1.2 Research objectives

(a) To fully understand the situation of the implementation of climate change mitigation strategy and climate change adaptation strategy in the port, analyze their strengths and weaknesses, and understand the reasons why climate change mitigation strategy has received more attention.

(b) To look into the implementation of climate change mitigation strategy and climate change adaptation strategy based on the investigation of Shanghai Port and AHP model, judge whether the climate change mitigation strategy is indeed the most favorable strategy for the port at this stage and the reasons.

1.3 Dissertation Structure

Chapter 1 introduces the research background, defines the research goal and establishes the research structure.

Chapter 2 reviews the literature on climate change mitigation strategy, climate change adaptation strategy and the relationship between the two strategies, and points out the research gaps that need to be filled

Chapter 3 introduces the definition of adaptation strategy and mitigation strategy, and points out the interaction between the two strategies

Chapter 4 introduces the implementation of climate change mitigation strategy in ports, and takes the ports in Taiwan Province of China as an example to study the climate change adaptation strategy of Taiwan ports.

Chapter 5 introduces the implementation of China's port climate mitigation strategy, and introduces several typical climate change mitigation measures.

Chapter 6 analyzes the relationship between the climate change adaptation strategy and the climate change mitigation strategy of the port, their advantages and disadvantages, and the reasons for their non-coexistence.

Chapter 7 introduces the investigation scope of Shanghai Port, and puts forward some propositions through the collected facts and previous literature.

Chapter 8 establishes the analytic hierarchy process (AHP) model based on the investigation of Shanghai Port and carries out the calculation.

Chapter 8 analyzes the results of AHP model and points out the limitations of the paper.

2. Literature on climate change adaptation and mitigation

The research of foreign scholars and Chinese scholars on the impact of climate change on ports are different. Chinese scholars prefer to study mitigation measures of port to climate change, while some foreign scholars have started to work towards climate change adaptation of ports.

2.1 Literature on climate change adaptation and mitigation of ports

Becker et al. (2012) investigate the impact of climate change on global port operation through the method of questionnaire survey and point out that most ports had made few preparations for climate change. Ng et al. (2013) make an empirical analysis of four ports in Australia and presented the idea that effective climate adaptation solutions not only involve physical layout and engineering projects, but also the need to fundamentally transform the existing management and planning practices. Wu et al. (2013) analyze the possible impact of climate change on China's ports, and put forward measures and suggestions for ports to cope with climate change. Nursey-Bray and Miller (2012) study the impact of global climate change on the port and shipping industry and the training need analysis of Australia's for climate change. They point out that the Australian port and shipping industry needs to make more investment in how to address the problem of climate change, and that the port and shipping industry will benefit if they make more training in vulnerability assessment of the port. These measures will reduce the burden on ports under climate change in the future. A new concept of ‘port climate risk exposure function along the sea–land boundary axis’ is introduced by Mutombo and Ölçer (2017). They use this concept to assess perceived climate risks to port infrastructure from relevant experts. Peng et al. (2020) establish the demand model of typhoon anchorage and the optimization model of typhoon anchorage based on the joint dispatching of port groups. According to the model, Peng

optimizes the anchorage of Fujian Province, and puts forward corresponding planning suggestions according to the results. Wu et al. (2018) put forward countermeasures by analyzing and studying the situation and causes of ship anti typhoon safety in Huizhou Port. Wang and Zhang (2018) analyze the impact of competition and cooperation among ports on investment in climate change adaptation. Lin et al. (2020) investigate the attitude of port organizations towards climate change and calls for more attention to better understanding and assessment of climate change impacts. Lin highlights the importance of government policies towards the development of adaptation strategies on ports, including emerging economies like China. Fu (2020) reviews the relevant research on climate change adaptation, such as the international mechanism of climate change adaptation under the United Nations Framework Convention on climate change and the experience of major countries, and puts forward a complete set of core decision-making process and key supporting mechanism for climate change adaptation. Yang and Ge (2020) identify a desirable set of adaptation strategies for port infrastructure and facilities at the Kaohsiung port in the face of climate change impacts based on vulnerability assessment criteria.

Chinese scholars have done a lot of research on the CCM of Chinese ports and related policies of China. Chen et al. (2016) analyze the problems of green port construction in China and puts forward some policy suggestions. Dai and Yang (2020) analyze the green transportation strategies under the two emission policies. The research conclusion shows that the implementation of the two carbon emission policies have promoted the increase of the freight flow through the dry port and the development of the container rail transport mode has been achieved. Ye et al. (2015) study the project of transformation of oil power drive to electric power drive of Chinese ports' tyre crane and put forward the existing problems. Pan and Fan (2011) study various alternative fuels for container trailers and compared their environmental and economic benefits. Peng (2012) studies the promotion of shore power in China and point out the existing

problems. Lai (2021) studies the development of sea rail intermodal transport of Chinese ports in 2020, and made statistics of detailed data

2.2 Literature on the interaction between climate change mitigation and adaptation

Some scholars think that CCM and CCA are closely related, while others think that they are opposite, because there will be trade-offs and conflicts between the two strategies. In the relationship between CCM and CCA, many scholars have made relevant research.

Dang at el. (2003) analyze possible contradictions and synergies between CCM and CCA and the implications for developing countries and sustainable development targets. Sharifi (2020) points out the conflicts and trade-offs of climate change mitigation and adaptation and integrated approaches dealing with conflicts and trade-offs. Jiang et al. (2020) construct an economic model to compare the impacts of CCM and CCA in affecting the outputs of the executing port and the other ports in its network, considering the effects of market interactions. Gong et al. (2020) study the investment tendency of port to CCM and CCA under different budget, disaster intensity and frequency and some other conditions.

2.3 Research gap

From these previous studies, it can be seen that scholars have done a lot of research in the ports' climate change mitigation strategy such as green port and port energy conservation and emission reduction. There are also research on the term of ports' climate change adaptation, such as the impact of extreme weather on port infrastructures and operations. However, there are some deficiencies in these studies and some research gaps need to be filled in. For example, there are few researches on

the comparison of the two strategies for ports and few researches on the impact of CCM and CCA on port development. Besides, it is also worthy of study which of the two strategies is more economic for the port and more favorable for the ports development for the time being? This paper hopes to compare the two strategies by studying the impact of CCM and CCA on the port, which can fill the literature gap of the above research.

3. Introduction of adaptation and mitigation

3.1 The definition of climate change mitigation

The temperature of the earth is determined by the rate at which the sun radiates to the surface of the earth and the rate at which the surface absorbs heat and radiates out into outer space. Some gases in the atmosphere, such as carbon dioxide, ozone and Freon, can absorb the long-wave radiation emitted from the earth to the outer space, but allow the short-wave radiation from the sun to the surface to pass through without obstacles. These gases in the atmosphere play an important role in controlling the surface temperature of the earth. These gases are collectively referred to as Greenhouse Gases (GHGs). According to scientific observations, the concentration of greenhouse gases in the earth's atmosphere has increased this century. Because of the increase of the GHGs, the path of heat from the earth's surface to outer space is blocked. As a result, the balance between absorbing solar radiation and radiating radiation from the earth's surface for a long time is interrupted and the earth's surface temperature increases. This phenomenon is known as the ‘Greenhouse Effect’. Greenhouse effect is one of the main causes of global climate change. In order to slow down the rate of global climate

change, the climate change mitigation (CCM) strategy has been proposed. The goal of CCM is to improve greenhouse effect and slow down global climate change by controlling the emission sources of greenhouse gases. The CCM strategy has many concrete measures, such as improving energy efficiency, development of renewable energy, increasing the use of renewable energy, improving land use pattern and so on.

3.2 The definition of climate change adaptation

Climate change adaptation (CCA) is a climate change strategy closely related to CCM. To some extent, it can be said that climate change adaptation is implemented in order to minimize the impact of adverse consequences of climate change when CCM's long-term goals have not been met. CCA is implemented in fields that will be affected by global climate change such as agriculture, forestry, animal husbandry, water resources, urban planning, coastal planning, ports and so on.

1) In the field of agriculture, global climate change will reduce crop yields, increase the amount of water needed for crops because of the increasing temperature and so on. The corresponding CCA measures include strengthening agricultural infrastructures, development of new biotechnology, high and stable yield measures, scale farming and improving crop resilience.

2) Rising temperatures will increase the extent of land desertification, reduce wetland resources and reduce biodiversity. In order to cope with these situations, in the field of forestry and ecosystems, CCA measures can be implemented such as afforestation, supervising the management of nature reserves, strengthening the prevention of forest fires, scientific management of animal husbandry, avoiding overgrazing and grassland degradation.

3) Warming climate will increase river evaporation, the frequency of flood disasters and the contradiction between supply and demand of water resources. CCA measures in the corresponding fields include strengthening water infrastructure to improve flood

control and drought resistance, water supply capacity and resilience.

4) Due to geographical reasons, ports are very vulnerable to global climate change. For example, rising sea level, frequent extreme weather and storm surges, river flooding and drought will all affect port operations. There are many adaptability measures that can be adopted by ports authority, including raising the height of the breakwater to prevent the giant wave, extending the length of time for wharf elevation design to cope with sea level rise, strengthening port machinery such as bridge cranes, preparing more alternate distribution plans and so on. In addition to the industries mentioned above, there are other adaptation strategies, including the establishment of climate prediction monitoring and forecasting systems.

3.3 Differences of climate change adaptation and mitigation

The efforts required by CCA and CCM to achieve the goal of coping with climate change is different. The nature of CCM strategy is proactive, which is achieved by reducing emissions of GHGs, while CCA is a reactive strategy implemented after the adverse impact of climate change has been felt. The different natures of CCA and CCM make a distinction between the two strategies. First, the goal of reducing greenhouse gas emissions is not achievable in the short term, so CCM strategy needs a long-term effort to achieve the success of the strategy. The goal of CCA strategy is to minimize the impact of climate change that has been felt, so the temporal focus of CCA strategy is short and medium term. Then, the consequences of climate change (sea level rise, storm surges etc.) tend to appear in one region, so the spatial scale of adaptation strategies is always regional or national. In contrast, the spatial scale of mitigation strategies is global as reducing GHGs is the common goal and responsibility of all mankind on the earth. Because of the different spatial scale, climate change mitigation leads to injustice. If two adjacent regions make different efforts in mitigation strategies (one area puts in a lot of efforts, but the other doesn't),and finally

they are equally affected by climate change, it will lead to free rider effect. The so-called free riding effect refers to that some people in the same interest group do not make efforts to achieve the goal, which will inhibit the motivation of others in the group to make efforts. Besides, emission targets can be accurately quantified, measured and predicted, so CCM strategy is more certain than CCA strategy.

	CCA	CCM
Spatial focus	Local and region	Global
Temporal focus	Short and medium term	Long term
Sectoral focus	Wider range of sectors	Energy-intensive sectors
Scale of cooperation	National and regional	International
Nature of action	Often reactive; can be proactive if adaptation is based on projected climate impacts	Proactive, aimed climate stabilization
Level of uncertainty	More uncertain because frequency and uncertainty of future climate impacts is not well known	More certain as emission abatement targets are determined that can be updated regularly to reflect new projections
Justice issues	Less justice as some areas are disproportionately affected by climate impacts, despite historically being less responsible for climate change	Countries less vulnerable to climate impacts may not be motivated to contribute to achieving mitigation targets

Table 1. The differences between CCM and CCA (adapted from Sharifi (2020))

4. Port climate change adaptation strategies

4.1 The impact of climate change on ports

Ports are important nodes in the supply chain, which are located along the sea, rivers and lakes. Due to geographical location, ports are very vulnerable to the phenomenon brought about by global climate change. For example, the melting of polar glaciers caused by global warming will lead to sea level rise, and seaports are the most affected. Frequent and intense storm surges and higher wave heights will pose a threat to the operation and infrastructure of the seaports.

(1) Damages to port infrastructure and cargo.

(2) Deterioration of navigation conditions in port and waterway (reduction of navigation safety)

(3) Relocation of port operations to other ports not affected by extreme weather

(4) Flood caused by overload of drainage system

(5) Structural damage to infrastructure caused by increased soil moisture

(6) Reduce of the clearance under the bridge because of the rising sea level

(7) Increased cost of infrastructure construction and maintenance

(8) Blocking of ports collection and distribution network

Specifically, climate change poses the greatest threat to port infrastructure. Therefore, when formulating climate change adaptation strategies, port authorities should mainly consider adjusting the port infrastructure so that it can adapt to extreme climate. Port authorities should increase the height of breakwater to cope with larger waves, extend the wharf elevation and design life to in response to the rise of sea level, strengthen the wharf equipment to cope with typhoons and gales, and strengthen the drainage capacity of port drainage facilities to cope with heavy rainfall. In addition, ports authorities should also consider the port's cargo warehouse and other aspects. The impacts of climate change on port infrastructure are summarized in Table 2.

Infrastructure	Annotation
Infrastructure of the port	The higher wave caused by typhoon and the rise of sea

front	level will put forward new requirements for the design height of breakwater
	When typhoon occurs, the adaptability of the port anchorage will also affect the safety of the ship
Cargo handling facilities	Cranes, forklifts, tire cranes and so on.
Drainage facilities	Heavy rainfall will overload the port drainage facilities and cause flood.
Collection and distribution networks	Strong wind and heavy rain will stop or even block the internal roads and external goods distribution roads of the port.
Cargo storage facilities	Typhoon and storm surge will affect the cargo storage facilities of the port.
Waterways of ports and bridges	Typhoons and storm surges will make the waterway of the ports impassable. Sea level rise will lead to the increase of channel depth in some areas, which is conducive to the navigation of ships. But at the same time, sea level rise will lead to the reduction of the clearance under the bridge of some cross sea bridges, which will affect the navigation of ships passing under the bridge.

Table 2. The impacts of climate change on port infrastructure

4.2 Port climate change adaptation strategies

As mentioned above, the adaptation strategy is to improve the ability of the system to cope with external pressure and reduce the vulnerability of the system through the internal adjustment of the system. The adaptability measures of the port are mainly aimed at sea level, high waves caused by storm tide, heavy rainfall, deterioration of water quality inside the port and waterway blockage. In order to deal with global climate change, ports need to adjust not only the infrastructure of ports. The port adaptation strategy should not be scattered, but systematic. In addition to the improvement of facilities, it should also include the redesign of various standards, the change of facilities location, the education and training of practitioners, cooperation with other institutions, and the detection and evaluation of climate, etc.

Specific adaptation measures of ports in response to climate change include following (Yang and Ge (2020)):

(1) Increase the design standard of wharf, such as increasing the design elevation of wharf and considering the design period

(2) Reinforce construction facilities such as guardrail and breakwater

(3) Reinforce shore cargo handling equipment, such as crane, tyre crane, gantry crane, bridge crane, etc

(4) Raise the height of wharf and breakwater in response to huge waves and rising sea level.

(5) Increase the slope of the wharf to enhance the drainage capacity of the wharf

(6) Dredge and deepen the waterway

(7) Prepare alternative logistics solutions and routes when the collection and distribution network is paralyzed due to extreme weather

(8) Promote the water circulation inside and outside the breakwater and prevent the deterioration of water quality inside the breakwater

(9) Strengthen the monitoring of infrastructure status

(10) Redesign of drainage system and redevelopment of design standards for hydraulic structures

(11) Grasp the movement of typhoon and take correct measures in time

(12) Plan, construct and take use of typhoon shelter waters rationally

(13) Multi department linkage and set typhoon warning signal

(14) Make standby plan for port emergency

(15) Detection technology of abnormal events

(16) Better planning of land use in port areas that are vulnerable to floods

(17) Preparation of flood control materials

4.3 Vulnerability analysis

To formulate a complete climate change adaptation strategy is to not only combine specific adaptation measures but also take the macro level of the adaptation into consideration. Before the port authorities formulate climate change adaptation strategies, they need to conduct vulnerability analysis on the port. The vulnerability analysis includes exposure analysis, sensitivity analysis and resilience analysis. The so-called exposure refers to the frequency and possibility of the port suffering from the disasters caused by climate change. In order to determine the exposure, it is necessary to analyze the future climate change trend and risk degree of the port area, and then the risk of the port suffering from climate disasters in the future can be predicted. Sensitivity refers to the damage or threat of the port suffering from the disasters caused by climate change. Sensitivity analysis should include the prediction that the impact of different climate change phenomena on the port in the future, that is, the sensitivity of the port to these disasters. The impact can be reflected by the size of damage compensation. Resilience refers to the capacity of the port to recover to its original state after disasters. Resilience analysis generally includes the assessment of the disaster response capacity of port legal and management organizations. Ports with strong resilience usually have backup logistics and collection and distribution schemes to cope with traffic congestion caused by extreme weather. When the authorities formulate the adaptation strategy, they should first consider the macro level, determine the strategic direction, and then combine the scattered adaptation measures to form a complete CCA strategy.

4.4 Examples of port climate change adaptation

Due to geographical location, Taiwan Province of China is very vulnerable to tropical storms and typhoons. In order to improve Taiwan's ability to adapt to climate change, On January 29, 2010, the “Proposal for Promoting Climate Change Adaptation Policy Program and Action Plan” was set up. In 2012, the Executive Yuan of Taiwan province

approved and issued the 'National climate change adaptation policy outline'. Eight work groups were set up by the Ministry of Science and Technology, the Ministry of Agriculture, the Ministry of Economy, the Ministry of Transportation and Communication (MOTC) and other departments to formulate detailed climate change adaptation plans and action plans for various fields. These groups would follow 'National climate change adaptation policy outline' to form the general direction of the future action in the field of climate change adaptation. MOTC released a comprehensive plan called "National Climate Change Adaptation Action Plan for 2013–2017" and the following adaption measures related to ports were issued.

(1) Regularly monitor the height of tides and waves in long run, the data obtained can be used as a reference for future design standards.

(2) Evaluate the reconstruction capacity of the old wharf to cope with climate change, such as wharf elevation, seismic and wave resistance capacity and wharf bearing capacity.

(3) Carry out safety inspection on the use of port facilities, rectify possible safety problems and make necessary repairs.

(4) Improve the drainage facilities of the port to prevent the impact of rainfall on the operation of the port.

(5) Evaluate the necessity of port construction of living infrastructure and study the possible construction sites and methods.

(6) Inspect comprehensively the ports elevation and back facilities of the terminals

(7) Adjust the rubber revetment facilities of the wharf to avoid the damage to the ships and the wharf caused by strong winds and waves.

(8) Clean up the silt in the sea area and channel of the port, dredge the channel in time to ensure the normal operation of the port.

Then in 2018, on the basis of "National Climate Change Adaptation Action Plan for 2013–2017", MOTC released "National Climate Change Adaptation Action Plan for

2018–2022". There are further port related adaptation initiatives that are mentioned in the new action plan including measures related to living facilities in the port. While there are also measures related to coping with sea level rise. The measures lately issued are as follows.

(1) The port companies shall review the port design standards, including the design life to cope with climate change, large ships and various types of terminals (such as bulk cargo terminal, fishing port, LNG terminal, etc.).Companies should also evaluate the risk factors of wave, wind, rain and current to the ports.

(2) International ports should cooperate with the Institute of transport to monitor marine meteorology such as wind, water depth, current, tide and wave.

(3) The ports should improve the design elevation and capacity of key wharf.

(4) Ports should build closed circuit television monitoring system in order to strengthen the monitoring of port water area and land.

Since the global warming in the 19th century, the rate of world sea-level rise is about 0.1 meters to 0.15 meters per 100 years. However, the fact is that the impact of such rising speed on port facilities, such as wharfs and breakwaters, is still limited. But the world sea level will rise one meter in the next 100 to 200 years according to the statistics of NASA. By that time, the impact of sea level rise on port facilities will be much greater than today. This is why both "National Climate Change Adaptation Action Plan for 2013–2017" and "National Climate Change Adaptation Action Plan for 2018–2022"have measures involving coping with sea-level rise:

Strengthen the existing drainage facilities, set up drainage ditch, collect sediment and discharge sediment into water.

Improve the design elevation and breakwater elevation of each important wharf. The new design standards are shown in the Table 3.

Ports	Original elevation level	New elevation level

Kaohsiung	CD.+2.60m	CD.+4.30m
Keelung	CD.+3.00m	CD.+4.00m
Taichung	CD.+6.20m	CD.+6.50m
Taipei	CD.+4.00m	CD.+5.5m

Table 3. Design elevation level of new wharfs and breakwaters (data from Yang and Ge (2020))

5. Status of the port mitigation in China

5.1. Overview on mitigation strategy of China's ports

In September 2019, the "Outline for the construction of a transportation power" issued by the State Council of China proposed that China should promote the conservation and intensive use of resources, strengthen energy conservation and emission reduction, pollution prevention and control, and strengthen the protection and restoration of transportation ecological environment. China's president stressed that "China's port authorities should aim to build a world-class smart ports and green ports." today, China's port industry is striving to build a world-class port and promote mitigation strategy. In the "guidance on building a world-class port" which is jointly issued by 9 departments including the Ministry of transport, the national development and reform commission, the Ministry of finance, the Ministry of natural resources the Ministry of ecological environment and other 4 departments, it is clearly proposed that China should speed up the construction of green ports, focus on strengthening pollution prevention and control, build a clean and low-carbon port energy consumption system and strengthen resource conservation, recycling and ecological protection. Under the guidance of these guidelines, the effect of the mitigation strategy of China's ports

began to appear. First, the concept of mitigation strategy has been deeply rooted in the hearts of the port authorities. Local governments, port groups and terminal enterprises attach great importance to the strategy. Most of them have formulated and implemented special plan related to CCM, and allocated special funds to support port's CCM. Each port issues the green development report every year, and actively participates in the technical exchange and experience sharing activities related to the promotion of CCM within the country, port industry and port groups. Secondly, each port and container terminal enterprise has set up functional departments of CCM, most of which are led by the company leaders and equipped with specific management personnel, so that each department has clear responsibilities and the management organization is becoming more and more perfect. Many port enterprises have established a complete special assessment system for energy conservation and environmental protection standards. While establishing the incentive and restraint mechanism related to CCM within the company, the ports companies also require relevant cooperative enterprises to abide by the company's environmental requirements and norms and jointly promote the reduction of emissions by signing environmental protection agreements.

Some port enterprises have carried out energy management system, environmental management system certification and energy audit. Enterprises continuously improved the management level of green development by actively implementing rectification measures. Many ports not only build their own environmental monitoring points in the port area and wharf operation area to regularly monitor the emission of pollutants such as sulfur dioxide, nitrogen dioxide, PM2.5 and ozone, but also develop and establish environmental management information system to realize the functions of environmental data query, pollution calendar and meteorological data comparison. In addition, many ports have developed and

established energy efficiency management information systems to realize automatic collection and analysis of electric energy so that they can regularly carry out energy balance test on electricity, oil and water consumption. By this way, ports canto improve energy management and provide scientific basis for energy-saving technology transformation and improvement of energy utilization rate.

Third, various port emission reduction technologies are being actively promoted. Many ports are vigorously building and promoting the effective use of shore power. Shore power coverage has reached a very high level. The so-called shore power refers to the high-power variable-frequency power supply equipment specially designed and manufactured for the harsh environment of high temperature, high humidity, high corrosion and heavy load impact. Energy feedback technology, frequency conversion or DC (direct current) drive technology are widely used in quayside container crane, container gantry crane and other main equipment. The volume of combined rail and water transport is growing rapidly. The proportion of water and water transfer in some domestic ports exceeds 70%, and the transport structure has been continuously optimized. LNG powered trailers and electric trailers, stackers, front cranes, patrol cars, etc. are speeding up the configuration and use, and the proportion is constantly increasing. In some ports, the use proportion of the above port machinery and equipment has exceeded half. Besides, the use of solar energy, wind energy, photovoltaic technology and other technologies are accelerating. The renovation of energy-saving lighting system, energy-saving transformer, high-level small air conditioning and other places is also in progress in many ports.

As a result, the concentration of ammonia nitrogen, nitrogen oxide, COD and sulfur oxide in many ports can meet the emission standards in wastewater and air discharge. The energy consumption per unit throughput of the terminal and the carbon dioxide emission per unit throughput can also meet the standard.

5.2. Introduction of ports emission reduction technology

5.2.1. Introduction of the promotion of shore power in China

When the ship berths, the engine of the ship also needs to run to provide power for the ship. However, the main fuel of marine engine is diesel. Burning diesel will act as an agent for additional pollution and greenhouse gas emissions. The emergence of shore power technology is to alleviate this phenomenon. The goal of shore power technology is to replace the fossil energy on board with clean energy on shore, so as to reduce the waste of energy on the premise of ensuring the daily operation of the ship and the operation of handling equipment. The benefits of using shore power are obvious. In 2000, Gothenburg port in Sweden took the lead in using this technology. As a result, the emissions of ships berthing at the port decreased by as much as 94% to 97%. The use of China's onshore electricity technology is relatively late than other countries. Qingdao port took the lead in using ship shore power in 2009. In 2017, China's Ministry of Communications issued the "Port Electricity Layout Plan", in which the target of that more than 50% of containers, RO, cruise ships, 3000 ton passenger transport and 50000 ton dry bulk cargo berths will have shore power facilities nationwide by 2020 was put forward. Under the call of the plan, China's domestic shore power market showed explosive expansion from 2017 to 2018. By the end of 2017, about 30 sets of High-voltage Port power system facilities and 840 sets of low-voltage port power system facilities had been added. According to statistics, by 2020, about 150 sets of High-voltage port power system facilities and about 3100 sets of low-voltage port power system facilities had been added in China’s ports. In fact, shore power is an energy-saving and emission reduction technology that China has been focusing on promoting and applying since 2010. However, due to various factors, the promotion and application of shore power has not achieved the expected results, mainly for the following reasons.

5.2.1.1. Difficulties of promotion of shore power

(1) Technology difficulties

Most of the shore power systems in China adopt the way of direct power supply from land power grid to ships. At present, China's domestic power grid is mainly 50 Hz, but the power frequency required by international ships is usually 60 Hz. Therefore, the port needs to provide frequency conversion facilities for ships. Nowadays, the domestic low-voltage power frequency conversion technology is more mature, but most of the port shore power facilities need high-voltage frequency conversion technology. However, there are still many technical difficulties for Chinese ports to overcome such as harmonic control, electromagnetic compatibility, system control and topology.

(2) Large investment, long return period

Whether for shipowners or port companies, the use of shore power facilities requires a huge investment. For the port, the counterfeiting for the construction of shore power facilities is 2 million RMB per megawatt. However, for shipowners, the cost for the transformation of high-voltage power on shore is 2 million yuan, and because the shore power facilities have not been popularized in all aspects, the utilization rate of shore power after the transformation is low, the economic benefit is not obvious, and the return period of investment can reach 10 years or even longer. To sum up, shipowners and port companies are not willing to build and transform shore power facilities.

(3) Low utilization and high idle rate

According to the reasons mentioned above, the popularization of shore power has been greatly hindered. Shore power is an emission reduction measure that the Chinese government attaches great importance to, so the government has launched many policies to promote the popularization of shore power. It includes a series of rigid indicators to promote the construction of shore power equipment. Nevertheless, it still

faces the problem of low utilization. In order to solve this problem, many places have adopted special preferential policies to encourage berthing ships to use shore power. Shenzhen has taken measures to discount electricity and pilotage fees, and these measures have also achieved good results. In the whole year of 2019, all ports in Shenzhen had have used 18 million kilowatt of shore power, accounting for 45% of all shore power in China. However, in fact, the utilization rate of shore power in Shenzhen is only 9%. Therefore, it can be inferred that the utilization rate of shore power in other parts of the country is very low.

5.2.2. Status of RTGs with electric driven changed from fuel driven in China's container terminals

Changing fuel driven to electricity driven for rubber tire gantry is the project that RTGs changes its driving energy from its own diesel generator to the State Grid, so as to achieve the goal of energy saving and emission reduction. Traditional RTGs are driven by diesel. Such a driving mode has a big disadvantage, that is, huge greenhouse gas emissions and huge energy consumption. In the background of China's pursuit of building green ports, the huge greenhouse gas emissions of RTGs has become an urgent problem for port authorities. As early as in the "China Energy Saving Technology Policy Outline" in 2006, the relevant departments advocated the use of high-energy efficiency equipment, and pointed out that the loading and unloading equipment with electric energy as the power source should be preferred. Among the various handling equipment, rubber tire container gantry crane driven by electricity changed from fuel has been proved to very effective in reducing greenhouse gas emissions and saving energy after testing. Therefore, it has become one of the key projects promoted by the Chinese government. The Chinese government has successively issued a series of policies to support the project. The relevant policies are summarized in the Table 4.

Year	Policy	Content
2011	<Opinions of the State Council on speeding up the development of inland water transport along the Yangtze River>	Promote the transformation of the driving mode of the RTG in the container terminal, promote the efficient energy for the port handling equipment and transportation facilities, and promote the port power supply
2011	<12th Five Year Plan for energy conservation and emission reduction of highway and waterway transportation>	Change the 1600 sets of RTGS with the value of transformation from oil driven to electric energy driven, push forward the project of replacing oil driven with electricity driven for tire crane in general cargo terminal
2011	<Implementation plan for overall promotion of energy conservation and emission reduction in water transportation during the 12th Five Year Plan Period>	According to the application of the emission reduction policy in ports nationwide, select the emission reduction methods with wide application scope and good effect, such as RTG's oil driven to electricity driven and shore power, Promote these emission reduction policies and make relevant implementation plan
2012	<Guidance of the Ministry of transport on energy conservation and emission reduction in ports>	Continue to deepen the reform of port handling machinery from oil drive to electricity driven. Complete the "oil driven to electricity driven" work of existing RTGs and the "oil driven to electricity driven" work of some RTGs in general cargo terminal. Lay out Electric RTG (ERTG) in newly built and expanded container terminals; Encourage the use of electric tire cranes in general cargo terminals. Encourage the use of fully electric driven loading and unloading machinery and horizontal transport.
2014	<Main technical policies for highway and waterway transportation>	Promote the application of new energy-saving technologies to improve the energy-saving and energy efficiency of port handling and management level, promote the application of energy feedback

		technology and frequency conversion technology of port large crane, dynamic reactive power compensation and dynamic harmonic control technology of port handling equipment, and "oil driven to electricity driven" technology of tire crane

Table 4. Policy related to changing fuel driven to electricity driven for rubber tire gantry (adapted from Ye (2015))

5.2.2.1. Emission reduction, energy saving and cost saving effect of ERTGs

At present, the project of changing fuel driven to electricity driven for rubber tire gantry has been widely implemented in a series of ports such as Shanghai port , Dalian port, Qingdao port and so on. After the test, it is found that in the port where RTGs are transformed to ERTGs, the energy efficiency of the port is improved, the greenhouse gas emission is reduced, and the economic efficiency of the port is improved.

Terminal	RTG(L/Container)	ERTG(kWh/Container)
Qingdao Qianwan Habour	1.2	2.5
Dalian DCT	1.1	3.03
Shanghai Zhanghuabang	0.9	2.9

Table 5. Comparison of RTG and ERTG energy consumption in three ports ((data from Ye (2015))

It is estimated that only about 41.5% of RTG diesel generator's operation time is in loading and unloading operation, other time is empty consumption. This is one of the reasons for the high energy consumption of RTGs. However, when RTGs is changed to electric energy drive, that is, RTGs are transformed to ERTGs, the kinetic energy of standby, air conditioning, lighting, communication and other functions is directly supplied by the municipal power, which can save a lot of energy consumption. The above table shows the energy consumption of each container in three Chinese container terminals after the project of RTGs to ERTGs. Converting the unit into standard coal, the energy saving effect of ERTGs of Qingdao Qianwan terminal is the best, which is reduced from 1.5kg standard coal per unit container to 1kg standard coal.

Compared with reducing energy consumption, the effect in reduction of GHG emissions of ERTGs is more direct and considerable. ERTGs that are transformed from RTGs incompletely only uses its original diesel generator when transferring the site. ERTGs are driven by power grid during the rest working hours. In this case, a single ERTG can reduce about 1300 tons of carbon dioxide emissions and 3.6 tons of sulfur dioxide emissions for the port every year. This data is only the emission reduction benefit of the incomplete transformation of ERTGs. After the complete transformation, it can realize that the whole operation time is driven by relatively clean electric energy, and the emission reduction rate will reach 100%.In addition to emission reduction and energy saving, ERTGs have many other advantages. ERTGs can achieve good economic benefits.

Terminal	RTG(Yuan/Container)	ERTG(Yuan/Container)
Qingdao Qianwan Habour	6.6	2.3
Dalian DCT	7.04	3.18
Shanghai Zhanghuabang	6-8	1.6

Table 6. Cost comparison of RTGs and ERTGs (data from Ye (2015))

Table 6 shows the cost comparison of each container operated by RTGs and ERTGs. It can be seen intuitively that the cost of ERTGs is greatly reduced compared with RTGs. The cost reduction is mainly in two aspects. One is the reduction of energy costs. Electricity is cheaper than diesel. The average energy cost per container processed by RTGs is 6-8 yuan, while the cost per container processed by ERTGs is reduced to 2-3 yuan. The energy cost saved is about 60%. In the other aspect, due to the reduction of daily operation time of diesel generator set, the maintenance interval is correspondingly extended, which saves many material costs such as lubricating oil and filter. In addition, the decrease of failure rate can reduce the maintenance cost. In addition, the low vibration and low noise characteristics of ERTGs can greatly improve the working environment of workers.

5.2.2.2. Technical problems of ERTGs

To sum up, the project of replacing oil drive with electric drive of RTGs can save energy consumption, reduce emissions, save costs, reduce sound pollution and improve the working environment. Similar to shore power, although ERTGs have many advantages, they are not perfect in all aspects. According to the survey, there are still many problems in the promotion and implementation of modification of RTGs in China.

(1) As the oil driven RTG to electric drive is a relatively new technology some defects may be lead in the design of ERTGs. These design defects includes slow response of ERTGs, deviation from the scheduled line, leakage, data loss, and even collision in the process of operation. Compared with RTGs, the mobility and security of ERTGs are discounted, which leads to the underutilization of ERTGs.

(2) Due to the non-linear characteristics of some equipment and loads in gantry crane, the direct use of commercial power leads to a large number of high-order harmonics in the system. These harmonics reduce the efficiency of electric energy production, transmission and utilization, overheat the electrical equipment, generate vibration and noise, and make the insulation aging, shorten the service life, or even fail or burn out. At the same time, it also seriously interferes with communication equipment and electronic equipment.

(3) The resistance of ERTGs to severe weather is very weak. Because ERTGs need a large number of electrical components. When there is thunderstorm, it will threaten the operation of ERTGs and the safety of the whole container yard.

5.2.3. Alternative fuels for ports' machinery and trailers

In order to implement the climate mitigation policy, Chinese ports have put a lot of effort into the power of port machinery, such as the electric energy driven ERTGs

mentioned in the previous section. However, electric energy has many limitations, which makes it impossible to use in all port machinery. In order to achieve the goal of emission reduction, the port has found many other clean energy sources that can replace diesel oil of port mobile machinery.

(1) Liquefied natural gas (LNG) is a typical kind of clean energy that can be used in port tractors, trailers, stackers, front cranes and patrol cars. The main component of LNG is a mixture of methane and a certain amount of ethane, propane and heavy hydrocarbons. In the process of liquefaction, a lot of impurities are removed from LNG. As a result, the purity of LNG is very high. It does not contain carbon dioxide and sulfide and is a kind of colorless and odorless gas, which has no harm to human body, and is non-toxic and non corrosive. Therefore, the emission of LNG carriers is very low, almost close to zero. Compared with the machinery driven by fuel, the emission of carbon monoxide is reduced by 97%, nitrogen oxides by 80%, carbon dioxide by 24% and sulfur dioxide by 90%.

(2) In addition to LNG, LPG (liquefied petroleum gas) can also be used as fuel for port mobile machinery. LPG is a mixture of propane and butane, usually accompanied by a small amount of propylene and butene. LPG is a mixture of oil and natural gas generated under proper pressure. The tail gas emitted by LPG driven trailers does not contain benzene and lead, and the sulfur content is extremely low. However, the content of carbon monoxide in the exhaust gas from burning LNG does not decrease significantly. Although the content of carbon monoxide in the exhaust gas is lower than that in the gasoline exhaust, the content of carbon monoxide is higher than that in the exhaust gas from burning gasoline. As carbon oxide is one of the components of greenhouse gases, LPG is not a good alternative fuel to prevent global warming.,

(3) CNG (compressed natural gas) is formed from natural gas after dehydration, filtration, dust removal, desulfurization, and then pressurized by compressor below

20MPa.The main component of natural gas is methane. Similar to LPG, CNG is also considered as a relatively clean alternative energy. Carbon monoxide and nitrogen oxides in the gas generated after combustion are lower than LNG, but the content are more than that in gasoline. Therefore, CNG is not a good choice for climate mitigation strategy.

(4) Dimethyl ether is a kind of alternative fuel which is really suitable for climate mitigation policy. The NOx emission of dimethyl ether engine is 50% lower than that of diesel engine, and the content of particulate matter, carbon monoxide and hydrocarbon in its exhaust is very low, which has a strong environmental protection advantage. In addition, in terms of performance, the test results show that the minimum stable speed, maximum speed and acceleration performance (direct gear acceleration and starting continuous shift acceleration) of the whole vehicle with DME engine are similar to those of diesel engine, and some of them are even better than diesel engine. However, it is worth considering that the average price of diesel oil in China is 7500 yuan per ton, and the combustion efficiency of diesel oil is about 1.8 times that of dimethyl ether, which means that the price of dimethyl ether should be controlled within 4100 yuan per ton in order to achieve economic benefits. Now the market price of dimethyl ether in China is between 4000 yuan and 4400 yuan per ton. If the price of dimethyl ether is higher than 4100 yuan, the DME engine will only have social benefits but no economic benefits.

5.2.4. Multimodal transport

According to China's maritime law, multimodal transport refers to the coordinated transport of multiple means of transport with at least one mode of transport by sea. Multimodal transport has advantages in many aspects. The development of multimodal transport can not only promote the transformation of transportation structure and

accelerate the structural reform of transportation supply side, but also has great guidance and practical significance for promoting the development of modern logistics and achieving cost reduction and efficiency increase. Besides, the contribution of multimodal transport to environmental protection has become another important reason for Chinese government to develop multimodal transport. More importantly, multimodal transport can effectively reduce greenhouse gas emissions. The development of multimodal transport is a climate change mitigation measure.

5.2.4.1. Current situation of sea rail combined transport in China

The main characteristics of China's Container Rail water combined transport volume are: small total volume, high concentration, fast speed and small proportion. In 2010, the total volume of China's rail water intermodal transport was only 1.627 million TEUs. In 2018, the data has successfully increased to 4.5 million TEUs. In 2020, China's ports have successfully increased the volume of rail water intermodal transport to 6.68 million TEUs. Although the data has increased by nearly 50% in the past two years, the overall business volume is still very small. China's rail water intermodal transport business is very concentrated, mainly concentrated in seven ports, namely Dalian, Yingkou, Tianjin, Qingdao, Lianyungang, Ningbo, Shenzhen and Yantian port. These ports account for about 90% of China's total through rail transportation. Nevertheless, the proportion of water rail intermodal transport volume of these ports in the overall container transport volume of the port is still very small. In 2016, the proportion of water rail intermodal transport volume of these seven ports in the total transport volume was only 2.4%, while in 2018, the proportion increased to 3.6%. Among the seven ports, only Yingkou Port has more than 10% water and rail transport capacity. There is a big gap between the water rail intermodal transport volume of ports in China and that of excellent ports outside China. For example, the data of Bremen and Hamburg ports have reached more than 30%. It can be seen that there is

still a lot of room for the development of China's ports in rail water intermodal transport. The Chinese government attaches great importance to water rail intermodal transport and has issued a lot of relevant policies to support the development of multimodal transport in China. Important documents on multimodal transport issued by Chinese government departments since 2016 are summarized in the Table 7.

Year	Policy document	Content
2016	<Notice on publishing the list of the first batch of multimodal transport demonstration projects>	Select Dalian, Yingkou, Qingdao and other port enterprises as the demonstration ports of rail water combined transport project.
2017	<Notice on further encouraging multimodal transport>	Point out the future development method and direction of national multimodal transport, and make it clear that multimodal transport has become a national strategy
2018	<Notice on printing and distributing the three year action plan for further promoting the development of multimodal transport in the Yangtze River Economic Belt>	Propose the requirement that the railway access rate of ports in the Yangtze River Delta will reach more than 80 percent and the annual average growth rate of rail water combined transport volume of key demonstration ports will be more than 15
2018	<Three year action plan for promoting transport structure adjustment (2018-2020)>	Speed up the construction and equipment upgrading of intermodal transport hub; Speed up the development of Container rail water combined transport;Encourage railway, port, shipping and other enterprises to strengthen cooperation, and promote shipping containers through railway collection and distribution ports

Table 7. Policy on the development of sea rail combined transport

With the promulgation of these documents, the development of China's rail water intermodal transport has been put into a boost. Today, the annual growth rate of container volume of rail water intermodal transportation in China's coastal ports can reach more than 30%. The growth rate of large ports such as Shanghai port and

Guangxi Beibu Gulf port can reach more than 65%. The growth rate of Shanghai port even reached an astonishing 80% in 2020. The total container volume of the first batch of seven demonstration ports (Liaoning port, Yingkou port, Qingdao, etc.) for rail water intermodal transport projects reached 5.609 million in 2020, This data is more than three times of the national port data in 2010. It can be seen that China's rail water intermodal transport is on an expressway. However, in order to achieve the rapid development of China's rail water intermodal transport, there are still some problems to be solved by government departments

(1) The arrival railway does not realize the interconnection of all port areas, which leads to the short-distance connection operation of containers in the process of transportation to each port area, resulting in the reduction of transportation efficiency, the increase of cost and the decrease of safety.
(2) The railway station facilities in some inland ports are very old, which can not meet the needs of the port for the combined transport of rail and water, leading to the stagnation of the development of the combined transport of rail and water in some inland ports.
(3) The construction of rail water transport is limited by urban planning and land use. Some ports need to expropriate a large amount of land for the construction of rail water transport, which leads to such practical problems as excessive investment in infrastructure.
(4) Because the railway and port belong to two systems respectively, the information of railway system is not released to the public, resulting in insufficient information exchange. The ports cannot track the location and arrival information of containers, so it cannot arrange the operation in advance, which reduces the efficiency.
(5) There are many independent standards for railway and waterway transportation, such as business data standard, goods name code, document format standard, safety

management system, freight charging rules, packaging and loading requirements, insurance and compensation standard, goods handover service specification, responsibility identification, etc.

6. Analysis of the tendency to CCM strategy

Climate change mitigation and climate change adaptation are all considered successful climate change srategies. In many fields, scholars believe that climate change adaptation and climate change mitigation should be adopted at the same time, so as to minimize the impact of climate change while mitigating the speed of climate change. However, it is undeniable that in today's situation, mitigation strategy has received far more attention than adaptive strategy. The same is true in ports. Many ports invest more on reducing greenhouse gas emissions and building more environmentally friendly ports, but not on making ports better cope with various extreme climate and marine phenomena caused by climate change. This tendency is a topic worthy of study. In this paper, the following would like to compare the implementation of the two strategies in the port to explore the reasons for this tendency and its rationality.

6.1. Trade-offs and conflict between CCM and CCA

Some scholars believe that climate change adaptation is opposite to climate change mitigation. They should not be used to deal with climate change at the same time because there are many trade-offs between them. Trade-offs mean that when two strategies are implemented at the same time, one strategy will have a negative impact on the implementation of the other strategy. This paper has mentioned many trade-offs

between climate change adaptation and climate change mitigation that occur in many areas. The typical trade-off is that some climate change adaptation measures will lead to more greenhouse gas emissions, thus reducing the effect of climate change mitigation. A similar observation called inducing effect appears in the traffic engineering. In order to alleviate the road congestion, traffic planners may take the method of increasing the number of lanes. But this method may make the congestion more serious because more lanes will induce more cars to the road. The same is true for ports. The use of CCA and CCM at the same time may reduce the effect in some aspects. For example, the change of oil power drive to electric power drive for tire cranes is a typical climate change mitigation measure in ports. However, due to the direct use of electricity as energy supply, high-voltage cables and a large number of electrical components increase the risk of system security. The overhead sliding contact wire adopted by ERTGs (Electric rubber tyred container gantry crane) has poor ability of resisting strong wind and lightning. When extreme weather such as tropical storm and typhoon comes, it will greatly reduce the safety factor of the port. In other words, although the port can reduce port emissions through such mitigation measures, such projects will affect the effect of port adaptation measures. Correspondingly, there is also the situation that climate change adaptation discount the benefits of climate change mitigation. Although the adaptation policy has been proved to have a good effect in dealing with extreme climate and sea level rise, the port's adaptation strategy will inevitably increase the operation of the port. Increasing the operation may greatly reduce the port's efforts in dealing with climate change, for example, it will increase emissions and reduce the benefits of the mitigation strategy. However, the marginal impact of CCA on the port is less than that of CCM. In other words, CCM may have more side effects on the port's efforts to cope with climate change. Although CCM is considered to be a more orthodox way to deal with the impact of climate change, CCA is more excellent in this aspect, because it has less stimulation to the port to deal with

climate change. Of course, the position of CCM cannot be overturned by this point. At least it can show that it's not advisable to pay attention to CCM and ignore CCA unilaterally.

6.2. Economic factors restricting the common development of CCM and CCA

There are not only trade-offs but also economic conflicts between CCM and CCA. Gong et al. (2020) talked about port expansion and natural disasters prevention in his article. According to Gong's article, when the investment budget of the port is lower than medium, the port will not choose to invest in CCA, but will greatly focus on the expansion of port capacity budget by an economic model. In fact, the issue is very meaningful. Many measures of mitigation strategy will greatly increase the capacity of the port. For example, multimodal transport is a climate mitigation strategy. In order to realize the multimodal transport of the port, the port needs to build railways or demolish the surrounding areas of the port, which has been mentioned in 5.2.4.1. Thus, CCM can be seen as the expansion of the ports capacity. The prevention of natural disasters mentioned in Gong's article is very similar to CCA strategy. Therefore, Gong's article can be used to better understand whether the port should give priority to CCM or CCA when considering economy. In the case of high and low port budget, private port and public port, the investment priority of port to CCM and CCA is different.

From an economic point of view, it is well-established that ports now tend to invest in CCM rather than CCA. More investment in CCM can ensure that port assets are not affected by currency depreciation. Due to the uncertainty of extreme climate, it is more risky for port managers to invest in CCA. According to reliable data, sea level may not rise significantly until 50 years later, and the service life of port assets may not reach 50 years. Port managers have every reason to replace these assets before the sea level rises sharply within 50 years, and there is no need to invest in CCA. It may seem that

such a decision is not farsighted, but for port managers, they still prefer to invest in the capacity building of the port first rather than CCA. When the capacity of the port expands to a certain extent, the focus of investment may also change. It can be concluded that the greater the capacity of the port, the higher the investment level of the port should be in CCA. Because the larger the operation range of the port, the greater the impact it will receive after encountering extreme weather.. In addition to port capacity, the intensity of extreme climate phenomena caused by climate change will also affect the investment tendency of port managers. The greater the intensity of extreme climate, the more likely port managers are to invest in CCA strategy. Compared with private ports, this phenomenon is more obvious in public ports. The reason is that the assets of public owned ports actually belong to the public rather than private, so in the face of disasters, port managers will pay more attention to the safety of port property. There is a very important corollary to this conclusion. In the future, with the further development of global climate change, extreme climate is likely to become more and more serious. This means that the port investment will be transferred to CCA step by step, and even CCA may become a compulsory plan, which is very different from today's situation.

6.3. Policy and social reputation building

In addition to economic factors and trade-offs, the tendency between CCM and CCA is also related to the policy and social reputation. The policy support for CCM is often greater than that for CCA. There are many possible reasons.

One possibility is that policy makers may think that the consequences of climate change will not cause significant differences in the future. But there are regional differences in this point. For example, if some areas are affected by tropical storms more than other areas every year, the authorities in these areas may give CCA a higher priority.

Another possibility is that the unpredictability and uncertainty of climate change are too strong which make the authorities lack some accurate understanding of the consequences of climate change.

There is also a possibility that the authorities think that the urgency of climate change is not strong enough. For example, sea level rise may not be significant until 50 years later, and port managers have enough time to prepare for other port assets. So they don't think it's time to pay attention to CCA.

As far as China is concerned, the Chinese government has issued many policies and action plans to support the emission reduction actions of Chinese ports. The Chinese government has explicitly listed the CCM policy of ports as one of the goals of building first-class ports. Some specific measures to reduce emissions, such as the development of water rail intermodal transport, have even been raised to one of the national strategies. It can be seen that the Chinese government attaches great importance to the CCM policy of ports. By contrast, CCA has received much less attention. The Chinese government has issued some action plans to cope with extreme weather caused by global climate change, but it has not issued a specific action plan for it. Port organizations generally believe that CCM is more conducive to implementation than CCA, because the policy support of CCM is greater than CCA. Another important reason is that compared with CCA, it is easier for ports to establish a good image among the public by implementing mitigation strategies(Lin et al. (2020)). If ports pay too much attention to CCA, they may inadvertently exaggerate the negative impact of climate change and the vulnerability of ports.

7. The actual investigation of Shanghai Port

In the chapter 6, the comparison between the climate change adaptation strategy and the climate change mitigation strategy of the port has been fully elaborated. These comparisons are deduced through the research and analysis of the literature. In order to verify the correctness of these conclusions and make them have more practical significance, this paper decides to make an empirical analysis of the actual situation of Shanghai Port in China, and uses the analytic hierarchy process model to compare CCM and CCA so as to analyzes which strategy Shanghai port should consider more investment.

7.1. Scope of investigation

Shanghai Port Group Co., Ltd. is a state-owned terminal operator in Shanghai. Shanghai Port Group has set up many subsidiary companies to manage its ports, including Shengdong International Terminal Co., Ltd. in Yangshan Port and Zhendong International Terminal Co., Ltd. in Waigaoqiao port. This paper found 10 senior employees from the two largest port areas (Shanghai Waigaoqiao Container Port and Yangshan Deep Water Port) in Shanghai and conducted in-depth interviews with them (the contents of the questionnaire are shown in Appendix A). The official positions involved manager of personnel department, manager of engineering department, manager of general manager's office, secretary of party committee and employees of operation department, engineering department and information department (the list of the respondents' position and length of service is shown in Appendix B).

7.2. Brief introduction of Yangshan Deepwater Port and Waigaoqiao Port

Yangshan Port is about 32 km away from Luchao port in Nanhui of Shanghai in the northwest, 90 km away from Beilun port in Ningbo in the south, and only 45 nautical

miles away from international routes. It is the closest deep-water port to Shanghai and has become the new coordinate of Shanghai international shipping center. Yangshan Deepwater Port is now mainly composed of four main terminal areas. The first phase and the second phase of Yangshan port are managed by Shengdong International Terminal Co., Ltd..The third phase of Yanshan port is managed by Guandong International Terminal Co., Ltd.. The fourth phase of Shanghai Yangshan Deepwater Port, which was opened for trial operation at the end of 2017, is managed by Shangdong International Terminal Co., Ltd., which is also the largest fully automatic terminal in the world. Now Yangshan Deepwater Port has a total of 8 km long quay line, 88 bridge cranes and 23 container berths. In 2020, the throughput of Yangshan Port exceed 20 million TEUs. In January 2021 alone, the throughput of Yangshan Port broke the historical record, reaching 1.965 million TEUs.

Waigaoqiao Port connects the Yangtze river deep water coastline and Waigaoqiao Free Trade Zone. It is about 7 km away from Wusong port in the West and 85 km away from the Yangtze River Estuary in the East. The first phase of the Waigaoqiao terminal is is a quayside wharf. It is operated and managed by Shanghai Pudong International Container Terminal Co., Ltd., with a coastline of 900 meters, three container ship berths and an annual throughput of about 2.6 million TEUs.. The second and third phase terminals are operated and managed by Shanghai Zhendong international container Co., Ltd. The phase II and phase III terminals have a total coastline of about 1600 meters and five container berths, and the annual throughput exceeded 6 million TEUs since 2013. In 2020, the phase II and phase III terminals completed a total of 6.12 million TEUs. In addition to the first, second and third phases, Waigaoqiao port has developed the fourth, fifth and sixth phases of wharfs.

7.3. Propositions from the combination of literatures and the actual situation of Shanghai Port

After interviewing the senior managers and basic staff of several main terminals in Shanghai port, this paper has basically understood the attitude of Shanghai Port towards the two strategies and can put forward several propositions through the previous literature research and the actual situation.

(1) Proposition 1. Respondents believe that Shanghai Port pays more attention to return than investment.

Shanghai Port pays more attention to the return compared with investment. This may be due to the fact that Shanghai Port Group is a publicly owned and state-owned port company. Compared with private companies, public companies generally tend to pay less attention to cost control and pay more attention to return.

(2) Proposition 2. CCM needs more investment than CCA

CCM needs more investment than CCA, which can be explained by Jiang's theory. Jiang et al. (2020) proposed that the marginal effect of CCM on port operation is greater than that of CCA. It is inevitable that CCM will need more investment than CCA. This is also considered to be a major advantage of CCA, that is, less investment is required. This can also be proved by some facts, such as the multimodal transport of the port mentioned in 5.2.4.1, which has a great marginal impact on the operation of the port and require a lot of investment.

(3) Proposition 3. CCM will bring more economic benefits than CCA

Although CCM needs more investment, it will also bring better returns to the port, sometimes these returns are not just about reducing emissions. For example, in addition to the emission reduction effect, multimodal transport will also bring economic benefits and higher efficiency to the port. Similar to multimodal transport,

other climate change mitigation measures of the port, such as the project of tire crane oil power to electric power drive and shore power, most can achieve economic benefits while reducing emissions. Compared with CCM, CCA can hardly bring ancillary economic benefits to the port except for coping with extreme climate and sea level rise. CCA is inferior to CCA in this respect.

(4) Proposition 4. CCA can effectively reduce the vulnerability of the port, CCM may make the port more vulnerable in the face of extreme weather

The goal of CCA is to improve the port's ability to cope with extreme climate in the short term. Therefore, compared with CCM, the vulnerability of ports to extreme climate will be significantly reduced after the implementation of CCA strategy, which is also the biggest feature and advantage of CCA.

Different from CCA, CCM cannot not effectively reduce the vulnerability of the port, instead may make the port more vulnerable in the face of extreme climate. For example, ERTGs are rubber tyred container gantry cranes that uses electricity. Compared with tyre cranes in the past, the greenhouse gas emissions of ERTGs is about zero, which can alleviate the global climate change. However, due to more electrical components of ERTGs and the external sliding contact line that ERTGs need to track, the ability of port to cope with extreme weather such as tropical storm or typhoon will be weakened. According to the respodents, the failure rate of ERTGs shows a significant increase after heavy rain and storm. If Shanghai Port wants to achieve the goal of reducing port vulnerability and improving port resilience to disasters, CCA should be implemented rather than CCM.

(5) Proposition 5. The effect of CCM strategy of Shanghai Port is remarkable

Respondents believe that the emission reduction effect of Shanghai port is excellent. This is not only a subjective judgment, but also can be proved by some objective data. By the end of 2020, the proportion of LNG application of truck tractors in Shanghai port reach 95%, and the proportion of energy-saving RTGs such as hybrid power reach 90%. Some port operation companies have tried out photovoltaic power generation projects. According to the calculation of a certain port area, the photovoltaic power generation project can reduce the CO2 emission of the port area by 1500t per year. Compared with 2018, the comprehensive energy consumption of Shanghai port in 2020 decreased by 30000 tons of standard coal to 400000 tons of standard coal.

(6) Proposition 6. For Shanghai port, the policy support of CCM is more than that of CCA

Policy support is very important for a company or an industry, especially for public and state-owned enterprises. In this regard, it is undoubtedly very beneficial for Shanghai Port to implement CCM policy. The Chinese government attaches great importance to the CCM strategy. The government has issued many guiding policies to support the CCM strategy of ports, which has been discussed in detail in 5.1. Chinese government also provides many policy support for many specific port emission reduction measures, such as the construction of multimodal transport, shore power facilities, oil to electricity driven transformation of port tyre crane, etc. (5.2.1, 5.2.2 and 5.2.4.) In contrast, the policy support of CCA strategy is much less. There are only some sporadic guiding policies on prevention of typhoon and flood, but no complete and systematic policies. Therefore, it is undoubtedly very beneficial for Shanghai port to implement CCM rather than CCA.

(7) Proposition 7. CCM strategy needs more technical support than CCA strategy

Compared with CCM, CCA needs less technical support. There are few aspects of CCA that need scientific and technological support, such as monitoring sea level and wave height, forecasting extreme weather, etc. In addition, some scholars also put forward a very interesting CCA measures that need technical support. The port changes the wharf apron into a floating wharf floating on the sea. In this way, the port does not need to change the design elevation of the wharf to cope with the rise of sea level, because the elevation of floating wharf will change according to the height of sea level. But this is only a novel idea, no container port has realized it. Compared with CCA, CCM needs relatively higher required technical support. For example, many technical difficulties need to be overcome in the conversion of oil power drive to electric power drive for RTGs (mentioned in 5.2.2.2). Fortunately, Shanghai Port has done a good job in this aspect. According to the interviewees, Shanghai Yangshan Port has fully realized the electric power drive of the RTGs. All the ERTGS are rail cranes, that is, the ERTGs operate according to the pre-designed track, which can avoid all kinds of problems arising when ERTGs transfer site. In addition to ERTGs, the port's shore power facilities are also a project in great need of technical support. According to the interviewees of Shanghai port, the utilization rate of shore power in Shanghai port is still relatively low. Part of the reason is that the technology is not very mature. The use of shore power needs to cooperate with ship owners to transform the ship, but the transformation rate of the ship is not high at present. In addition, because the voltage in China does not match the voltage of foreign ships, many times we have to carry out voltage transformation and other work, which makes the use of the program more complicated. Besides, the shore power also needs to solve the harmonic problem and so on. The technology required by shore power facilities is quite complex.

(8) Proposition 8. The frequency and intensity of extreme weather phenomena will greatly affect the preference of Shanghai port for CCM and CCA

The frequency and intensity of extreme climate phenomena caused by global climate change are very important factors to consider for ports to choose climate change response strategies. When the port capacity and investment level are higher, the intensity and frequency of extreme climate will greatly affect the port's choice of climate change response strategy. The reason is that extreme weather will cause more damage to ports with large capacity. The total assets' value of Shanghai Port Group Co., Ltd, the operating company of Shanghai port, had reached 155.9 billion yuan by 2020, and the net profit reached 8.3 billion yuan in 2020 alone. Based on these facts, it can be inferred that the capacity and investment level of Shanghai port are very high, so the frequency and intensity of extreme climate will have a significant impact on the choice of climate strategy of Shanghai port according. In addition, public ports are more likely to invest in CCA strategy than private ports when the intensity and frequency of extreme climate increase. This is because the assets of public ports belong to the public, and port companies should be more responsible for the safety of these assets. Shanghai Port Group Co., Ltd. is a state-owned enterprise, so the frequency and intensity of extreme climate will greatly affect the choice of climate strategy of Shanghai port. This is also confirmed by the results of the actual investigation. The ten respondents of Shanghai port scored the highest on the importance of frequency and intensity of extreme weather phenomena among all five rule factors, which means that they think that frequency and intensity are the most important factors to consider.

(9) Proposition 9. The intensity and frequency of extreme climate in the future are uncertain, which makes the port despise CCA strategy

According to Gong et al. (2020), port investment in prevention of extreme weather is closely related to the intensity and frequency of extreme climate. The respondents think that the intensity and frequency of extreme climate are not so high. They think

that the existing typhoon and flood control measures of the port are enough to cope with the extreme climate experienced by Shanghai port at the present stage, and they think that the design elevation of the port wharf and the elevation of the breakwater are also high enough. As long as the sea level does not rise extremely in the short term, the operation of the port will not be affected greatly. Even the respondents of Waigaoqiao Port believe that sea level rise will also have a beneficial impact on the operation of the port (the waterway depth of Waigaoqiao port has always been a stumbling block that hinders Waigaoqiao port from becoming a larger port). If sea level rise, the water depth of the port can be deepened, and larger ships can be allowed to enter and leave the port. On the other hand, according to Wang and Zhang (2018), the variance of climate change will lead ports to reduce investment in CCA strategy. Wu and Ji (2013) point out that China's large-scale and long-span climate change prediction is basically accurate, but because the climate change prediction technology is still in its infancy, there is still great uncertainty in the short-term prediction of specific regions. In other words, it is difficult to accurately predict the impact of extreme climate and sea level rise on Shanghai port in the future, which may reduce the possibility of port investment in CCA strategy.

(10) Proposition 10. Compared with CCA, CCM is more conducive to the maintenance and establishment of port reputation

In addition to some tangible factors, the respondents of Shanghai Port believe that the establishment and maintenance of port’s reputation would also affect the port's choice of climate change response strategy. They think that compared with climate change adaptation strategy, climate change mitigation strategy is more helpful to help the port establish a good corporate reputation and image in the society and customers. Good reputation can bring more positive publicity, more customers and higher social status

to the company, which is also very important. Besides, reputation is not only reflected externally, but also plays a role within the company. According to the respondents from Waigaoqiao Port, the job satisfaction of the workers in the terminal has increased significantly after the transformation of the electric energy drive of the tyre crane in the port area. The reason is that the diesel driven RTGs will emit a lot of greenhouse gases and produce noises in the port area, which leads to the bad working environment of workers. After the electric energy transformation of RTGs, this phenomenon has been greatly improved. The air quality inside the port has been improved and the noise has been reduced. After the implementation of some climate change mitigation measures, the reputation of the port company in the hearts of internal staff has been maintained, which is conducive to the healthy and stable development of the company. Respondents generally believe that whether it is internal team building or external reputation building, respondents the climate change mitigation strategy is more helpful to the company.

8. Establishment of AHP model

8.1. Introduction of AHP model

Analytic hierarchy process, referred to as AHP, is a decision-making method that decomposes the elements related to decision-making into objectives, criteria, schemes and other levels, and carries out qualitative and quantitative analysis on this basis. The first step of the analytic hierarchy process is to establish a hierarchical structure model. The goal is to divide the decision-making objectives, factors (decision criteria) and objects into the highest level, middle level and lowest level according to their

relationship, and draw a hierarchical structure diagram. The highest level refers to the purpose of decision-making and the problems to be solved. The lowest level refers to the alternatives in decision-making. The middle layer refers to the factors considered and the criteria for decision-making. For two adjacent layers, the high layer is called rule layer, and the low layer is called index layer.

8.2. Hierarchical model diagram

According to the factors interviewees provide that may affect Shanghai port's choice of climate change response strategy, the paper creates a hierarchical model diagram (Figure 1). Detailed reasons for the selection of indicators and the explanation of indicators are shown in the Table 8.

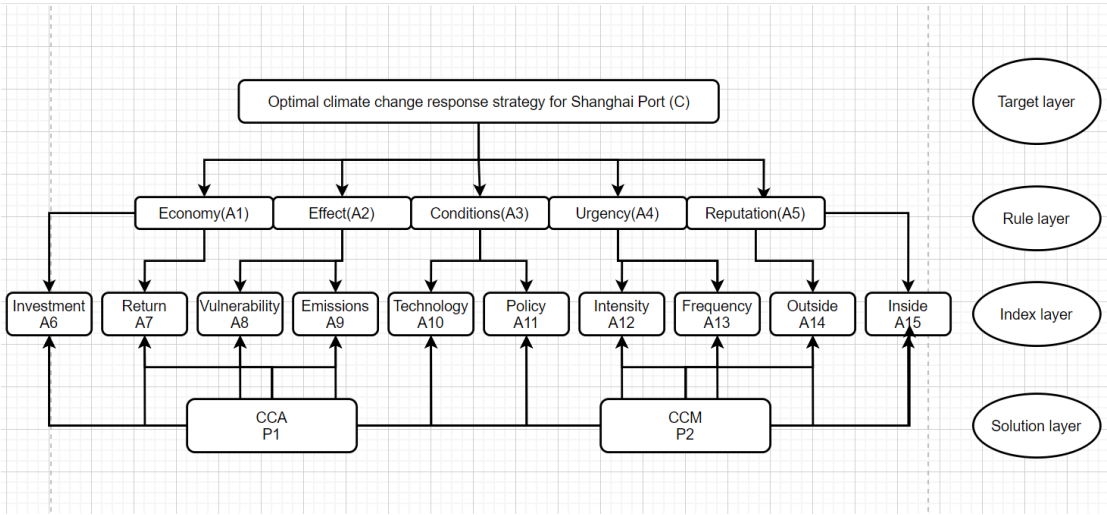

Figure 1. Hierarchical model diagram

Economy	Investment	The economic factor is one of the important factors for port enterprises to choose a strategy.
	Return	
Effect	Vulnerability	The "effect" here refers to whether the vulnerability of the port has been reduced after the implementation of CCA strategy and whether the greenhouse gas emissions have been significantly reduced. Vulnerability and emission reduction are the fundamental
	Emissions	

		objectives of CCA and CCM. If the implementation of the strategy does not achieve effective results, it will certainly reduce the investment desire of the port to this strategy.
Condition	Technology	According to the respondents, conditions are also one of the important factors, such as policy support and scientific and technological capability. Take shore power for example. The promotion of shore power needs preferential policies from the government for shipowners(5.2.1.1). At the same time, shore power also has many technical difficulties that need to be solved by sufficient technical ability.(mentioned in 5.2.1.1)
	Policy	
Urgency	Intensity	According to Gong et al. (2020), the intensity and frequency of extreme climate phenomena caused by climate change will affect the port's choice of climate change strategy. Generally, the greater or higher the intensity or frequency of extreme climate, the port will be more inclined to climate change adaptation strategy.
	Frequency	
Reputation	Outside	In addition to some visible indicators, intangible indicators will also affect the port's strategic choice, such as reputation. Good reputation can bring benefits to the port, such as more customers, etc. According to interviewees, port practitioners generally believe that CCM is easier to set up a good social image for the company than CCA. And climate response strategy will also have an impact on the company's internal. A good example is that the bridge crane drivers are definitely more inclined to CCM, because CCM can effectively reduce the various pollution in the port yard, so that their working environment is better.
	Inside	

Table 8. Explanation of the indicators

8.3. Calculation process

8.3.1. The construction of the first-level judgement matrix

The construction of judgment matrix is generally carried out by nine point scale method. In the matrix, $a_{ij}$is the comparison result of the importance of element i and element j.

Judgement	Value
Element i is as important as element j	1
Element i is slightly more important than element j	3
Element i is obviously more important than element j	5
Element i is far more important than element j	7
Element i is extremely more important than element j	9
Intermediate value of adjacent judgment	2,4,6,8

Table 9. Nine point scale method

Ten interviewees were asked to make the pairwise comparison of the importance of five elements in the rule layer and score them according to Table 9.The scores were averaged to get the first-level index judgment matrix in Table 10.

	A1	A2	A3	A4	A5
A1	1	0.555556	0.454545	0.357143	0.37037
A2	1.8	1	1.3	1	1.5
A3	2.2	0.769231	1	0.6	1.1
A4	2.8	1	1.666667	1	1.4
A5	2.7	0.666667	0.909091	0.714286	1

Table 10. The first-level index judgment matrix

8.3.2. Consistency check

In order to verify the rationality of the results, it is necessary to test the consistency of the first level judgment matrix. Equation 1 and Equation 2 were used to calculate CI and CR. The value of Cr can be found in Table 11. Standard value of average random consistency index RI according to the order of the matrix.

$$\mathrm{CI} = \frac{(\lambda max - n)}{n - 1}$$

Equation 1

$$\mathrm{CR} = \frac{CI}{RI}$$

Equation 2

Matrix order	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 11. Standard value of average random consistency index RI

In general, If CR is less than 0.1, the consistency of the judgment matrix can be considered acceptable, otherwise the judgment matrix needs to be modified.CI, RI and CR is calculated to be 0.014801, 1.12 and 0.013215 respectively, which proves that the matrix has passed the consistency test.

8.3.3. The construction of the second-level judgement matrix

Similarly, according to average of the importance scores of the index layer, the second-level index judgment matrices are obtained. (Table 12, Table 13, Table 14, Table 15 and Table 16)

A1	A6	A7	Weight
A6	1	1.7	0.62963
A7	0.588235	1	0.37037

Table 12. Second-level judgment matrix of A1

A2	A8	A9	Weight
A8	1	0.8	0.444444
A9	1.25	1	0.555556

Table 13. Second-level judgment matrix of A2

A3	A10	A11	Weight
A10	1	1.2	0.454545
A11	0.833333	1	0.454545

Table 14. Second-level judgment matrix of A3

A4	A12	A13	Weight
A12	1	0.666667	0.4
A13	1.5	1	0.6

Table 15. Second-level judgment matrix of A4

A5	A14	15	Weight
A14	1	0.4	0.285714
A15	2.5	1	0.714286

Table 16. Second-level judgment matrix of A5

8.3.4. The calculation of the weight scores of the indexes in the index layer

The first-level judgment matrix can be transformed into the normalized matrix (Table 17) and the weight scores of the five indexes (Table 18) in the rule layer are obtained then.

A1	0.095238	0.139186	0.085276	0.097276	0.068966
A2	0.171429	0.250535	0.243889	0.272374	0.27931
A3	0.209524	0.192719	0.187607	0.163424	0.204828
A4	0.266667	0.250535	0.312678	0.272374	0.26069
A5	0.257143	0.167024	0.170551	0.194553	0.186207

Table 17. The normalized matrix

	Weights
A1	0.097188
A2	0.243507
A3	0.19162
A4	0.272589
A5	0.195095

Table 18. Weight scores of the indexes in the rule layer

The comprehensive evaluation index system is calculated by multiplying the weight of the second-level indexes (Table 12, Table 13, Table 14, Table 15 and Table 16) and the corresponding weights of the first-level indexes (Table 18). The results are shown in Table 19.

Target layer	Rule layer	Index layer	Weight
	A1(0.0972)	A6(0.6296)	0.0612
		A7(0.3704)	0.0360
	A2(0.2435)	A8(0.4445)	0.1082

		A9(0.5556)	0.1353
	A3(0.1916)	A10(0.5455)	0.1045
		A11(0.4545)	0.0871
	A4(0.2726)	A12(0.4)	0.1090
		A13(0.6)	0.1636
	A5(0.1951)	A14(0.2857)	0.0557
		A15(0.7143)	0.1394

Table 19. Target total ranking

8.3.5. The construction of the scheme level judgment matrix

According to the respondents' ratings, the relative importance of the alternative climate response strategies relative to the elements in the rule layer can be determined by pairwise comparison. The judgment matrices of the scheme layer are obtained as follows. (from Table 20 to Table 29)

A6	CCA	CCM	Weight
CCA	1	2	0.6667
CCM	0.5	1	0.3333

Table 20. The judgement matrix of A6

A7	CCA	CCM	Weight
CCA	1	0.33	0.25
CCM	3	1	0.75

Table 21. The judgement matrix of A7

A8	CCA	CCM	Weight
CCA	1	2.8	0.7368
CCM	0.3571	1	0.2631

Table 22. The judgement matrix of A8

A9	CCA	CCM	Weight
CCA	1	0.2857	0.2222
CCM	3.5	1	0.7778

Table 23. The judgement matrix of A9

A10	CCA	CCM	Weight
CCA	1	1.3	0.5652

CCM	0.769231	1	0.4348

Table 24. The judgement matrix of A10

A11	CCA	CCM	Weight
CCA	1	0.285714	0.2222
CCM	3.5	1	0.7778

Table 25. The judgement matrix of A11

A12	CCA	CCM	Weight
CCA	1	1.2	0.5455
CCM	0.833333	1	0.4545

Table 26. The judgement matrix of A12

A13	CCA	CCM	Weight
CCA	1	1.1	0.5238
CCM	0.909091	1	0.4762

Table 27. The judgement matrix of A13

A14	CCA	CCM	Weight
CCA	1	0.357143	0.2631
CCM	2.8	1	0.7368

Table 28. The judgement matrix of A14

A15	CCA	CCM	Weight
CCA	1	0.2857	0.2222
CM	3.5	1	0.7778

Table 29. The judgement matrix of A15

8.3.6. The calculation result

According to Table 20-Table 29, the matrix of scores can be summarized in Table 30.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	10
CCA	0.666667	0.25	0.736842	0.222222	0.565217	0.222222	0.545455	0.52381	0.263158	0.222222
CCM	0.333333	0.75	0.263158	0.777778	0.434783	0.777778	0.454545	0.47619	0.736842	0.777778

Table 30. The matrix of scores

By multiplying the score matrix in table 31 and the matrix in table 18, the weight scores of the two strategies can be obtained in Table 31 .

Scheme	Scores
CCA	0.4288
CCM	0.5712

Table 31. Comprehensive weight scores of CCA and CCM

9. Conclusion and limitations

9.1. Conclusion of the AHP model

According to the actual situation and the results of AHP model, the result can be obtained that Shanghai Port prefers climate change mitigation strategy to climate change adaptation strategy. However, there are several points that need to be noted. The first point is that this conclusion does not mean that Shanghai Port completely ignores climate change adaptation. Shanghai Port also has specific measures for typhoon prevention and flood control. The second point is that this conclusion only holds at the present time point. The future trend must be that CCM and CCA will be in parallel to achieve the best response to global climate change. One reason is that CCM and CCA have their own advantages. For example, CCA has less marginal impact on the port compared with CCM. The second reason is that extreme climate and sea-level rise will become more and more obvious with the passage of time, which makes the CCA strategy that is despised now gradually valued by people, and the government's policy support for CCA will correspondingly increase. In the future, CCA strategy may develop into one of the strategies that the port must implement, and

its status may reach the same or even higher level as CCM.

9.1.1. Analysis of AHP results

The following is to analyze why Shanghai port is more inclined to climate change mitigation strategy nowadays.

(1) Economic factors also prove that it is more economical for ports to choose CCM strategy. Although CCM strategy needs more investment, its return is also very large. Compared with CCA, CCA strategy has little return. The low return of CCA may lead to the depreciation of port assets, which is also the reason why many ports do not choose CCA strategy. However, respondents believe that economic factors are not one of the first factors to be considered when Shanghai Port chooses the global climate change response strategy. They believe that, compared with economic factors, Shanghai port should give priority to the effect of strategy and the frequency and intensity of extreme weather when selecting the strategy.

(2) CCA strategy helps to reduce the vulnerability of Shanghai port, and CCM strategy can help Shanghai port to reduce emissions effectively. Respondents believe that the reduction of emissions is more important than the reduction of vulnerability for the time being. Therefore, in terms of the implementation effect, the weight score of CCM is slightly higher than that of CCA.

(3) The urgency of extreme climate and sea level rise will promote the implementation of CCA. However, respondents think that the extreme climate and sea-level rise that Shanghai Port suffers have little impact. The port only needs to take some basic protective measures before the extreme climate arrives, for example, let the bridge crane enter the rivet hole and fix it with wind proof tie rod. Respondents working in Yangshan Port believe that the sea-level rise will not affect the port operation in the short or medium term because the wharf elevation of Yangshan Port and is high enough. On the contrary, they think that the rise of sea level will

deepen the channel depth of the port, which is even a good thing. Therefore, in terms of urgency, the weight score of CCA is not high.

(4) Easier to implement makes CCA another big advantage over CCM.CCA does not require ports to have a lot of technical capacity, and many CCM measures require high-end technology. However, the technical capability of Shanghai Port is excellent. It is reported that the proportion of LNG application of container truck tractor in Shanghai port has reached 95%, and the proportion of energy-saving RTG has reached 90%. Shore power is also steadily promoting the construction. In addition to these basic measures, Shanghai Port is also trying to take new emission reduction measures such as photovoltaic power generation. Therefore, in fact, Shanghai Port hardly needs to worry about the obstacles of CCM strategy due to insufficient technical capacity. It makes the CCM strategy of Shanghai Port go smoothly.

(5) Both of policy support and reputation building boost Shanghai port to implement CCM strategy.

It can be summarized and emphasized that Shanghai Port is more inclined to climate change mitigation strategy at present due to the full policy support, strong technical capacity, collateral economic benefits brought by CCM, excellent emission reduction effect, better reputation building and internal team building. By contrast, insufficient government attention, low intensity and frequency of extreme climate, no obvious sea level rise and no obvious economic benefits all restrict the implementation of climate change adaptation strategy in Shanghai Port.

9.2. Limitations

This paper studies the attitude of Shanghai Port towards the two main climate change coping strategies (climate change mitigation and climate change adaptation) through on-site interview and questionnaire survey, and compares the applicability of the two

strategies through AHP model. It comes to the conclusion that the climate change mitigation strategy is more meaningful for Shanghai Port at present. However, there are still some limitations. The first limitation is that the research of this paper is mainly based on the subjective attitude of port managers and employees towards climate change strategy, and lacks some objective data to evaluate the two strategies. The second is that climate change is ongoing, so the research content of this paper is timely. Especially for CCA strategy, with the continuous change of climate, the implementation of CCA strategy will also change. Therefore, the current research results can not represent the comparison results of CCM and CCA in the future. It is hoped that future scholars will make further and even predictive research on these two strategies on the basis of this paper.

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APPENDIX A. QUESTIONAIRE

Please indicate your information:

Port:
Company:
Position:
Working period:

Please rate the following questions according to the scoring criteria in the table. (For example, if you think that economic factors are important, please write "economic factor" and rate the importance according to the table).

Judgement	Value
Element i is as important as element j	1
Element i is slightly more important than element j	3
Element i is obviously more important than element j	5
Element i is far more important than element j	7
Element i is extremely more important than element j	9
Intermediate value of adjacent judgment	2,4,6,8

The main theme of this questionnaire is climate change response strategy (adaptation strategy and mitigation strategy).

(1) When Shanghai Port selecting climate change strategies, what do you think is the importance of economic factors(i) (investment and return) compared with implementation effect(j) (vulnerability and emission reduction achievements)?

(2) When Shanghai Port selecting climate change strategies, what do you think is the importance of economic factors(i) (investment and return) compared with the urgency(j) (Intensity and frequency) of extreme weather and sea level rise?

(3) When Shanghai Port selecting climate change strategies, what do you think is the importance of economic factors(i) (investment and return) compared with the condition(j) (technology capacity and policy support)?

(4) When Shanghai Port selecting climate change strategies, what do you think is the importance of economic factors(i) (investment and return) compared with the reputation(j) (social reputation and reputation establishment among staff)?

(5) When Shanghai Port selecting climate change strategies, what do you think is the importance of implementation effect(i) (vulnerability and emission reduction achievements) compared with the urgency(j) (Intensity and frequency) of extreme weather and sea level rise?

(6) When Shanghai Port selecting climate change strategies, what do you think is the implementation effect(i) (vulnerability and emission reduction achievements) compared with the condition(j) (technology capacity and policy support)?

(7) When Shanghai Port selecting climate change strategies, what do you think is the implementation effect(i) (vulnerability and emission reduction achievements) compared with reputation(j) (social reputation and reputation establishment among staff)?

(8) When Shanghai Port selecting climate change strategies, what do you think is the importance of urgency(i) (Intensity and frequency) of extreme weather and sea level rise compared with the condition(j) (technology capacity and policy support)

(9) When Shanghai Port selecting climate change strategies, what do you think is the importance of urgency(i) (Intensity and frequency) of extreme weather and sea level rise compared with the reputation(j) (social reputation and reputation establishment among staff)?

(10) When Shanghai Port selecting climate change strategies, what do you think is the importance of the condition(i) (technology capacity and policy support) compared with reputation(j) (social reputation and reputation establishment among staff)?

(11) The importance of Investment compared with return in Shanghai Port?

(12) The effect of climate vulnerability reduction when implementing CCA compared with emissions reduction when implementing CCM ?

(13) The importance of frequency of extreme weather compared with the intensity of extreme weather?

(14) The importance of technology capacity compared with policy support?

(15) The importance of social reputation compared with reputation among staff.?

When considering the following factors, do you think Shanghai port will prefer CCA strategy or CCM strategy? Please give a score (for example, if you think that CCA strategy requires less investment and will make ports more inclined to invest in CCA, please write "CCA" and mark your scores.. The scoring standard is the same as the above part.)

(1) Investment

(2) Return

(3) Vulnerability

(4) Emissions reduction

(5) Intensity of extreme weather

(6) Frequency of extreme weather

(7) Technology capacity

(8) Policy support

(9) Social reputation

(10) Reputation in the company

APPENDIX B. List of the position of the respondents

Company	Position/Department	Length of service
Zhendong International Container Terminal Co., Ltd(the operation company of Phase 2 terminal of Waigaoqiao Port)	Personnel department	More than 10 years
Zhendong International Container Terminal Co., Ltd	Engineering Technology Department	More than 10 years
Zhendong International Container Terminal Co., Ltd	Party Committee Department	More than 10 years
Shengdong International Container Terminal Co., Ltd(operation company of Yangshan Port Phase 1 and Phase 2 terminals)	Manager of the general manager office	More than 10 years
Shengdong International Container Terminal Co., Ltd	Engineering Technology Department	More than 10 years
Shanghai Harbor e-Logistics software Co.,Ltd(information technology support company for Yangshan Port)	Deputy Party secretary	More than 10 years
Shangdong International Container Terminal Co., Ltd(operation company of Yangshan Port Phase 3 terminal)	Operation Department	5 years
Shangdong International Container Terminal Co., Ltd	Engineering Technology Department	2 years
Shangdong International Container Terminal Co., Ltd	Engineering Technology Department	2 years