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Analysis of the incentives in environmental strategies implementation in Chinese ports

by

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Abstract

China, known as the center for global manufacturing, experienced fast growth and became the largest exporter in the world. With the increasing import and export volumes, China's ports also expanded rapidly. For now, there are seven Chinese ports that count to the top ten container ports in the world. However, during this fast growth process, the negative impact brought by the shipping industry has increased. The high level of SO_2 emissions by the vessels together with the dust and noise generated during port operations create an enormous damage to the coastal region and become a serious threat to human health.

This thesis aims to map out the current environmental strategies and the regulation framework concerning port and shipping industry; to examine the practical implementation of certain measures; and then to evaluate the obstacles in China's green port policy.

With the support of scientific research of various environmental schemes and self-gathered information regarding the existing practice and regulations, we find that the construction of China's green shipping and port is strongly controlled on the national level. Local port authorities together with other stakeholders such as ship operators are less proactive to be greener given the lack of financial and policy support. Most ports are still in the stage of improving energy efficiency by using electricity instead of fuel in gantry cranes operation. China is also lagging behind in environmental monitoring and most ports do not have their own emission inventory which is considered to be the fundamental material for green policy making. Nonetheless, with the increasing awareness from both publicity and government, China began to gradually carry out reasonable and systematic environmental planning. It is expected to have promising outcomes if strict regulations are effectively implemented; financial incentives are provided; and suitable environmental measures are identified and carried out by port authorities.

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List of Abbreviations

CCS	China Classification Society
ECSA	European Community Ship-owners' Associations
EMSA	European Maritime Safety Agency
EPB	Environmental Protection Bureau
EPD	The Hong Kong Government Environmental Protection Department
EPI	Environmental Performance Indicator
EU	European Union
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
MEP	Ministry of Environmental Protection of the People's Republic of China
MGO	Marine Gas Oil
MOT	Ministry of Transport of the People's Republic of China
NDRC	National Development and Reform Commission
NPC	National People's Congress
NRDC	Natural Resources Defense Council
OGV	Ocean Going Vessel
SMPG	Shanghai Municipal People's Government
UNCTAD	United Nations Conference on Trade and Development
VSR	Vessel Speed Reduction
ECA	Emission Control Area
WHO	World Health Organization
WSC	World Shipping Council

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1 Introduction

1.1 Background

According to the 2009 World Bank report, one of the reasons of development of globalization is that the low cost of transport cost encouraged different countries to use their comparative advantage and trade with each other. In this way, maritime transport which is considered to be more cost efficient and environmentally friendly compared to other modes of transportation grew fast to meet the increasing transport demand of raw material and intermediate goods transport (Corbett & Winebrake, 2008). Based on the data from the United Nations Conference on Trade and Development (UNCTAD), maritime transportation takes over nearly 80% percent of the total international trade volume.

China, after becoming a member of WTO, benefited from the globalization, became the well-known “world factory” and experienced huge growth in exports and imports. Not surprisingly, the volume of maritime transportation in China also has soared from 2.2 billion metric tons in 2005 to 6.14 billion metric tons in 2015 in order to catch up with the rapid economic growth (The Statistics Portal, 2016).

However, international shipping also brings many negative impacts such as the greenhouse gas emission. According to the report “Green House Study 2014” from IMO, 20.9 million tonnes of NO_x and 11.3 million tonnes of SO_x has been generated by international maritime transportation annually from 2007 to 2012 (IMO, 2014). The tremendous greenhouse gas emissions together with water, noise and waste pollution has become a great threat to the environment, human health and climate. Review of emission inventory of Shanghai port and vessels in the Shanghai area (2014) pointed out that the emission of vessels was one of the main sources of air pollution, accounting for 12.4% of city SO_x emissions, 11.6% of city NO_x emissions and 5.6% of city $PM_{2.5}$ emissions (Shanghai Environmental Monitoring Center, 2014).

These adverse influences brought by the shipping industry are considered to be even more serious in China due to the following reasons:

The first reason has to do with the geographical characteristics. The population of China is not evenly distributed across the country. 40.9% of the population reside in the East Coast of the country with an average population density of 400 people per square kilometre. Especially in the area of the Yangtze River Delta and the Pearl River Delta, the population density in these regions amounts up to 1000 people per square kilometre. In Hong Kong, the density of the population is even higher - over 13.000 people per square kilometre. Not surprisingly, the East Coast is also the area where the busiest ports are located and the economic level is relatively higher than the inland area. All kinds of pollution and emissions generated by ports have a huge impact on the health of the residents. Based on the 2010 Global Burden of Disease Study, about 1.2 million of premature deaths can be attributed to air pollution with NO_x, SO_x.

The second reason is connected to the problem that dates back into the Chinese history. Long before the time of the Chinese economic reform, there was no large Chinese mainland port because there was no high domestic demand of shipping. However, after the economic reform, the infrastructure of ports and the related projects started to grow and develop on a large scale all over the country in order to provide fundamental support to the continuous fast growth of the economy (China Academy of Transportation Sciences, 2015). Nowadays, the well constructed and managed ports such as Shanghai and Shenzhen not only serve as an important node in the logistic network but also play an important role in stimulating the economic growth. They form an industry cluster in its inland regions, the Pearl River Delta and the Yangtze River Delta. Both of them are considered to be among the busiest container ports in the world, which can be seen from the 2014 ranking list developed by the UNCTAD and the WSC based on their total throughput. We report this ranking list in Table 1.

Table 1: Top 20 container terminals and their throughput in 2014

Rank	Port	Country	Volume(million TEU)	Share of world total
1	**Shanghai**	**China**	**35.3**	**5.2%**
2	Singapore	Singapore	33.9	5.0%
3	**Shenzhen**	**China**	**24.0**	**3.5%**
4	**Hong Kong**	**China**	**22.2**	**3.2%**
5	**Ningbo-Zhoushan**	**China**	**19.5**	**2.8%**
6	Busan	KOR	18.7	2.7%
7	**Qingdao**	**China**	**16.6**	**2.4%**
8	**Guangzhou**	**China**	**16.2**	**2.4%**
9	Jebel Ali	UAE	15.3	2.2%
10	**Tianjin**	**China**	**14.1**	**2.1%**
11	Rotterdam	Netherlands	12.3	1.8%
12	Port Klang	Malaysia	11.0	1.6%
13	**Kaohsiung**	**China**	**10.6**	**1.5%**
14	**Dalian**	**China**	**10.1**	**1.5%**

15	Hamburg	Germany	9.7	1.4%
16	Antwerp	Belgium	9.0	1.3%
17	**Xiamen**	**China**	**8.6**	**1.3%**
18	Tanjung Pelepas	Malaysia	8.5	1.2%
19	Los Angeles	U.S.A.	8.3	1.2%
20	Keihin Ports	Japan	7.9	1.2%
Total for Chinese ports in top 20			**177.2**	**25.9%**
Top 20 of world			**311.8**	**45.6%**
World total			**684.4**	**100%**

Source: UNCTAD and WSC

In this fast development process, many mistakes have been made related to the environment issues. One of the worst mistakes is the structure of energy use in port infrastructure and equipment such as quay cranes and all kinds of handling systems like reach stackers, straddle carriers, rubber-tyred gantry crane, rail-mounted gantry crane system and others. Most of the equipment in ports used petrol or diesel as the energy source and that lead to the inefficiency of energy utilization and air pollution in the port region.

Under huge pressure of climate change and lagging behind in the development of clean energy, China (which is responsible for 25% of global carbon dioxide emissions) promised the world that before 2020 the CO_2 emission per unit of GDP will be reduced to 55% in comparison with the 60% level in 2005 (Climate Action Tracker, 2014). China also declared that it would like to limit CO_2 emission further to 35% and reach the peak of CO_2 emission by 2030 at the latest (Mercator Institution for China Studies, 2015). In order to meet these goals, the twelfth national five-year plan carried out by China included the measures to tackle the environmental issues of the transportation industry which accounts for approximately 12% of the total national energy consumption (China IRR, 2012). More specifically, according to the National Climate Change Plan (2014-2020) issued by the State Council, solutions for saving energy and cutting emissions have been suggested for port and shipping sector with the aim to decrease the emission of CO_2 per unit of cargo or passenger by 13% compared to the level recorded in 2010 (The State Council, 2014).

Even though, as mentioned above, China has already started to look into the situation of port and shipping industry in terms of environmental problems, there are still not many strict mandatory regulations to deal with pollution of port and shipping industry. That is why, some local governments have taken the initiative in their hands and started to look for solutions to pollution in the port and shipping sector.

1.2 Scope and limitation

A port is an area equipped with special terminal equipment, coverings a certain land and water area and has facilities for the vessels to enter and leave, for the passengers to embark and disembark, and for the cargo to be loaded and unloaded (NPC, 2003).

In general, China's ports can be divided into two large categories, inland river ports and coastal ports.

Depending on the national plan for coastal ports which was issued by the State Council in 2006, coastal ports can be further divided into five groups based on the geographical position, Bohai Rim, Yangtze River Delta, Southeast Costal Area, Pearl River Delta, and Southwest Coastal Area. Moreover, the plan of establishing eight transportation systems among the coastal ports (for coal, petroleum, iron ore, containers, food, commercial cars, mainland-island rolling, and passengers) has already come into action. Based on the report prepared by the Port Economic Development in China, there are some 150 ports along the coast of China which together count for 64% of the total throughput of Chinese ports in the period from 2002 to 2012 (China Academy of Transportation Sciences, 2014). These ports range from regional container hub ports such as Dalian (one of the busiest mixed cargo ports in Bohai Rim with a throughput of 10.1 million TEU containers, 44.1 million metric tons of petroleum product, 6.4 million metric tons of bulk grain and 3.6 million passengers as per data from 2014 (Dalian Port (PDA) Company limited, 2014), to container feeder ports such as Quanzhou (one of the biggest petroleum and LNG storage and distribution port in Southeast Costal Area, with a throughput of 17.98 million metric tons of crude oil and 1.89 million TEU containers as per data from 2014 (MNW, 2015). Although ports are different in terms of their natural characteristics such as location and geographical position, size, industry base and throughput, they all have huge impact on environment of the region based on their main activities they perform. However, a unified solution to tackle the environmental problems of ports can hardly work (NRDC, 2014).

In this paper, we mainly focus on the environmental issues of the coastal ports of China because we witness the throughput of coastal ports are high, marine traffic is busy and in turn the pollution is considered to be serious. We only mention few inland river ports due to the level of development of ports and the information available.

Since each port has its unique situation and is influenced by its regional strategic position, this paper does not recommend any specific environmental strategies for each of the ports. In practice, each port needs to evaluate the cost-effectiveness of a certain environmental method and to develop its own set of solutions.

1.3 Research question and objectives

This paper aims to provide the stakeholders with the information about the impact of port and shipping sector on the environment, human health and climate. We study related regulations in implementation and ways to control the levels of pollution. The main research questions that we aim to answer in this thesis are the following:

(1) Who are the stakeholders in developing measures to reduce port and shipping pollutions in China?

(2) What is the existing regulation framework and environmental schemes regarding port and shipping pollution?

(3) What is the environmental and economic impact of the deployment of certain environmental strategies in China?

(4) What could be the barriers for Chinese ports to introduce measures for reducing maritime pollution?

Depending on the research questions mentioned above, the objectives of this paper are:

(1) to work out inventories of information regarding the environmental schemes and regulations framework in port and shipping sector in China.

(2) to report the advantages of each measure if it was evaluated.

(3) to assess the differences between Europe and China in the governance of environmental schemes.

1.4 Structure

Chapter one gives an overview of the development of China's shipping and port industry and stresses the associated negative impact on environment and human health. Chapter two discusses in detail about the environmental measures that can be applied to improve the environmental performance of ports and vessels operation. Chapter three describes China's port and environmental governance; presents the current regulation framework; and lists the measures deployed within China's ports in practice. Chapter four discusses about the characteristics of China's environmental governance in maritime industry and points out the challenges to promoting green ports and shipping in China. The last chapter is the conclusion including summary of the essential points argued in the previous sections and the associated suggestions for China’s environmental governance.

2 Literature review

There are various pollution sources in port and shipping sector such as air pollutants emission, oil spills, ballast water and sewage discharging. In accordance with the guidebook about port environmental issues published by the United Nations in 1992, air quality, water quality, noise & vibration and waste management are the major impacts and required to be monitored and carefully controlled during waterside ship operation and landside cargo handling activities (United Nations, 1992).

Each port has its unique profile in terms of its natural, economical, administrative and social conditions. In order to have a clear picture of the ports' environmental performance and implement the measures which are considered to be the best solution for the environmental problems, suitable Environmental Performance Indicators (EPIs) need to be selected, monitored and evaluated (Donnelly, et al., 2007). Wooldridge, Puig and Darbra (2014) assessed and came up with twelve EPIs that are fit for EU ports. These EPIs include both qualitative (such as environmental policy) and quantitative indicators (such as carbon footprint).

Based on the literature review carried out for this study, we point out several management methods that can be used for the port environment. The most widely used one is the EcoPorts tool, Self Diagnosis Method (SDM). It is proved to be helpful for port authorities to have an overview of the characteristics of the port and the environmental management and it is useful to identify the environmental risks and monitor the compliance with the regulations (Darbra, et al., 2004). Other methods include The Port Environmental Review System (PERS) which is regarded to be a specific port standard, and the Strategic Overview of Significant Environmental Aspects (SOSEA) which can help policy makers recognize which environmental sector should be mainly focused on (Darbra, et al., 2005).

According to Lam and Notteboom (2012), the measures and policies with respect to marine environment can be divided into three categories: (1) pricing mechanisms, (2) systems for environment monitoring and measurement and (3) regulation control.

Pricing mechanisms can be discussed from two aspects, penalty and reward. Penalty is the price the polluter has to pay for the violation of environmental regulations. Reward is to motivate port users to operate in a more environmentally friendly way. The environmental charging system as a typical reward scheme will be further discussed in the section below.

Environment monitoring and measurement is an essential and fundamental method to locate the marine pollution source and therefore, it plays an important role in applying effective measures to tackle the problem.

In this respect, it is important to note that setting up the vessel emission inventory can be helpful to understand the characteristics of the vessel pollutants emission in terms of time and space, and based on the data processed it can be used to assess the impact of vessel emission on the ecosystem in the port region. Moreover, the inventory can also support further research on the impact of the vessel air pollution on human health, on the estimation of the environmental impact of the upcoming China's ECAs and on port's environmental measures decisions related to cost-effectiveness analysis (ICF Internaitonal, 2014). China is behind in the development of research on environmental protection. It is only in recent years that the action plan for preventing marine pollution (2015-2020) was created by China's government. Moreover, only recently the government started to look into the issue of environmental monitoring and proposed to establish a nation-wide monitoring system, as well as to develop a measuring methodology for the first time. Although the systematic monitoring has not been set up in national level, several busy ports such as Shanghai and Hong Kong have already come up with their vessel emission inventories years ago. The Hong Kong port started to publish the emission inventory since 2000. Based on the 2014 Emission Inventory Report, shipping contributed to 44% (14000 tonnes), 33% (36200 tonnes) and 36% (2100 tonnes) of the total emissions of SO_2, NO_x and PM_{10}. The Transport Department of Jiangsu Province carried out the vessel emission inventory in the Beijing-Hangzhou Canal area with base year of 2014 (China Ports & Harbours Association, 2016). Shenzhen port has just started the program in July 2016 by providing 1.2 million Yuan to the contractor that will carry out the research (Bidchance, 2016).

Regulatory control is a compulsory method applied to manage shipping operations. Regulations can be classified into international conventions such as MARPOL, national or local legislation and even private contracts.

It is worth to note that in the landlord ports such as Rotterdam and Antwerp, regulations on environmental standards can be included by port authorities in the land lease agreements and force the terminal operators to operate in a more environmentally friendly way. However, in China, not much information of this practice can be found. In accordance with the research, the marine environment control in Chinese ports mainly relies on the various Chinese regulations which are listed in the third chapter of this thesis. Next to this, we also study the impact on China's marine environment.

In this chapter, the existing good practices in solving the problems of air pollution, water pollution, noise and waste management are listed and discussed. Moreover, the specific situations about how these measures are applied in China's ports will also be analyzed.

2.1 Measures for air pollution

In port and shipping sector, a variety of solutions have been implemented to reduce air pollution from waterside (coming from the vessels) and landside (coming from the quay cranes, yard handling equipment, trucks and other equipment). Good environmental strategies which are widely used in practice are discussed in the sections below.

2.1.1 Shore power

Shore power, also can be called as 'cold ironing', means that vessels use landside electricity, rather than the power generated by fuels onboard of the vessels when they are berthed. By connecting to onshore power supply, vessels mange to turn off their auxiliary engines and use local electricity grid to perform their basic functions such as communication, loading, unloading, pumps, lighting, refrigeration and all kinds of other equipment for safety, production and living. Shore power is mainly composed of shore-side power supply system which manages to meet the different requirements of onboard voltage and ship-side power receiving system which is able to use shore power by making change in onboard settings.

As an alternative to onboard electricity supply, the advantage of this solution is that it can decrease the amount of carbon dioxide, air pollutants such as SO_x and NO_x, noise and vibration generated in the region of port. In this way, the employees of the port and the local communities nearby can benefit from higher air quality and less noise and vibration which could be worse if shore power is not deployed (World Port Climate Initiative, 2013).

A lot of research has been carried out in this field over the past few years. Zis (2014) used ship-call data to evaluate the ship emission reduction attributed to the deployment of onshore power supply and vessel speed limitation, pointing out that if every vessel on berth adapts shore power, CO2, SO2, NOx and black smoke (BC) emission can be reduced by 48%–70%, 3%–60%, 40%–60% and 57%–70% respectively . Based on a modified equation of Corbett's (2009), Chang and Wang (2012) found out that if shore power is implemented on every single vessel calling at Kaohsiung port, CO_2, SO_2, NO_x and particulate matter (PM) would be decreased by

57.2, 63.2%, 49.2 and 39.4% respectively. Ballini and Bozzo (2015) conducted a study on the socio-economic benefit of deploying shore-side electricity on a cruise ship dock in Copenhagen. By fitting the data of cruise ship traffic in 2012 into the EVA model, they reached a conclusion that the external cost of health can be reduced by 2.8 million euros each year in case 60% of the electricity demand is met by onshore power supply. According to Liqun Bai, the chairman of Port of Lianyungang (one of the ports that first put cold ironing technology into practice in 2010 and became the only Chinese low-carbon port for demonstration in 2012), in conservative estimation, 7 million tons of fuel per year is consumed by auxiliary engine during vessel hotelling which represents 40%-70% of the total carbon dioxide emission from the port. Based on this data, if this amount of electricity is generated by Alternative Maritime Power, nitrogen oxides (NO_x), sulfur dioxide (SO_2) and particulate matter (PM_{10}) can be lowered by 47665, 37800, and 2214 tons respectively.

Even though environmental benefit can be achieved in the theoretical studies as mentioned above, practical performance of this environmental strategy varies a lot due such factors as the type and condition of the vessel, the capability of using shore power, the amount of electricity needed while hotelling and the way that the power provided to the vessels is generated (e.g., coal, solar energy, wind energy, natural gas), the consideration of the stakeholders regarding the investment and payback period.

The type and condition of the vessel include such factors as ship design, age and maintenance condition. These factors will determine the emission level of the ships. It is easy to tell that a ten-year old ship will generate more exhaust fumes compared to a newly built ship given the fact that the vessel type and other conditions the same. Therefore, the benefit of adapting cold ironing to less efficient vessels is bigger.

The capability of using shore power is an essential technical factor which influences performance of this technology. From the respective of terminals, there are differences in the power needed, frequency and voltage of electricity across the world. When it comes to ships, the onboard electrical system also varies in voltage and frequency because of the type and size of the vessel, and this difference can make the investment of the onboard system up to 3 million dollars (China Traffic News Network, 2015). This challenge of interoperability hinders the adaption of shore power for now, even though the international standard of cold ironing, known as IEC/ISO/IEEE 80005-1 Utility connections in port, has been published in 2012 (World Port Climate Initiative, 2013).

The amount of electricity needed on berth is also a key technical factor since the electricity requirement makes a huge difference on the investment of shore power system. For example, the peak demand for electricity of a cruise vessel (>300m) is 12.5 MV; but for tankers, it could only be 2.5 MV.

The way that the power provided to the vessels is generated can be considered vital. Since onshore power supply can only transfer the generation of electricity from ship-side to shore-side in order to avoid the pollution in port region, the power required remain the same if it is evaluated as a whole. In this way, the source of energy for shore-side power plant to use determines the amount of pollutants generated in the ecological system. If the source of electricity is from the renewable energy such as solar, water and wind energy, the air pollution can be expected to be zero. However, in China, 70% of power was generated by coal in 2014 which has been planned to decrease in the future (China Energy Network, 2014). In this circumstance, the amount of CO_2 emitted by coal-fired power plants is expected to be higher because coal generates more CO_2, though it produces less SO_2, NO_x and particulate matter (PM) in comparison with marine diesel fuel with a maximum of 1000 milligrams per liter (World Port Climate Initiative, 2013).

The economic benefits are also considered to be vital for all the stakeholders (e.g., port authorities, terminal operators, ship-owners and shore power suppliers, as well as nearby-residents). According to Ballini and Bozzo (2015), for the onshore power supply project of a cruise vessel pier in Copenhagen, the time for reaching a balance between the investment and external health cost is 12-13 years. In China, the cost is substantially higher for various reasons. First, the frequency of electricity provided in the port region is 50 Hz which is lower than the onboard electricity frequencies of 60 Hz mostly used in vessels. Second, the power supply capacity is lower than required in many old ports (Baidu Wenku, 2012). Therefore, remodeling is necessary in most cases, which leads to higher infrastructure costs. Third, from the side of ship-owners, the return on investment and utilization rates tend to be low since the turnaround times in ports are lengthy. Thus the cost includes not only the price of onboard equipment but so the cost of time is relatively high. Considering the depression of the shipping market, many ship-owners are unwilling to adapt this technology (China Traffic News Network, 2015).

In general, it depends whether port is suitable for deploying shore power. The overall effect needs to be examined in the feasibility study with all the stakeholders involved.

2.1.2 Low-sulphur fuel switching

Fuel switching, short for low-sulphur fuel switching, refers to the fact that ships need to switch to a fuel with low-sulphur content when in port (e.g. vessels switch from heavy fuel oil (HFO) to Marine Gas Oil (MGO) on berth.

This environmental strategy can be divided into two elements based on different requirements of the percentage of sulphur in the bunker oil in different regions.

The first element is that ships need to use lower sulphur content fuel on berth, for example, vessels visiting EU ports are required to use low –sulphur fuel by law from 2010 onwards, with a maximum of 1000 ppm sulphur content. This regulation covers the time spent at berth (AEA Technology, 2009).

The second element is that ships have to adapt to low-sulphur fuel switching within the certain water area. For instance, vessels are asked to comply with the same standard as mentioned above in the EU within 24 nautical miles (nm) from the coastal line of California which is in line with the California's Ocean-Going Vessel Clean Fuel Regulation (CA-CFR) adopted in 2012 (Port of Long Beach, 2015). Moreover, from 2015 onwards ships have to keep the percentage of sulphur content in marine fuel under 0.1% when they enter into the emission control areas (ECAs) which is in line with the Annex VI of the MARPOL Convention (EMSA, 2010).

It can be clearly noticed that this environmental strategy pays attention to the level of sulphur in marine fuel. One of the reasons is that sulphur in the fuel makes a huge difference on the particle size and distribution of particulate matter (PM) which could lead to high health risk of the population living in the coastal areas given that high level of PM will cause premature death (Tan, et al., 2009).

The “benefit” from the aspect of the environment is considered to be positive. Based on the study of speed reduction and fuel switching in Kaohsiung Port, Chang and Jhang (2016) using activity-based model found that fuel switching together with ship speed reduced to 12 knots from 20 nautical miles away from the coast can lower the emission of SO_2 by 43 % in bulk ships and by 48 % in container ships. Kotchenruther examined the performance of the two environmental strategies, the North American Emissions Control Area (NA-ECA) and CA-CFR which is noted above, on the basis of $PM_{2.5}$. Both of these strategies proved to be quite effective. For CA-CFR, a significant decrease in $PM_{2.5}$ by 30%-52% (0.09-0.78 mg/m^3) was achieved by comparing $PM_{2.5}$ emission in a period of 6 years (3 years before and after the adoption of CA-CFR). For NA-ECA, a decrease in $PM_{2.5}$ by 45%-50% (0.12-0.23 mg/m^3) was also found. In both cases, the local residents gain the benefit of improving the air quality significantly. CE Delft carried out a study about the impact of forcing ships using the bunker fuel with 0.1% sulphur content instead of 1% from the beginning of 2015. Although the figures on air pollution reduction are not the same in every report, the results are still inspiring. Within the range of the North and Baltic Sea, Sulphur concentration decreased by at least 50% during the year of 2015 and lead to a benefit of 4.4-8.0 billion Euros in terms of residents’ health and environment.

Together with the corresponding increase of 2.3 billion Euros, the overall effect of this regulation turns out to be significantly positive.

The “benefit” in terms of the economy, however, is evaluated to be negative from the point of view of the ship-owner. The low-sulphur fuel is expected to be 70 percents to 80 percents more expensive compared to the heavy fuel oil due to the cost of the production. As a consequence, most of shipping sectors will have to deal with the burden of increased bunker cost. In general, the impact can be analyzed in two different ways based on types of the ships and based on the routes the ships take.

As to the types of the ships, the more fuel intensive the ships are, the more increase on the operational cost they have to face. It has been estimated in the report of COMPASS study that the proportion of bunker cost in ship operational cost is 32% in Ro-Ro ships. Although this result is not conclusive, it was still widely believed that this segment will have a tough time. However, based on CE Delft study in 2016, there is no significant low-sulphur related influence on Ro-Ro transport.

When it comes to different ship routes, not surprisingly, the ship-owners who run short sea business are affected deeply and have to face a relatively higher rise in operational cost in comparison with trans-continental shipping. The reason is pretty clear - larger proportion of routes in short sea shipping is within the ECAs where low-sulphur fuel switching is compulsory. Based on the estimation of the European Community Ship-owners’ Associations (ECSA), bunker cost will experience an increase of 25.5% and result in a rise of 18% on freight rate and 14.5% loss on volume given that the price of marine gas oil (MGO) is 750 dollars per ton. If the price of MGO turns out to be 1000 dollars per ton in the future, even though the chance is reckoned to be low, it is estimated that a 30.6% increase in fuel expenditure, 60% rise on freight rate and 50% loss in volume will take place. Furthermore, given the price of MGO within the range of 600-800 dollars per ton, it is worth to note that short sea shipping will face market loss and this losing volume would shift to other transport modes such as rail and truck if its route is relatively short. After all, short sea shipping will still remain cost advantage over other transport modes (EMSA, 2010).

In China, however, the related issues such as fuel availability and technical problems may become the barrier in adapting this environmental strategy.

For the availability of fuel, the challenge of fuel provision is expected to grow. There are two main reasons. First, the vessels which depart from Chinese ports heading to ECAs tend to take on the low-sulphur fuel with 0.1% sulphur content in Chinese ports from 2015 in line with the Annex VI of the 1997 MARPOL Protocol. Second, based on the implementation plans of emission control area of Pearl River Delta, the

Yangtze River Delta and Bohai Rim issued by the Ministry of Transport of the People's Republic of China, the use of low-sulphur fuel also began to increase from 2016. It is worth to note that the price of low-sulphur fuel has the possibility to decrease because of the economy of scale, even though it is hard to predict. Nonetheless, the capability to provide sufficient good quality low-sulphur bunker fuel in Chinese ports will be the determinant of whether the implementation plan can be smoothly carried out in China.

Technical issues are worth Chinese vessel operators' attention. There were few cases of propulsion failure when switching fuel. The cause of propulsion failure – so it was found – was due to the nature of the boilers which were originally designed to consume HFO (AEA Technology, 2009). Luckily, these problems can be solved by modifying the boilers and by having them operated by experienced crews.

2.1.3 Vessel speed Reduction

Vessel speed reduction, also known as slow steaming, refers to the practice that ships sail at a speed which is much lower than their maximum speed.

This environmental strategy can be discussed from two different perspectives. One refers to the "slow steaming" which can be seen as the volunteer act of shipping companies to reduce the operational cost of the vessels. Another one can be called "vessel speed reduction" which more often comes out as a mandatory or incentive measure to deal with air pollution issues by governments or port authorities.

Notteboom and Cariou (2009) classify vessel speed in a clear manner. The majority of vessels are designed to sail at normal speeds ranging from 20 knots to 25 knots. Sailing at a speed ranging from 18 knots to 20 knots can be viewed as slow steaming when the vessel's maximum speed is up to 24 knots. A speed of around 15 knots to 18 knots refers to super slow steaming. Costs are reduced by lowering the speed down to around 12 knots to 15 knots. Nowadays, slow steaming has become an operational strategy for many shipping lines in order to not only reduce bunker costs but also to tackle the problem of overcapacity which has resulted from the economic crisis (Notteboom, 2011). According to a market survey involving over 200 shipping companies, 75% of the fleet adapted slow steaming; i.e. sailing at a speed ranging from 15 knots to 21 knots (Lee, 2014).

For the environmental and economical benefit of slow steaming, Cariou (2011) points out that a decrease of 11% in carbon dioxide emissions was achieved by applying slow steaming from 2008 to 2010. Moreover, in his paper, he also argues that the strategy of slow steaming can only be financially feasible when bunker costs are at least ranging from 300 to 400 dollars per ton. This is quite easy to understand since there is no willingness for shipping lines to slow down their vessels which could result in unreliable service performance in order to cut bunker costs if the price of fuel is already low. Chung-Yee Lee (2015) comes up with a model to evaluate the relationship between shipping time, fuel cost and service reliability and points out that in order to provide the same service frequency when ships engage in slow steaming, additional capacity needs to be deployed. However, the savings in bunker costs are larger than the expenditures in putting more vessels in operation, especially in a period over overcapacity. Chang and Wang (2014) assess the cost–benefits of slow steaming under different market situations and find out that the optimal speed which a shipping line decides to sail at is a dynamic trade-off and under circumstances of high bunker costs and low freight rates, slow steaming can become a very efficient solution for shipping companies to maximize their returns.

When it comes to vessel speed reduction (VSR), in most cases it is also an environmental measure to control regional pollution levels and protect mammals such as whales from collisions with ships (Chang & Park, 2016). In practice, many ports have implemented this strategy to reduce air pollutants around coastal areas. Back in 2001, the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) were the first ports that introduced voluntary VSR strategy by inviting ship operators to take part in the Green Flag Program. At the beginning, both ports asked shipping lines to limit their speed to 12 knots within 20 nautical miles and in return ship operators would benefit from a 15% discount on docking rates the first day. From the year 2009 onwards, the original designed 20 nautical miles range was extended to 40 nautical miles and the discount provided was further increased to 25% at POLB and 30% at POLA (Port of Long Beach, 2015). The Port San Diego and the Port Authority of New York & New Jersey also followed and set up Reduced-speed zones (RSZs) in 2009 and 2010 respectively.

According to Kevin Maggay who worked for the Environmental Management Division of POLA, it is worth to mention the VSR advantages: the short time frame for adoption, easy to track and monitor by using AIS data and low administrative cost of running the program.

Besides the convenience of running the strategy, the environmental benefits of VSR are also found to be significant. Based on the vessel-visiting-data of Kaohsiung Port in 2011, Chang and Jhang (2016) find that by limiting vessel speed to 12 knots within the area of 20 nm away from the port, carbon dioxide can be reduced by 41% and 14% in container and bulk vessels respectively. Yusuf Khan (2012) uses one Panamax container vessel and one post Panamax container vessel to examine the emission of air pollutants and discovers that the amount of CO_2 and NO_x emitted per nautical mile (kg/nm) can be lowered by 61% and 56% respectively if ships limit their speeds from cruising speeds to 12 knots. He also mentions that the Total Pollutant Emitted of $PM_{2.5}$ can be further reduced from 5% to 9% in case large size container ships slow their speeds down from 15 knots to 12 knots when sailing within the RSZ (20nm). However, there is no environmental benefit for small and medium size container ships under this situation. Furthermore, with the expansion of RSZs, the reduction of air pollutants will increase linearly.

Apart from contributing to reducing air pollution, VSR also can prevent ship accidents. Based on real accident data, Chang and Park (2016) point out that establishing RSZs manages to lower ship accidents by 47.9% by comparing the damage levels and frequencies of vessel accidents between ports applying VSR and ports not using VSR. In China, there are no regulations or incentive programs for speed limitation zones for the time being. In some cases, vessel speed reductions are required in certain areas for a period of time because of safety considerations.

Some negative impact of this strategy has also been researched. Fagerholt (2015) investigates some realistic shipping routes and finds that the total amount of carbon dioxide emitted on some routes is estimated to be higher because shipping lines tend to sail longer routes to minimize the time in ECAs and reduce their speeds in ECAs but speed up outside ECAs based on the ECA regulations (Fagerholt, et al., 2015).

2.1.4 Emission control area

Based on the MARPOL Annex VI which came into force in 2005, emission control areas (ECAs) are defined as the sea areas where related regulations are posed on vessels for limiting the emission of all kinds of air pollutants such as carbon dioxide, sulphur oxides, nitrogen oxides and particulate matter (IMO, 2016).

In general, there are only four ECAs: the North American area, the United States Caribbean sea area, the North Sea area and the Baltic Sea area. The regulations regarding ECAs can be mainly divided into two parts: the control of SO_x and PM, the control of NO_x (IMO, 2016).

As stated in regulation 14 of MARPOL Annex VI, standards for SO_x and PM emission are applied in all the four ECAs. Since 2012, for ships sailing outside the ECAs, it is required to use bunker oil with no more than 3.5% sulphur content. For ships navigating within the ECAs, bunker oil with no more than 0.1% sulphur content is allowed to be used from 2015 onwards. Moreover, the low-sulphur fuel is not mandatorily asked as long as other measures such as scrubbers which can contribute to the same environmental performance is adapted (IMO, 2016).

As mentioned in regulation 13 of MARPOL Annex VI, rules relevant to limiting NO_x pollution are set only in two American ECAs: the North American area and the United States Caribbean sea area. Simply speaking, diesel engines with an output of more than 130 kW on vessels built before 2016 are required to meet the Tier III NOx standards in which different weighted cycle emission limits are asked for in accordance with different ranges of the rated speeds of engines. For the vessels not operating in these two ECAs, Tier II requirements are applied (IMO, 2016). In this way, the environmental efficiency of the engines on large size vessels such as mega container ships is mandatorily asked. Ships are expected to greener and less efficient vessels will be phased out with time passing by.

The environmental benefits of the ECAs are much higher than their costs. In accordance with the estimation of the North American ECA from EPA, this environmental strategy is highly cost-effective.

Speaking of environmental improvements, the entire coastal area and even some inland areas gain from the ECA. It was estimated that 0.92 million tons of SO_x, 0.09 million tons of $PM_{2.5}$ and 0.32 tons of NO_x are now no longer emitted annually by 2020. In other words, SO_x, $PM_{2.5}$ and NO_x emissions will be reduced by 86%, 74% and 23% respectively in comparison with the scenario of no-ECA. Moreover, the health condition of residents is also expected to improve. For instance, the number of premature deaths that can be prevented can range from 5500 to 14000 annually. Together with other health related issues such as acute respiratory symptoms, the total health benefits can amount up to 47-110 billion dollars in 2020 (EPA, 2010).

When it comes to the ECAs cost which includes administration, verifying, use of low-sulphur fuel and other costs, it is estimated that some 3.2 billion dollars will be spent for improving the environmental performance of the vessels in order to meet the ECAs requirements in 2020 (EPA, 2010).

On 4 December 2015, the Ministry of Transport of the PRC issued the implementation plan for emission control area of the Pearl River Delta, the Yangtze River Delta and Bohai Rim.

This plan will be short for the China's domestic ECAs plan. Although the standards for lowering air pollutants emission are much lower than those in the existing ECAs designated by the IMO for now, the Chinese domestic ECAs plan has the intention to learn from the IMO experience and meet the MARPOL Annex VI requirements by the end of 2019.

China's domestic ECA plan is developed based on four principles: (1) Pay attention to joint control of air pollutants emission in key regions; (2) Keep fair competition among ports and encourage the application in some vital ports; (3) Take vessel traffic density and regional economical level into consideration; and (4) Be in accordance with the relevant domestic regulations and international conventions.

Generally speaking, the regulations are about sulphur content limitations on vessel bunker oils which are the source of all kinds of air pollutants. Moreover, in accordance with MARPOL Annex VI, China's domestic ECA plan also allows shipping lines to use equivalent measures such as scrubbers, onshore power supplies and LNG fuels (MOT, 2015).

It is also worth mentioning that Tzannatos (2010) has carried out a study on the cruise terminal in the Port of Piraeus and found out that shore power and the use of low sulphur fuels both contribute to promising reductions in air pollution. In comparison to low sulphur fuel, shore power performs better in terms of controlling for air pollution but shore power bears higher costs of energy generation. Together, a 25% reduction in the total cost of fuel and environmental pollution was witnessed compared to the use of low sulphur fuel when at berth.

This result implies that for the aim to cut the emission of air pollutants as much as possible in cruise terminals, the utilization of shore power is essential, even though low sulphur bunker oil is used onboard the vessel. As mentioned in the above section, this large difference in environmental performance of these two methods is mainly because cruise ships spend more time at berth, consume more energy and cause more damage to regional environment. Therefore, based on this point, it could be vital for China's port authorities to introduce onshore power systems to cruise terminals first and only then deploy the technology further to container terminals because liner shipping vessels call the terminal more frequently hence ensure high and stable levels of utilization of shore power.

The geographical characteristics of three China's domestic ECAs are presented in the figures below:

(1) The Bohai Rim area, with key ports of Qinhuangdao, Tangshan, Tianjin and Huanghua.

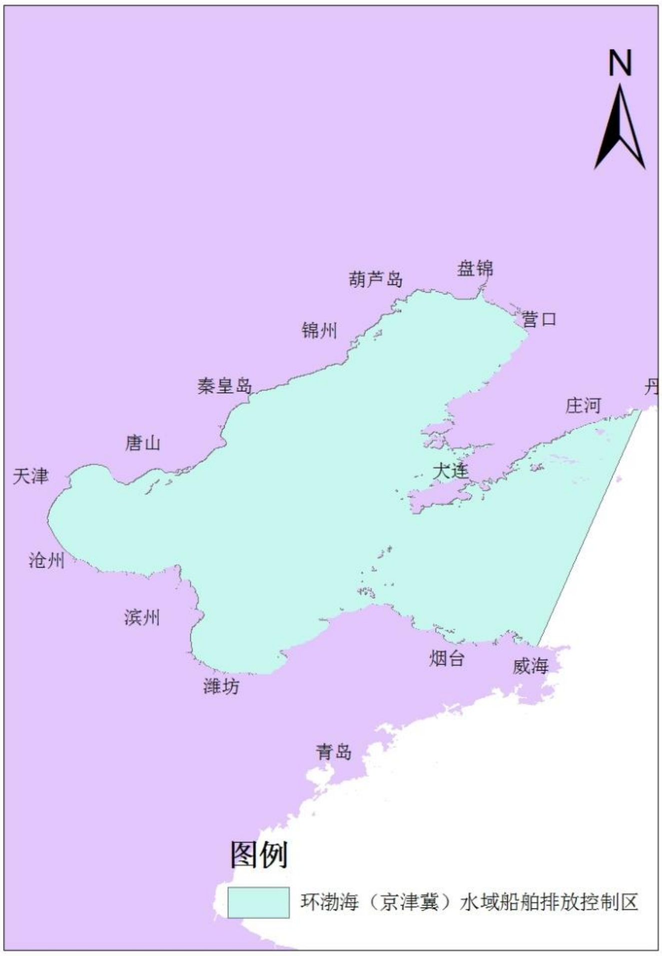

Figure 1: Map of Bohai Rim ECA.

Source: MOT

(2) Yangtze River Delta, with key ports of Shanghai, Ningbo-Zhoushan, Nantong and Suzhou.

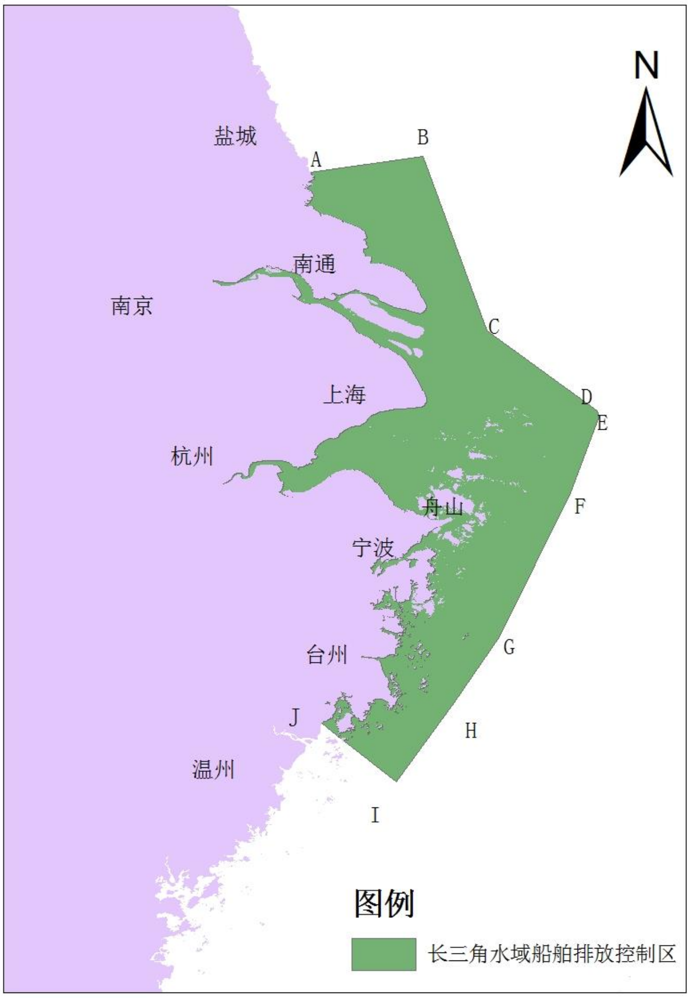

Figure 2: Map of the Yangtze River Delta ECA.

Source: MOT

(3) Pearl River Delta, with key ports of Guangzhou, Shenzhen and Zhuhai.

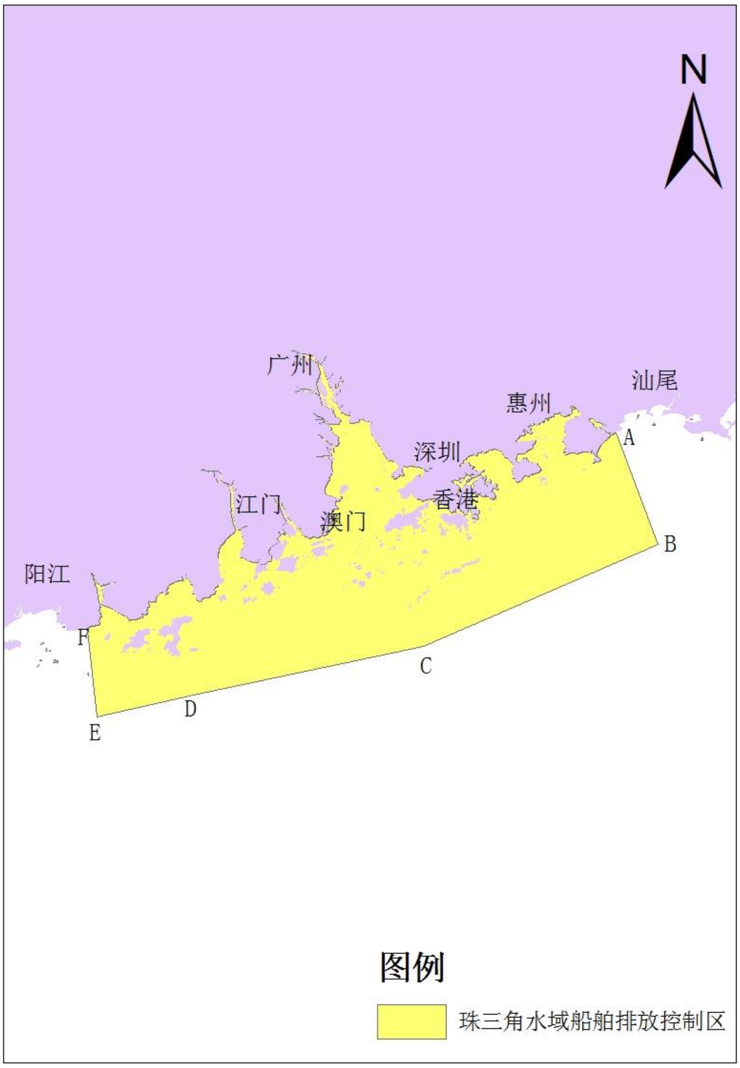

Figure 3: Map of the Pearl River Delta ECA.

Source: MOT

It is clear from the figures that unlike the existing North America ECA where the whole coast line is covered and protected, China's domestic ECA only defines the area of three major regions where there is massive pollution from ships. From our point of view, this geographical characteristic has the potential to result in unfair competition between the ports located in the ECAs and the ports located outside the ECAs. For instance, Port of Qingdao which is located outside the Bohai Rim ECA may become more competitive compared to the ports located inside the Bohai Rim ECA and share the same hinterland such as Port of Yantai and Port of Weihai.

Nonetheless, the regulations within the ECAs are going to be carried out step by step based on the strict schedule was described in the plan. The practical performance will be assessed in each implementation stage and the time for stepping into the next stage could be moved up depending on the evaluation of the local government.

The regulations in each application stage are summarized in Table 2.

Table 2: Summary of each implementation plan of China's domestic ECAs

Effective date	Regulations
1 January 2016	Ports that are within the China's domestic ECAs can voluntarily ask vessels to use bunker oil with no more than 0.5% sulphur content on berth.
1 April 2016	In the key ports within the Yangtze River Delta ECA, bunker oil with no more than 0.5% sulphur content shall be used for vessels on berth.
1 January 2017	In the key ports within the China's domestic ECAs, bunker oil with no more than 0.5% sulphur content shall be used for vessels on berth.
1 January 2018	In the ports that are within the China's domestic ECAs, bunker oil with no more than 0.5% sulphur content shall be used for vessels on berth.
1 January 2019	Within the whole area of the China's domestic ECAs, bunker oil with no more than 0.5% sulphur content shall be used for vessels' operation.

Source: MOT and Maritime Safety Administration of Shanghai

For now, the key ports within the Yangtze River Delta ECA, Ningbo-Zhoushan, Shanghai, Nantong and Suzhou have already applied the regulations as mentioned above and will do the demonstration for other ports. According to the estimation from Shanghai Environment Monitoring Centre, a reduction of 10% in $PM_{2.5}$ and 18% in SO_x can be realized in the implementation stage of 2018; 60% of $PM_{2.5}$ and 80% of SO_x can be avoided in the implementation stage of 2019 (China Maritime Transport Network, 2016).

The local report regarding the costs and benefits of the plan will be first developed and then the performance of the previous measures will be evaluated before the end of 2019 as mentioned in the implementation plan. Then whether to further apply the measures below will be decided: (1) Further lower the percentage of sulphur content in bunker oil down to no more than 0.1% for vessels operating within ECAs; (2) Enlarge the geographical area of ECAs; and (3) Develop other measures for limiting emissions (MOT, 2015).

2.1.5 *Environmental charging schemes*

Environmental charging, also known as port pricing, can be regarded as a method to deal with the negative environmental effect brought up by maritime transportation based on 'polluter pays' principle.

Different environmental charging mechanisms have been developed and implemented in recent years. According to the report of the European Commission on differentiated port infrastructure charges, one of the most widely used green port charges in the U.S. and the EU is that port authorities provide rebate on port dues to shipping lines with the aim to reward ship operators whose ships' environmental performance exceeds the compulsory requirement of international conventions and domestic laws (European Commission, 2016).

In practice, Port of Long Beach introduced the Green Ship Incentive Program in order to lower the NO_x emission from shipping. Based on regulation 13 of MARPOL Annex VI, the program rewarded 2500 dollars per call to vessels which engines meet the requirements of Tier II standards which lead to 15% decrease in NO_x and the reward will be further up to 6000 dollars per call if Tier III standards which will contribute to 80% decrease in NO_x are met (Port of Long Beach, 2016).

Unlike the rebate system in Port of Long Beach that a fixed amount of money is provided to clean ships, most ports in the EU took advantage of the various environmental index such as the Environmental Ship Index (ESI), Green Award (GA), the Clean Shipping Index (CSI), and Blue Angel (BA); and rebate on port dues are given to the vessels which are qualified. For example, Port of Rotterdam not only provides 10% discount on port dues to ships whose ESI score is above 31 and also gives 6% discount on port dues to crude oil, product tankers and LNG carriers that are certified with GA; In Bremen, 5% discount on port dues is provided to ships with an ESI score ranging from 30 to 40 and 10% discount is given to those with more than 40 in ESI score; Hamburg gives 2% discount on port dues to ships with BA certificate; In Zeebrugge, 10% discount on port dues is rewarded to vessels with an ESI score more than 30 given that the amount of rebate is no more than 750 Euros (European Commission, 2016); and in the year of 2014, Prince Rupert and Vancouver devoted more than $1.1 million dollars in discounts to green vessels based on the Right-Ship (Green Port, 2015).

It is no doubt that ports have environmental benefits through application of the environmental charging schemes. However, as mentioned in the EU report, because of the lack of the data which should be collected with the help of port environment monitor, the exact amount of air pollution reduction cannot be calculated.

It is also important to understand that the environmental charging measures do not bring any incentives to ship operators to act greener in the short term. According to Tongzon (2009), port dues constitutes only a small portion of the total ship operation cost and factors such as terminal handling efficiency, good location are the main factors for shipping lines to call a port or not, which also indicates that the demand elasticity to port dues is considered to be relatively low. This way, the implementation of environmental charging schemes is considered not to make much difference on the behaviour of ship-owners in the short term. The following examples may very well illustrate this matter. Although an environmentally friendly reward is given by ports, ship-owners or charterers may not change the ships already under deployment to meet the related standards and get the reward. One of the reasons is that the benefit from the reward is rather low for ship operators compared to the total cost of running a ship, which means that the environmental reward cannot be one of the determinants for deploying a vessel or chartering a vessel in the short term. Another reason is that the duration of a time charter is fixed for a certain period of time such as three, six months or even one or two years in most cases and this character of a time charter force the related parties not to change the choice of ships in the short term.

Despite of that, it could be considered as a trigger for clean shipping and could make some impact in the long term. For instance, ship-owners may decide to choose more environmental efficient ships when they order new vessels since the stakeholders in the maritime industry are more and more concerned about environmental issues and more related legislation and environmental reward is on its way. As mentioned above, great value could be created along the supply chain by ports adapting environmental charging schemes when we look into these matters in the long term.

2.1.6 LNG powered vessels

Liquefied natural gas (LNG) is known as clean energy which can be used as an alternative fuel for vessel operation.

Smith (2010) estimates that compared to HFO, if LNG is used as the only energy source onboard, the emission of NOx, SOx and CO2 can be decreased by 80 to 85%, nearly 100% and 20 to 30% respectively.

With stricter limit on vessel air emission in ECAs, using LNG as vessel fuel becomes a reasonable choice for ship operators. Many researchers have started to look into this matter.

Acciaro (2014) applies real option model and find out that there are two determinants for LNG vessel investment. One is the future price difference between LNG and marine fuel. Another one is the cost of vessel retrofit. Based on the uncertainty of LNG market in terms of its availability and reliability, he further points out that government may support LNG application by undertaking incentive measures, issuing related technical standard of LNG ships and more importantly controlling the price of LNG within a favourable range.

Schinas and Butler (2016) discuss the obstacles that lie on the way of promotion of LNG fuelled vessels. They point out that the change of onboard crew, the availability of LNG-bunkering infrastructures and uncertainty of vessel air pollutants restrictions in the future will also make vessel operators reluctant to step into this field.

China is active in adapting LNG as vessel fuel. The project called “fuel to gas” has been implemented for six years since the first dual fuel ship successfully operated in 2010. Duel fuel vessels can save 21% bunker cost if 66.9% of fuel oil is replaced by LNG. If 84.88% of fuel oil is replaced, then the save in fuel cost can be further up to 27.6% (Xinhuan Net, 2013).

However, with the lack of financial incentives, regulations, uniform technical standard and the construction of relevant infrastructure, the development of LNG vessels remains stalled.

For now, the most serious issue regarding LNG vessel is the cost. First, the cost of new building LNG vessel is way higher than a diesel powered one. Second, the cost for retrofit is around 1 million Yuan. In this way, the high investment cost makes shipping operators not so proactive in this clean energy. In this way, MOT issued the subsidy plan in 2014. For new building LNG vessels of which the completion time is within 2013 to 2015 will receive subsidy of 0.6 to 1.4 million Yuan. However, the subsidy policy only covered the certain time range as mentioned above. For now, ship-owners who would like to invest in LNG vessels will no longer get any subsidy from MOT. Another essential factor is the price difference. With the uncertainty of LNG price and without the clear cost effectiveness, investors are more likely step back from this field.

In national level, as stated in MOT’s action plan (2015-2020), promoting inland LNG vessels became one of the main strategies to control the pollution in inland waterways. In order to further direct the investor into LNG vessel market, MOT with the help of CCS has developed relevant standard for LNG vessels and facilities for bunkering: The standard for LNG powered vessels became effective in 1 September 2013; and rules for vessels with the function of LNG bunkering have just come into practice in 1 December 2015. Moreover, the plan also mentioned the revise of the existing standard about LNG bunkering infrastructure, the systematic construction plan for LNG infrastructure, the expansion of the scope of LNG pilot projects and the improvement of LNG utilization in port operation vessels and trucks.

2.2 Measures for water pollution

There are a number of activities in port resulting in water pollution, which can be divided into two main categories, vessel operation and cargo handling.

During vessel operation, oil spills, ballast water and sewage discharging could bring huge negative impact on the environment. In case of oil spills, sediment could be severely polluted. Toxic matters which are contained in oil could be stored in the water bottom. Then the contaminants can be transferred to food chain which will become a significant risk for health of marine animals and human (UK Marine Special Areas of Conservation, n.d.). Oil spills may take place during tragic vessel collision accident, vessel bunkering operations, loading/unloading activities, vessel leakages, shipbreaking and shipbuilding activities (Port of Rotterdam, 2009). The corresponded measures to deal with oil spill problem is to control the scale of pollution as soon as possible, prevent the oil from spreading away by adapting oil booms, remove the oil from sea water by deploying skimmers and then transfer it for treatment (O'Brien, 2016). In case of ballast water discharging, the stability of local ecosystem may be damaged or even destroyed because of the alien maritime species such as the red tide which can be brought from another end of the world in ballast water. To tackle this issue, approved ballast water management systems need to be installed onboard before the deadline which is regulated in BMW Convention. The related standards for ballast water are also included in this international convention, even though each country may demand different requirement (IMO, 2016). In case of sewage discharging, visual pollution may happen in port area and the bacteria contained in the sewage may result in pollution of sea water and sediment. Depending on the Annex IV of MARPOL, without any proper handling, sewage may be discharged 12 nautical miles away from the coastal line. Moreover, Convention also requires government to establish reception facilities with enough capacity to handle sewage as well as other waste liquids such as bilge water and oily wastes (IMO, 2016).

During cargo handling, dust and runoff of all kinds of bulk cargo such as grain, iron ore, coal and fertilizers can be blown off by the wind into the seawater of port. Then port environment may get polluted because of the toxic constitutions that are contained in the dust and runoff. There are measures that could be taken to lower this negative impact. First method is to make the storage of bulk cargo within an enclosed space which can contribute to less dust and runoff pollution. Second method is to install sprinklers in storage area of anti-humid bulk cargoes such as iron ore and coal which will also decrease the amount of dust generated. Third method is to deploy efficient and environmentally friendly equipment for vessel loading and unloading. A covered belt system can be used for loading process and Pneumatic unloaders or Continuous mechanical unloaders can be deployed for discharging process (United Nations, 1992).

In general, in order to improve water quality in the port area and to prevent water pollution, regulations on bunker operation and penalties on pollution need to be introduced and enforced; proactive handling from the port service users and consistent monitoring of the port authorities are essential for quick response to any environmental incidents that may happened (Port of Rotterdam, 2009).

2.3 Measures for noise pollution

Noise generated from vessel operation and cargo handling could bring significant adverse effect on workers in port, nearby community and marine mammals.

Human health can be highly affected by noise. In accordance with the report of the World Health Organization in 1999, noise may lead to hearing problems, sleeping disorders, high blood pressure related diseases, weak performance at work & study and even violent behavior (WHO, 1999). In addition, the marine mammals can also suffer from the noise produced by port and vessel operations. Based on the study of Convention on Biological Diversity, noise may lead to communication problems, deafness, lowering the chance of feeding and possible decreasing biodiversity in the long run (Convention on Biological Diversity, 2012).

Solutions for reducing noise pollution can be divided into three parts: source method, propagation method and receiver method (NoMEPorts, 2008).

Speaking of the source method, it is rather clear that it is a way to control the noise emission from the source. The following measures can be carried out: reduce aggressive cargo handling behavior; upgrade port handling equipment and trucks to use more electricity than diesel fuel; and take advantages of sound absorbing materials. For instance, the engine of a vessel can generate a lot of noise. However, as discussed in the previous sections of this paper, the deployment of shore power system manages to decrease noise to a large extent because engine of a vessel can be turned off on berth with the help of onshore power supply.

The propagation method can be regarded as a way to decrease noise on transmission paths. Various measures can be taken to reduce noise. First, to stop port activities at a certain time. Second, to move the location of port activities away from local neighborhoods. Third, to build sound barriers surrounding sources of noise, such as bulk cargo handling areas.

Receiver method refers to the solution that is applied in the local community to prevent noise pollution. For example, the installation of sound insulation windows can be a good practice to reduce the noise effect.

In China, noise pollution is a serious problem because in many areas ports are located quite close to the local communities. Many projects regarding relocation of the port industry have already been carried out due to various reasons such as land restriction for expansion and environmental influence to local residents. However, noise pollution in China is much less of a concern compared to the serious problems of air pollution. It is only in 2015 that the government of Shanghai issued the regional regulation 'measures for control of vessel related pollution in Shanghai ports' and for the first time added noise reduction solutions (Chineseport Network, 2015). Depending on the regulation, it is required for vessels which operate in the sound sensitive area to turn off their sound devices. Certain vessels which may produce a lot of noise are also forbidden to navigate in Huangpu River and inland river of Shanghai (SMPG, 2015).

2.4 Measures for waste management

Waste management is extremely important for reducing sea pollution. There are varieties of waste generated on board of the vessel through daily operation and some waste needs to be treated on shore rather than disposed to the sea in order to minimize the environmental impact. Waste can be divided into five different categories based on the MARPOL Convention: all kinds of oily waste, toxic liquid from tank and cargo, sewage, garbage and harmful residues for ozone.

Port waste reception facilities with enough capacity are essential for waste treatment. The governments need to establish adequate port reception facilities to dispose waste according to MARPOL Convention. Communications between shipping lines and waste management service providers is also vital for smooth operation process and for meeting the requirements of port state regulations.

In August 2015, China's Ministry of Transport issued the action plan for preventing pollution in shipping and port sector (2015-2020). The action plan mentioned that ports and shipbuilding factories have to set up waste reception facility with enough capacity. Moreover, these facilities also need to make proper connection to the municipal public treatment systems (MOT, 2015). In order to stipulate this action plan, in April 2016 the Ministry of Transport of China published the notification about vessel waste reception and treatment. The notification asked each port which is located in the coastal area and along the Yangtze River to carry out its own construction plan for waste reception, transfer and treatment facilities. For other ports that are located in inland rivers, such as the Beijing-Hangzhou Canal and the Heilongjiang River, construction plans can be developed at provincial levels by each provincial transport management department. All the construction plans need to be finished and evaluated by the end of 2016 (MOT, 2016).

The regulations about waste reception facility in port have been effective for a long time. However, the outcome of the waste management in China is very disappointing, compared to the EU, especially in inland waterways. Author reckons that there are mainly two reasons behind this.

The first reason is connected to the practical performance of the facilities themselves. It is clearly regulated in the EU's port reception facility directive (PRF Directive) that the capacity of each facility should be sufficient and no delays should occur related to using facilities.

First, compared to the large scale coastal ports with busy shipping traffic such as Dalian, Shanghai and Shenzhen, most of the ports located along the China's inland waterways do not build facilities for waste reception with enough capacity. This situation leads to the fact that ship operators are forced to dump garbage into the water.

Second, it is worth to note the importance of no delays as mentioned above. Moon and Woo (2014) used a simulation model to investigate the influence of port efficiency on vessels from the economic and environmental aspects. They pointed out that the rise in port service time results in higher operation cost and CO2 emission for liner shipping vessels. However, ships in China are facing delay when using these facilities, especially in inland river areas. This situation makes many ship operators choose not to follow the rules. For example, the Transport Department of Jiangsu Province invested millions of Chinese Yuan to build waste reception facilities in Taihu Lake area. Although the maritime traffic is clearly very busy in this area, the use of facilities is extremely low.

The second reason is that China's regulation only talks about the establishment and operation of waste reception and treatment but does not carry out powerful enforcement measures, monitoring and supervision system. Moreover, it is a common practice for vessel operators to discharge waste into the sea in past years, which indicates that many vessel operators do not have an incentive to comply with the rules. Although some heavily polluted regions invested in vessel waste management long time ago, it is only from 25 April 2016 that the MOT started to work on the plan for setting up organized waste reception facilities nationwide (MOT, 2016).

Moreover, an essential point about the costs required for applying the rules and building of the facilities are the fees. According to the PRF Directive, it is compulsory to set up cost recovery system in each port and the cost of facilities needs to be financially balanced by the collected fees. All ships are responsible for paying the fees regardless of whether they use the service or not. The fees will vary based on the type, size and environmental performance of the ships. In China, the cost related issues are not discussed in the regulations.

2.5 Conclusion

In the previous sections, a variety of measures are discussed. In practice, not all the measures have been implemented in China. The strategies that have been applied in China's ports are summarized and discussed in Table 3.

Table 3: Overview of the Chinese strategies and objectives

1	Strategies	Shore power
	Application scope	Nationwide, both in coastal ports (e.g., Port of Shanghai and Port of Tianjin) and inland ports (e.g., Port of Hefei)
	Objectives	Reducing SO_x, PM and NO_x during vessel hotelling
	Considerations	High initial investment on both landside and onboard equipments
	Policy	Governments provide financial incentives and set up application target in terminal development plan.
2	Strategies	Low-sulphur fuel switching
	Application scope	Mandatory in Hong Kong, Port of Shanghai, Port of Ningbo-Zhoushan, Port of Nantong and Port of Suzhou; Voluntary in Shenzhen
	Objectives	Reducing SO_x, PM and NO_x during vessel hotelling
	Considerations	Fuel availability and port competitiveness
	Policy	Domestic regulations
3	Strategies	Emission Control Areas (ECAs)
	Application scope	Ports located in the Bohai Rim area, the Yangtze River Delta and the Pearl River Delta.
	Objectives	Reducing SO_x, PM and NO_x in coastal region
	Considerations	Fuel availability

	Policy	Domestic regulations
4	Strategies	Liquid natural gas (LNG)
	Application scope	Nationwide, inland vessels
	Objectives	Limiting the emission of SO_x, PM and NO_x in inland waterways
	Considerations	Fuel availability, price volatility, high capital cost of the vessels and landside infrastructure needed
	Policy	Governments provide financial incentives
5	Strategies	Waste reception facilities
	Application scope	Nationwide
	Objectives	Reducing water pollution
	Considerations	Investment in related port infrastructures and enforcement challenges
	Policy	Domestic regulations and financial incentives
6	Strategies	Equipments for preventing dust generation (e.g., enclosed storage and sprinklers)
	Application scope	Nationwide, coal and iron ore terminals
	Objectives	Reducing water and air pollution by limiting dust generation
	Considerations	Investment in related infrastructure
	Policy	Domestic regulations
7	Strategies	Marine pollutants monitor and management
	Application scope	Nationwide
	Objectives	Improve the enforcement of the measures mentioned above
	Considerations	Lack of experience and coordination of various maritime departments (e.g., maritime safety department, port authority and environment protection department)
	Policy	National plan
8	Strategies	Technology regarding reducing marine pollution
	Application scope	Nationwide
	Objectives	Promoting newly developed technology applied to control marine pollution
	Considerations	Time consuming and lack of vessel emission inventory
	Policy	Governments provide financial incentives
9	Strategies	Promote the revise of the regulations and standards regarding marine environment
	Application scope	Nationwide
	Objectives	Update the regulations to better control the pollution in port and shipping sector

	Considerations	Time consuming. For example, according to the national plan, the standard for building up vessel emission inventory will be completed by the end of 2020.
	Policy	National plan

Source: Elaboration of the author based on a variety of sources

According to the table, it is pretty obvious that China lacks marine environmental monitor and advanced technology (e.g., scrubber, energy saving vessel engines and ballast water test). Moreover, since the marine traffic is busy in Chinese ports, regulations such as use of low-sulphur fuel while vessel on berth will bring tremendous influence on fuel supplement. Under this circumstance, the feasibility and practical performance of certain environmental strategy needs to be carefully evaluated. Furthermore, as most of the strategies require high initial investment such as shore power and LNG powered vessels, the financial incentives provided by local or central governments are essential for their practical promotion given the fact that the shipping market is in depress nowadays.

In all, Chinese government has already taken various strategies to deal with marine pollution in port regions. However, it is also pretty obvious that compared to EU, China is still in its early stage of marine pollution management.

3 Marine environmental governance in China

In this chapter, Chinese environmental governance is discussed in general and then a case study on China's coastal ports, i.e. Shenzhen, Shanghai, Hong Kong and ports in Jiangsu Province is carried out. The reason why to choose those ports is that they are active in developing green policies, applying various environmental strategies, located in high population density regions and have high level of marine traffic.

Given the fact that different ports have their unique environmental policies depending on their local economic and political situation, various strategies that have been used by the ports are classified into two main categories, namely (1) regulations and standard, and (2) financial incentives. The measures in each category are listed in tables and further discussed in detail based on the gathered information of the ports in the case study.

The regulations are mainly discussed in three dimensions (e.g., issuing authority, effective time and content). The issuing authority can partially reflect the policy maker concerning certain environmental issues. The effective and revised time may give a hint on how active the government is concerning certain environmental issues. The content is to show the critical point mentioned in the regulations concerning marine environment.

Financial incentives are mainly discussed in two dimensions, namely application scope and impact objectives. The application scope is to show whether the strategy is nationwide or local applied. The impact objectives is to present how much pollutants can be avoided and what is the compliance rate of the strategies by ports and /or shipping lines.

In general, we use the method that includes collection of a wide range of written materials, gathering all the relevant information from the social media and analyzing the opinions of various researchers from the fields that are relevant to the topic of our research.

3.1 Environmental governance

Effective governance of environmental schemes is essential for limiting the damage to the ecosystems. In shipping, however, we witnessed that related environmental regulations are behind in comparison to other industries. Lister and Poulsen (2015) looked into the decisive elements for the establishment of international standards about shipping environmental issues. They pointed out in the study that the situation mentioned above could result from the lack of public awareness, the reluctance to cooperate with governments from the shipping industry and the uncertainty of the regulations which result from the fragmentation of the regulation and may further add difficulty to ship-owners' decision making. For example, the IMO sulphur regulation does not determine the deployment time for vessels to use bunker oil with sulphur content no more than 0.5%. The possible year of the IMO Sulphur regulation coming into force could be 2020 at the earliest or 2025 at the latest. In this way, the issue is brought to the doorstep of the ship operators since it is more reasonable to invest in LNG powered vessels given the implementation time of 2020 rather than 2025 (Lister, et al., 2015).

Author believes that the performance of port environmental measures may be affected by the unique characteristics of both Chinese environmental governance and Chinese port governance which will be furthered discussed in the sections below.

3.1.1 China's environmental governance

China's environmental governance has a really complex and fragmented structure which can be divided into two main levels: national department level and local government level.

For the national department level, it is obvious that the Ministry of Environmental Protection (MEP) should be the key player for the making and application of the regulations about the pollution of air, water, noise and soil. In practice, however, the function of the MEP is largely influenced by and overlaps with other departments. This overlapping may lead to time consuming decision-making process and fragmentation of environmental governance system (Geall, et al., 2014). For example, National Development and Reform Commission (NDRC) includes three environmentally related departments. First, the Resource Conservation and Environmental Protection Department which focuses on the establishment of China's circular economy, energy saving and water saving (NDRC, 2016). Second, the Climate Change Department which mainly is involved in the establishment of national climate change leading group, development of the low carbon market and, promotion of South–South Cooperation and conducting international negotiations (NDRC, 2016). Third, the National Energy Administration which works on the standardization of energy related industry, nuclear power management, making storage plans of oil and natural gas and electricity market operation and management (NDRC, 2016).

For local government level, there are Environmental Protection Bureaus (EPBs) which are responsible for implementation of the policies and strategies from the MEP and which also perform as monitoring and assessment functions. However, EPBs are not financially supported by the MEP but by local governments and this leads to constraints in EPBs' performance because other departments in the local government may have different goals on environmental issues and their willingness will make a difference (Geall, et al., 2014). To be specific, many local governments still strive for maximizing economic growth. In combination with the weak supervision and monitoring system, local governments often ignore pollution from companies' operational activities (Li, 2009).

3.1.2 China's port governance

Port governance is also considered to be a factor that can influence the performance of port environmental schemes.

According to the study of Xu and Chin (2012), China's port governance is strongly affected by historical matters and can be divided into three stages depending on the time line.

The first stage covers the time period from 1949 to 1984 when ports were completely owned and controlled by the central government. The drawbacks of this type of governance were that the development of ports was restricted financially, and local departments were not motivated to improve the performance of the port.

The second stage covers the time period from 1985 to 2001 when ports were managed on both national and local levels. The weaknesses of this stage were that conflicts between the central and local governments increased, and that port authorities that had positioned themselves as both regulators and market players caused confusion over the issue of governance. The good side of this stage is that foreign investment is allowed to access China's port sector for the first time in comparison to the first stage.

The third stage started in 2002 and is still functioning now. Ports are managed by port authorities. Port authorities are divided into two sectors: the administration department which becomes a department in the local government, and the port companies. During this period, two major development regarding China's port development took place. The first development is that the port reform went along with China becoming a member of the WTO, indicating that port investments became more open than before. The second development is that the newly published and effective port laws covered three essential points in the following ways. First, the development of ports needs to be planned at both national and local level, the former takes charge of port planning all over the country in order to meet regional demand and also avoid over investment, the latter is responsible for developing its own port strategy. Second, the related regulations about port operations are well explained; Third, port administration department is separated from the port authority and becomes a part of the local government with the duty to monitor and apply related regulations (Wang, et al., 2004).

When it comes to port environmental governance, different departments at the national level, such as the MOT, the MEP are involved.

3.2 Inventory of regulation framework

The environmental regulatory framework in China is divided into three parts: regulations on vessel pollution, regulations on limiting pollution in port region, environmental standards of vessel and port operations. No local provisions are included simply because the way they are drafted is mainly based on the national regulations and more importantly no observations have been found that certain port applies significantly stricter environmental standard compared to the national ones according to the knowledge of the author.

3.2.1 Vessel pollution related regulations

The main domestic laws of China regarding vessel pollution issues are listed in Table 4.

Table 4: Summary of regulations about vessel pollution

Laws	Issuing authority	Effective time	Content
Marine Environment Protection Law of the People's Republic of China	The National People's Congress	2000, revised in 2014	Encourage the utilization of clean energy and the application of efficient production techniques. Set up the penalty system for the punishment of various marine pollution behaviors.
Administrative provisions for preventing vessel	The State Council	2009, revised in 2014	Based on MARPOL 73/78, this provision establishes the liability of ship-owners, ship

marine environment pollution			operators and managers to set up vessel pollution management systems and build up the standards for insurance and pollution management agencies.
Administrative provisions for preventing vessel pollution in inland river area	Ministry of Transport	2005, revised in 2016	Regulate the waste discharge and reception. Prohibit the emission of exhaust fumes which does not meet the requirement from the engine.
Administrative maritime punishment provisions of the People's Republic of China	Ministry of Transport	2003, revised in 2015	Establish the punishment provisions for various maritime issues such as marine navigating, salvage operation, carriage of hazardous cargo and vessel pollution in the sea.

Source: MOT

3.2.2 Port pollution related regulations

The main China's regulations for reducing pollution in the port region are listed in Table 5.

Table 5: Summary of regulations about pollution in port region

Laws	Issuing authority	Effective time	Content
Provisions on hazardous cargo management in ports	Ministry of Transport	2004, revised in 2013	Regulate the operation of hazardous cargo and require port authorities to set up systems for emergency management, safety evaluation and supervision.
Rules for port statistics	Ministry of Transport	2006	Require the collection of data regarding energy consumption and environmental protection.

Standard of environmental protection in port projects design	Ministry of Transport	2008	Set up the standard for managing all kinds of pollutants produced during the construction of certain port project, which includes sewage, dust, noise, garbage, exhausted gas and oily water.
Provisions on port operation and management	Ministry of Transport	2003, revised in 2010, 2014 and 2016	Set up requirement on port waste management. Demand the parties involved in waste reception to be at least well equipped with professional pollutants reception vessels or vehicles.
Provisions on port construction management	Ministry of Transport	2007	For port project application, the environment impact assessment is demanded, in which the analysis of ecological impact, resource and energy consumption should be included.
Provisions on acceptance criteria in port projects	Ministry of Transport	2005, revised in 2014 and 2016	The acceptance criteria include the completion of the equipment for environmental protection, human safety, and occupational disease prevention.

Source: MOT

3.2.3 Standards for port and vessel pollution

The main China's environmental standards for port and shipping sector are listed in Table 6.

Table 6: Summary of standard for port and vessel pollution

Laws	Issuing authority	Effective time	Content

Provisions on dust control in coal and iron ore terminals	Ministry of Transport	2016	The provision includes the requirement of terminal layout, demand of proper dust control equipment, and standards for dust control in cargo loading and unloading process, storage, transfer, equipment maintenance and monitor.
Environmental quality standard for noise	Ministry of Environmental Protection	2008	Noise limitation in port and inland waterway areas is set up based on the time period of the day.
Standard of seawater quality in China	Ministry of Environmental Protection	1982， revised in 1998	The regulation divided China's seawater area into three categories: (1) marine conservation zone; (2) beach area and port; and (3) port and industry area. The water quality is assessed based on the content of various matters such as COD and SOx. Different seawater standards are applied to different areas.
Standard for vessel pollutants discharging	Ministry of Environmental Protection	1983	Establish the requirement for discharging a variety of vessel pollutants such as oily water, sewage and garbage.
Technical standard for vessel examination	Ministry of Transport	2008	For the vessels which are built after 1 September 2008, vessel should comply with the requirement in MARPOL Annex VI in terms of NOx, SOx emission and incineration onboard.

Limit for pollutants emission from diesel engines of non-road mobile machinery (phase 3 and 4)	Ministry of Environmental Protection	2014	The standard regulates the emission limits of CO, HC, NOx and PM. Type approval depends on the third phase of regulations since 2014.

Source: MOT and MEP

Standards and norms of the first two phases came into force in 2007, however, the weakness regarding vessel emission is that the regulation only sets up requirements for small vessel engines with the power of no more than 37 KW. For larger vessels, there are still no regulations to comply with.

Beside of the standards and norms listed in Table 5, the regulation regarding the norms on engine exhausted gas emission by the vessels is on its way to implementation. On 1 June 2015, MEP started public consultations for drafting this regulation, and it is expected to fill the gap in controlling air pollution caused by vessels (MEP, 2015).

3.3 Inventory of environmental measures

3.3.1 Low sulphur fuel used for vessels at berth

The management tools used are listed in Table 7.

Table 7: Summary of tools for promoting the use of low sulphur fuel

1	Tools	Air Pollution Control Regulation
	Application scope	Hong Kong, effective from 1 July 2015
	Content	The mandatory use of fuel with no more than 0.5% sulphur content
	Impact objectives	100% adoption by OGVs
2	Tools	Implementation plan of ECAs in Shanghai
	Application scope	Port of Shanghai, effective from 1 April 2016
	Content	The mandatory use of fuel with no more than 0.5% sulphur content
	Impact objectives	100% adoption by OGVs
3	Tools	Implementation plan of ECAs in Jiangsu Province

	Application scope	Port of Ningbo-Zhoushan, Nantong and Suzhou, effective from 1 April 2016
	Content	The mandatory use of fuel with no more than 0.5% sulphur content
	Impact objectives	100% adoption by OGVs
4	Tools	Implementation plan of China's domestic ECAs
	Application scope	Every port that locates within the three China's ECAs, effective from 1 January 2016
	Content	The voluntary use of fuel with no more than 0.5% sulphur content
	Impact objectives	100% adoption by OGVs
5	Tools	Subsidy for using low sulphur fuel and shore power; Green convention of Shenzhen port
	Application scope	Shenzhen, effective from 6 March 2015
	Content	If the sulphur content in bunker oil ranges from 0.1% to 0.5%, 75% of the cost difference between IFO380 and MDO is subsidized. If the sulphur content in bunker oil is below 0.1%, 100% of the cost difference between IFO380 and LSMGO is subsidized.
	Impact objectives	The shipping lines' adoption rate is 54.5%[1] (Shenzhen Environment Committee, 2015).

[1] Report of low sulphur fuel switching in Port of Shenzhen (Nov. 2015)

Source: MOT and EPD

3.3.2 Onshore power supply

The management tools used are listed in Table 8.

Table 8: Summary of tools for promoting the deployment of shore power

1	Tools	The action plan for preventing pollution in port and shipping sector (2015-2020)
	Application scope	Nationwide, effective from 27 August 2015
	Content	In China's main ports, by the end of 2020, 90% of the vessels for port operation and service such as pilot vessel and salvage vessels are required to use shore power. Moreover, 50% of the terminals for handling container, ro-ro and cruise ships need to have the ability to provide shore power.

	Impact objectives	NO_x, SO_2 and PM_{10} can be reduced by 47665, 37800, and 2214 tons respectively based on the scenario in which 100% of the vessels calling in China's ports use shore power on berth.
2	Tools	Fund for encouraging energy saving and emission control in transportation sector
	Application scope	Nationwide, effective from 20 June 2011
	Content	For projects for which the environmental benefits can be quantified, the reward will be the equivalent price of coal based on the amount of energy saved. For projects for which the environmental benefit cannot be quantified, such as cold ironing, 20% of the investment for equipments construction will be rewarded.
	Impact objectives	The fund aims to support the enterprises which devote themselves to cutting emission and improving the efficiency of energy utilization by applying and researching advanced technology.
3	Tools	Shenzhen green port construction plan (2016-2020)
	Application scope	Port of Shenzhen, effective from 20 June 2011
	Content	By the end of 2016, the main container terminals such as Yantian and Shekou in Shenzhen need to equipped with shore power. By the end of 2019, 80% of berth for container, ro-ro and cruise ships need to be equipped with shore power; and the utilization of shore power is expected to be higher than 15%.
	Impact objectives	Together with other environmental measures, Port of Shenzhen expects that CO_2 emission per TEU throughput can decrease by 4% by the end of 2020 compared to the year of 2015. The SO_x, NO_x and PM emitted by vessels on berth can be lowered by 75%, 20% and 40% respectively.
4	Tools	Subsidy for using low sulphur fuel and shore power on berth; Shenzhen recycling economy and energy saving fund
	Application scope	Port of Shenzhen, effective from 6 March 2015

	Content	The subsidy for the construction fee of shore power facilities is determined based on the principle that the subsidy should not exceed 30% of the construction cost. Port authorities charge shore power users 0.7 Yuan per kilowatt-hour for using electricity, and the related costs of the port authorities will be fully subsidized. The maintenance cost will also be subsidized based on the rate of 0.07 Yuan per kilowatt hour.
	Impact objectives	Promoting the implementation of the onshore power supply systems, provide incentives for shipping lines to use shore power on berth.
5	Tools	Implementation plan for power supply for international shipping vessels in Shanghai
	Application scope	Port of Shanghai, effective from 28 July 2015
	Content	30% of shore power construction cost can be subsidized. Only 50% of the cost for increasing electricity capacity will be passed through and another 10% of the cost will be subsidized from the port construction fee. Electricity is charged based on the price of Singapore Fuel Oil 180 cst (Platts). The maintenance cost will also be subsidized based on the rate of 0.07 Yuan per kilowatt-hour. In addition, the utilization of power supply is required to be over 60% for vessels with the ability of receiving shore power.
	Impact objectives	The shore power system of Wusong cruise terminal just came into service in 13 July 2016. It is estimated that the emission reduction of CO2, SO2 and NOx by 36000, 750 and 65 tons can be achieved based on the upcoming 488 ship visits this year. The systems in Waigaoqiao and Yangshan container terminal have also been completed and are expected to come into service after the commissioning (People Network, 2016).
6	Tools	Notification from Jiangsu Price-Fixing Bureau for promoting shore power implementation
	Application scope	Ports in Jiangsu Province, effective from 9 September 2015
	Content	For onshore power supply equipment, “fundamental electricity” price will not be charged and electricity peak time charging policy will not be deployed.

	Impact objectives	There are 7474 berth in ports of Jiangsu Province. Among them, there are 455 ones with the capacity to serve the ships of over 10 thousands tonnes. If every vessel use shore power, it is estimated that the saving of bunker oil can be at least 0.7 million tons and 8000 tonnes of NOx together with 4000 tons of SO2 can be avoided (People Network, 2015).

Source: Elaboration of the author based on a variety of sources

3.3.3 Liquefied natural gas (LNG)

The management tools used are listed in Table 9.

Table 9: Summary of tools for promoting the use of LNG in ports and shipping

1	Tools	The action plan for preventing pollution in port and shipping sector (2015-2020)
	Application scope	Nationwide, effective from 27 August 2015
	Content	By the end of 2016, LNG terminal design code should be further revised and published. By the end of 2017, standard system for using LNG in shipping sector should be developed. By the end of 2018, LNG related equipment, technologies and regulations shall be further developed.
	Impact objectives	Encourage the local governments and port authorities to use LNG in various operations.
2	Tools	Subsidy for inland operation vessel standardization
	Application scope	Nationwide, effective from 9 April 2014
	Content	Subsidy for LNG power ships ranges from 0.63 million Yuan to 1.4 million Yuan depending on the construction time and main engine power. For example, if the ship building time is between 1 October 2013 to 31 March 2015, and its main engine power is not below than 1000 KW, then the ship will get a subsidy of 1.4 million Yuan.
	Impact objectives	The pilot projects carried out from 2010 to 2012 did not gain much progress. Under the depressing shipping market, vessel retrofit nearly stopped. Green Power shipping company is one of the companies which mainly focuses on LNG vessel operation in the Yangtze River Delta. For now, 57 LNG vessels are in deployment. (Shipping Exchange Bulletin, 2016)

3	Tools	Fund of Jiangsu Province for energy saving and cyclic economy in transportation sector
	Application scope	Jiangsu Province, effective from 2008
	Content	Projects and studies with regard to energy saving can get benefit from the fund.
	Impact objectives	Based on the report of 2015, projects related to LNG trucks received 7.9 million Yuan as a reward. The vessel retrofit for using LNG got 0.1 million Yuan. The application of intelligent system in Port of Lianyungang received 1.21 million Yuan in total (Transport Department of Jiangsu Government, 2015).
4	Tools	Subsidy plan for LNG trailer and LNG station in Shenzhen Yantian district
	Application scope	Yantian terminal in Port of Shenzhen, effective from 6 June 2013
	Content	Before the end of 2015, 10 thousand Yuan will be subsidized for the deployment of one LNG trailer; and 10% of the investment for LNG station will be subsidized, but no more than 0.5 million Yuan.
	Impact objectives	Reach the goal of Shenzhen green port construction plan that 80% of container trucks use LNG and 9 LNG stations need to be completed by the end of 2019.

Source: Elaboration of the author based on a variety of sources

3.3.4 Green vessels

The management tools used are listed in Table 10.

Table 10: Summary of tools for promoting green vessels

1	Tools	Subsidy for inland operation vessel standardization
	Application scope	Nationwide, effective from 9 April 2014
	Content	In order to encourage the deployment of energy efficient vessels, inland river operation vessels of which the Energy Efficiency Design Index (EEDI) meet the requirement issued by the China Classification Society can get the subsidy which is calculated based on the vessel type and total tonnage of the vessel.

	Impact objectives	The energy efficient inland river ship is still in the stage of R&D as a national pilot project. It was just in January 2016 that Shanghai Marine Transport Research Institution announced that the model experience was approved. In the future, the vessel is expected to be deployed for service in the Pearl River Delta (The Pearl River Maritime Management Bureau, 2016).
2	Tools	Subsidy for inland operation vessel standardization
	Application scope	Nationwide, effective from 9 April 2014
	Content	The dismantlement of old vessels can benefit from the subsidy which is calculated based on vessels' type, total tonnage and age.
	Impact objectives	In order to accelerate the dismantlement of old ships, By the end of 14 September 2016, 3058 vessels have been dismantled in Jiangsu Province (Ifeng, 2015). The inland river vessels in Yancheng (a city in Jiangsu Province) account for10% of the total inland river vessels in China. As per 22 October 2015, 1254 vessels were dismantled and 142 million Yuan was given for subsidy (JSWMW, 2015).
3	Tools	Subsidy for inland operation vessel standardization
	Application scope	Nationwide, effective from 9 April 2014
	Content	Subsidies are used as a financial motivation to accelerate the installation of onboard sewage handling system- All subsidies can be divided into two categories. First category of subsidies is for adapting onboard sewage disposal device: subsidies for passenger ships are based on its passenger capacity; and subsidy for cargo ship is based on its total tonnage. Second category of subsidies is aimed to encourage installing sewage tanker. The size of the subsidy depends on the total tonnage of the vessel. For example, vessels over 2000 tonnes can get 25 thousand Yuan in subsidy.
	Impact objectives	Wuxi, a city in Jiangsu Province, has 58 vessels that are over 400 tonnes in register and all of them already have the sewage handling system installed onboard (Wuxi development and reform commission, 2015). However, related information is only reported by few cities.

Source: Elaboration of the author based on a variety of sources

3.3.5 *Other measures*

The management tools used are listed in Table 11.

Table 11: Summary of tools for the environmental strategies in port operation

1	Tools	Green Port Grade Evaluation
	Application scope	Nationwide, effective from 1 June 2013; but this green port grading project started in 2016.
	Content	The system comes up with the evaluation method and environmental indicator for China's green port. The requirements for energy consumption per ton and carbon dioxide emissions per tonne are set. Moreover, the standard of concentration of all kinds of air pollutants such as dust, sulphur dioxide, VOC and COD are also designed.
	Impact objectives	The system aims at promoting the development of green ports in China. Eight terminals have been awarded as four star green ports status in 2016.
2	Tools	Fund for encouraging energy saving and emission control in the transport sector
	Application scope	Nationwide, effective from 20 June 2011
	Content	Stated in the China's 12th Five-Year Plan, this specific fund was set up to encourage energy saving and emission control in transport sector. This fund is provided to support not only port related reforms but also all types of green technology research.
	Impact objectives	Port of Dalian and Port of Guangzhou received 11 million Yuan for green port upgrade; Port of Fuzhou received 6.7 million Yuan; Port of Rizhao received 13.6 million Yuan. Moreover, many LNG related projects on vehicles and vessels also received financial support (MOT, 2014).
3	Tools	The action plan for preventing pollution in port and shipping sector (2015-2020)
	Application scope	Nationwide, effective from 27 August 2015
	Content	By the end of 2020, 100% of the main iron ore and coal storage areas are required to be closed or surrounded by wind barriers.
	Impact objectives	Based on the National Plan, many local governments took their own initiatives to set their own goals.

4	Tools	The action plan for preventing pollution in port and shipping sector (2015-2020)
	Application scope	Nationwide, effective from 27 August 2015
	Content	By the end of 2020, ports and shipbuilding factories need to set up waste reception facility with enough capacity to handle oily water, sewage and garbage.
	Impact objectives	Local governments started to evaluate the capacity of the existing waste management facilities. A pilot project for drafting the construction plan started in Shenzhen on 1 April 2016.
5	Tools	Advice on prevention of vessel oily water pollution
	Application scope	Jiaxing, a city in Jiangsu Province, effective from 5 March 2016
	Content	The government buys public services for supporting local companies to receive and treat vessel waste and gradually build up the related operation system.
	Impact objectives	All the 1042 docks in the city finished setting up equipments for receiving vessel garbage and oily water. 2 waste treatment facilities and 2 vessels for receiving oily water started their operation (Wu, 2016).
6	Tools	Fund for promoting the development of renewable energy
	Application scope	The policy asks local government to take measures on supporting the research and utilization of renewable energy.
	Content	Nationwide, effective from 2 April 2015
	Impact objectives	Local governments are responsible for the supervision of the projects and the management of the fund.
7	Tools	Fund for promoting the development of renewable energy in Shanghai
	Application scope	Shanghai, effective from 21 April 2014
	Content	The fund provides support to the projects related to wind power and photovoltaic power. Reward for the investors supporting the use of renewable energy is calculated on the following principles: (1) The length of rewarding time is 5 years; (2) Reward of 0.2 and 0.3 Yuan per kWh is given to wind and photovoltaic projects respectively; (3) The annual reward for one project is no more than 50 million Yuan.

	Impact objectives	The companies which invest in projects on renewable energy will receive financial support in Shanghai. For example, the project of East Sea Bridge offshore power plant with installed capacity of 102.2 MW received the reward of 0.2 Yuan per kWh for 5 years' time from 2016 (Shanghai Development and Reform Commission, 2016).

Source: Elaboration of the author based on a variety of sources

4 Result and analysis

In the third chapter, we presented all the information about a variety of environmental measures and related incentive programs. Several points about China’s marine environmental governance became clear.

(1) It is different from port to port and region to region in terms of the environmental measures deployment. Ports or regions where marine traffic is busy and economic base is strong tend to apply more environmental schemes and incentive measures to control marine pollution. This is not a surprise due to the reasons below. First, the application of certain efficient environmental strategies such as shore power requires high investment in the first place and ports or local governments which have relevant knowledge, required technology and strong economical base tend to have the ability to support such initiatives. Second, regions with busy maritime traffic are more likely to be the areas which are relatively seriously polluted. In this way, departments at the national level, such as MOT tend to target the associated ports and take regulatory and/or measures of financial support to encourage and shipping to become greener;

(2) In 2016, the MOT launched the program “Green Port Grade Evaluation”. This program includes several different assessment categories and different types of terminals which are evaluated based on different criteria.

The first one is known as the enterprise concept which involves the establishment of environment management plan, a special fund for environmental governance, promoting the green port idea and related training for the employees.

The second one is called the action which evaluates the measures taken to achieve pollution control, energy saving and low carbon production process such as the setting up of the emergency plan for water pollution, the deployment of shore power, the use of renewable and clean energy.

The third one is known as the management which consists of the administration system, monitoring and supervision.

The last one is called the environmental performance which is quantitatively assessed based on various indicators such as the amount of CO2 emissions and other air pollutants emitted per ton of cargo handled as a share of clean energy utilization (MOT, 2013).

As mentioned above, MOT tends to encourage port to carry out systematic green port tools to improve region’s environment situation. Not surprisingly, local governments also give positive response to the evaluation. For example, Department of Transport of Tianjin issued a document called the Advice for Green Port Construction, which presents the goal to build at least 5 green terminals by the end of 2016 and at least 20 green terminals by the end of 2020. Similar goals and related environmental improvement indicators are also mentioned in various reports and plans of local or regional governments such as an Action Plan of Guangzhou Green Ports Construction (2014-2020).

For the first grade assessment, Shenzhen Shekou container terminal, Ningbo Beilun container terminal and Qinhuangdao coal terminal together with other three terminals were awarded the status of a four star green port in 2016 (People Network, 2016).

It is surely a positive signal to the industry because according to the research of Lam and Notteboom (2012), it turns out that ports which implement more combined measures tend to have better environmental performance;

(3) Five-year Planning is one of the China's development strategies. After the economic reform, the five-year plan is no longer the original socialist economy measure but gradually expanded its scope from economic development further to the improvement of culture, public service and ecological system construction (Jiang & Yan, 2015).

In accordance with the Twelfth Five-year Plan, MOT carried out its Energy Saving and Emission Control Action Plan during the Twelfth Five-year period in 2011 (MOT, 2011). The action plan not only encouraged the deployment of many environmental measures such as onshore power supply, electric powered RTGs and LNG powered terminal trucks, but also added drafting the relevant environmental regulations to the schedule.

It is worth to note that because of China's port governance, the environmental policies of port authorities are mainly directed by the MOT at the national level. In contrast, port authorities in the EU tend to be more flexible to carry out their local environmental regulations.

In general, based on the instruction of MOT as well as other national departments, China's local governments would be more likely to draft and issue their own marine environmental plans and normally set up even higher environmental requirements and goals compared to the national plan. Related tasks such as the deployment of certain environmental measures will be assigned to the sub-departments. This way, the plan can be well executed; the process can be clearly tracked and responsibilities - well distributed.

When China's ports are looked at as a whole in the year of 2016, it can be seen that the pattern of ports' environmental strategies application is strongly influenced and driven by the regional or national environmental action plans, national regulations and international conventions;

(4) The majority of ports are still taking measures that focus on promoting energy efficiency.

The project called "fuel to electricity" is still the main trend in ports nationwide with the aim to change the diesel fuel powered gantry cranes to the electricity powered ones in order to increase energy utilization and reduce air, noise and vibration pollution in the port region.

The project, known as "fuel to gas" is focused on promoting vessels to use LNG in inland rivers. Although MOT provide subsidy for newly built LNG vessels, the outcome is still hard to predict. The reason is that the number of vessels suitable for retrofit is way bigger than the number of newly built LNG vessels. The subsidy policy, however, does not include supporting vessel retrofitting.

However, for now, according to author's information, not many port authorities make any investment on projects regarding the utilization of renewable energy;

(5) With regard to vessel pollution, the main focus is put on the impact on air and water.

Speaking of vessel air pollution, there are still no specific regulations to limit the air pollutants emitted during vessel operation in China. It can be seen that the associated provisions are distributed in different regulations and standards. There are no very well organized regulations on this issue.

Moreover, based on the vessel gas emission standards listed in Table 5, a large number of vessels built before 2008 are unregulated in terms of air pollution.

Furthermore, especially for the vessels operating in the inland river area, there are no strict requirements on the quality of the fuel they use. For now, 90% of the inland river vessels use fuel with sulphur content ranging from 1% to 2% which is even lower than the China's ECAs requirement (Eworldship, 2015).

Therefore, it makes managing vessel gas emissions rather difficult.

For vessel water pollution issues, even though regulations in national and local level cover the water area in China, the practical performance turns out to be not good based on the information from the social media. It can be mainly blamed for the weak supervision by the marine authorities' and for the enforcement of these regulations.

But more importantly, vessels as mobile pollution sources are not included in the pollution assessment of the port region. In other words, the measurement of environmental performance of a port does not include the pollution brought by vessels (Huanqiu Network, 2015).

This way, local port authorities do not have the incentive to carry out strict environment measures to limit vessel pollution because ship operators may suffer higher costs and choose to call at alternative ports.

Therefore, the measurement method for port related pollutions should take the vessel impact into consideration and mandatory regulations on vessel emissions and discharging need to come into force;

(6) It is important to be aware that the development of green shipping and ports is still in its early stage of development in China. The lack of technology, experience, regulatory system, financial support is needed to be solved. Learning good practices from other places in the world would be extremely useful for smooth and effective promotion of green ports and vessels.

Because of the specific natural and economical profile of each of China's ports, the feasibility of certain environmental measures needs to be carefully assessed in advance.

Another issue here is that most of ports in China are not clear about their emission profiles. It is rather urgent for port authorities to begin working on their emission inventory so that they are able to have a clear picture of their impact on the local environment and recognize the main sources of air pollution and further deploy the corresponded measure to control the pollution;

(7) When it comes to the environmental level playing field, the need for cooperation in national level is pretty obvious, which has been shown in various pilot projects initiated by MOT. For the vessel waste disposal project, MOT nominated Port of Shenzhen and ports located in Suzhou area of the Beijing-Hangzhou Canal to come up with the construction plan. Then, based on this experience, the formal guidance of construction plan will be issued to all ports. Just as other pilot projects on shore power, the experience and knowledge will be shared among China's ports. With the accumulated information, MOT can further direct and promote the application of certain environmental strategy;

(8) Based on the good practices applied in the world, it is also worth to mention the difference between the EU and China.

Landlord ports are well applied in the EU in which the port authority leases the land to private operators for a certain period of time and could ask the operators to meet certain environmental standards and requirement (Lam & Notteboom, 2012). In recent years, the landlord port financing has also been used in several Chinese terminals such as the Yangshan container terminal in Shanghai that receives investments from 10 different companies including SIPG, COSCO, the Maersk Group and others (China Water Transport, 2011). However, we did not find evidence that this practice has been used by any other ports in China.

5 Conclusion

China, as the “world factory”, is facing serious environmental problems. Shipping as one of the main sources of pollution is too unregulated and adds up to the serious environmental situation in China’s coastal areas where the density of population is high and where economic activities are located.

Since the smog covered all of China in 2011, government faces a lot of pressure from the society. Chinese government became active and showed strong ambition to improve the environment in shipping and port sector by publishing various national plans, revising and establishing a variety of environmental regulations on marine issues, and giving financial support to stakeholders to improve their environmental performance. Many regions including Shanghai, Hong Kong, and Jiangsu Province, following the national plans began to take measures on environment management, such as the deployment of onshore power system and switching to low sulphur fuel.

This paper looked into various good practices to decrease pollution in shipping and ports and summarized the measures that were adopted by China’s ports as well as the most recent regulations on this issue adopted at different governmental levels in China.

Based on the information inventory, it is observed that ports behave differently regarding the application of green policy. It is easy to understand that ports such as Shanghai and Shenzhen with strong and mature economic hinterland are more proactive in applying various environmental strategies because the negative impact of shipping is much worse. Central government is also likely to pay attention to the environmental performance in such ports. Moreover, green policy is mostly made by the central government, and local governments just have to follow the ideas to further implement the measures. No evidence was found that ports were introducing their own strategies, not included in the National Plan, such as the environmental charging, which has been effective in the EU for many years. This phenomenon can be linked to the lack of open geopolitical culture in China and to the fact that most of the port companies are state owned and used to be directly managed by the central government. Furthermore, another characteristic in China green port and shipping development is the various pilot projects that have been approved and appointed by the central government; the projects could cover a wide range of field including technical research, construction plan drafting and the deployment of environmental measures. Various stakeholders are involved in shipping and there are complex relationships between them. The practical performance of certain greening policies is always influenced by various factors. Pilot projects are extremely helpful tools and provide insights for policy making and for assessing the measures that need to be introduced. This is, because through these pilot projects, the central government gains knowledge about the obstacles on the ground, and about costs and benefits of the measures in this process.

The research questions of this paper can be answered as following.

(1) The stakeholders involved in application of environmental strategies in ports are mainly government, port authority, ship-owners, terminal operators, and local community. In general, central government carries out national plan to promote the deployment of the measures. Then port authority has to evaluate the feasibility and utilization of the measures with ship-owners and other stakeholders.

(2) The existing regulation framework and environmental schemes together with their impact are listed in the inventory in the above chapter. According to the inventory, China has started to be active in promoting environmental standard in shipping and port sector. however, with the lack of the experience, environment monitor, well established regulation and standard and proper financial incentives, the practical performance of the measure are remained to be assessed.

With a basic understanding of the current situation about greening policies in China, the main challenges that China's regulators may come across are the following.

(1) The competitiveness in maritime industry is extremely high. Therefore, port authorities are reluctant to carry out the measures that are not compulsory in the national plan because most of the environmental strategies will give extra burden on ship operators and in turn lower the competitiveness of the ports.

(2) Because of the flawed regulation system and the weakness in supervision and enforcement, the performance of environmental strategies may be not as good as expected. Therefore, it is essential to update the outdated environmental standard to meet the current requirements and put effort in building efficient supervision system.

(3) Environmental measures such as shore power and the use of LNG need high investment. Since the shipping market is depressed, ship operators are not taking an active part in complying with such measures. Therefore, financial support is extremely important to stipulate green shipping and the application of environmental strategies.

(4) Emission inventories which have contributed to construction of green ports in the EU are vital for green policy making because it can help policy makers identify

the weaknesses in the port and vessel operation, and help recognize the priorities and further devote the resources to tackle the problems. However, among the ports in China, only Hong Kong and Shanghai have carried out emission inventories in shipping. As stated in the national plan, the systematic emission inventory of China's ports is expected to be set up in the near future. Thereby, optimized plans can be carried out by both national and local governments.

With the establishment of China's ECAs, the signal from the Chinese central government became clear that the development of green shipping and ports is underway, stakeholders involved need to carry out an environmental assessment in order to meet the high environmental standards in shipping.

In general, it is important for China to participate in international cooperation, and thereby learn some good practices and well executed regulations and adopt advanced technology. China's central government needs to keep promoting green technology innovation, and improving related regulations and supervision systems to better tackle and restrict polluters' behaviors. It also needs to establish an emission inventory nationwide. Local port authorities should adopt suitable measures according to their unique environmental problems and take quick actions based on the environmental monitor.

Bibliography

1. Acciaro, M., 2014. Real option analysis for environmental compliance: LNG and emission control areas. *Transportation Research Part D: Transport and Environment,* Volume 28, p. 41–50.

2. AEA Technology, 2009. *Cost Benefit Analysis to support the impact assessment accompanying the revision of Directive 1999/32/EC on the sulphur content of certain liquid fuels.*

3. Baidu Wenku, 2012. *Introduction of Alternative Maritime Power.* [Online] Available at: http://wenku.baidu.com/link?url=SZyGGyzdjBRbsPu1MPfdteS5VB217ElF1dHSdwM-ZWK7IXA8dXN2zwMuW2OZgInCdcnoGPIkLurPA4D0FAMG9eQDIOWmsu0-ywKo5akfMuO
[Accessed 17 7 2016].

4. Ballini, F. & Bozzo, R., 2015. Air pollution from ships in ports: The socio-economic benefit of cold-ironing technology. *Research in Transportation Business & Management,* Volume 17, pp. 92-98.

5. Bidchance, 2016. *Demand disclosure of Shenzhen 2015 vessel emission inventory research.* [Online]
Available at: http://www.bidchance.com/calggnew/2016/07/26/15599621.html
[Accessed 8 10 2016].

6. Cariou, P., 2011. Is slow steaming a sustainable means of reducing CO2 emissions from container shipping?. *Transportation Research Part D: Transport and Environment,* 16(3), pp. 260-264.

7. CE Delft, 2016. *SECA Assessment: Impacts of 2015 SECA marine fuel sulphur limits.*

8. Chang, C. C. & Jhang, C. W., 2016. Reducing speed and fuel transfer of the Green Flag Incentive Program in Kaohsiung Port Taiwan. *Transportation Research Part D: Transport and Environment,* Volume 46, p. 1–10.

9. Chang, C.-C. & Wang, C.-M., 2014. Evaluating the effects of speed reduce for shipping costs and CO2 emission. *Transportation Research Part D: Transport and Environment,* Volume 31, p. 110–115.

10. Chang, Y.-T. & Park, H., 2016. *The impact of vessel speed reduction on port accidents.*

11. China Academy of Transportation Sciences, 2014. *Port Economic Development in China.*

12. China Academy of Transportation Sciences, 2015. *Green Port Policy and Trend.* Fuzhou.

13. China Energy Network, 2014. *Seeking the Solution for Retrofitting Coal-fired power plants in China to pursue the 'Ultra Low emission' Goal.* [Online] Available at: http://www.china5e.com/news/news-874408-1.html [Accessed 17 7 2016].

14. China IRR, 2012. *The present situaion of energy consumption in Chiese transportation industry.* [Online] Available at: http://www.chinairr.org/view/V12/201205/22-99667.html [Accessed 7 7 2016].

15. China Maritime Transport Network, 2016. *The Limitation on vessel emission will be started in the Yangtze River Delta ECA from the first of April.* [Online] Available at: http://www.zgsyb.com/html/content/2016-04/05/content_481125.shtml [Accessed 25 7 2016].

16. China Ports & Harbours Association, 2016. *Vessel emission inventory in Beijing-Hangzhou Canal area.* [Online] Available at: http://www.port.org.cn/info/2016/192218.htm [Accessed 10 8 2016].

17. China Traffic News Network, 2015. *Break through the trap of cold ironing implemention.* [Online] Available at: http://www.zgjtb.com/shuiyun/2015-05/26/content_30127.htm [Accessed 17 7 2016].

18. China Water Transport, 2011. *The landlord ports in China.* [Online] Available at: http://epaper.zgsyb.com/html/2011-04/04/content_22004.htm [Accessed 18 8 2016].

19. Chineseport Network, 2015. *New regulation for vessel pollution in Shanghai ports are forced into practice.* [Online] Available at: http://www.chineseport.cn/bencandy.php?fid=47&id=209052 [Accessed 29 7 2016].

20. Ching-Chih Chang, C.-M. W., 2012. Evaluating the effects of green port policy: Case study of Kaohsiung harbor in Taiwan. *Transportation Research Part D: Transport and Environment,* Volume 17, pp. 185-189.

21. Ching-Chih Chang, C.-M. W., 2014. Evaluating the effects of speed reduce for shipping costs and CO2 emission. *Transportation Research Part D: Transport and Environment,* Volume 31, pp. 110-115.

22. Climate Action Tracker, 2014. *China, US and EU post-2020 plans reduce projected warming.*

23. Convention on Biological Diversity, 2012. *Scientific synthesis on the impacts of underwater noise on marine and coastal biodiversity and habitats.*

24. Corbett, J. & Winebrake, J., 2008. *The Impacts of Globalisation on International Maritime Transport Activity.* Guadalajara, Mexico.

25. Dalian Port (PDA) Company limited, 2014. *Annual report 2014.*

26. Darbra, R. M. et al., 2005. A procedure for identifying significant environmental aspects in sea ports. *Marine Pollution Bulletin,* Volume 50, p. 866–874.

27. Darbra, R. M. et al., 2004. The Self Diagnosis Method: A new methodology to assess environmental management in sea ports. *Marine Pollution Bulletin,* Volume 48, p. 420–428.

28. Donnelly, A., Jones, M., O'Mahony, T. & Byrne, G., 2007. Selecting environmental indicator for use in strategic environmental assessment. *Environmental Impact Assessment Review,* Volume 27, p. 161–175.

29. ECSA, 2010. *Analysis of the Consequences of Low Sulphur Fuel Requirements.*

30. EMSA, 2010. *The 0.1% sulphur in fuel requirement as from 1 January 2015 in SECAs - An assessment of available impact studies and alternative means of compliance,* EMSA.

31. EPA, 2010. *Designation of North American Emission Control Area to Reduce Emissions from Ships.*

32. EPD, 2016. *2014 Hong Kong Emission Inventory Report.*

33. European Commission, 2016. *Study on differentiated port infrastructure charges to promote environmentally friendly maritime transport activities and sustainable transportation.*

34. Eworldship, 2015. *New standard for vessel bunker oil.* [Online]
Available at:
http://www.eworldship.com/html/2015/ship_inside_and_outside_1210/109694.html
[Accessed 11 8 2016].

35. Fagerholt, K., Gausel, N. T., Rakke, J. G. & Psaraftis, H. N., 2015. Maritime routing and speed optimization with emission control areas. *Transportation Research Part C: Emerging Technologies,* Volume 52, p. 57–73.

36. Geall, S. et al., 2014. *China's Environment: Ambitions, Challenges and Opportunities for EU Cooperation.*

37. Green Port, 2015. *Incentivising cleaner shipping.* [Online]
Available at:
http://www.greenport.com/news101/opinion/incentivising-cleaner-shipping
[Accessed 30 3 2016].

38. Huanqiu Network, 2015. *Green shipping promotion.* [Online]
Available at: http://finance.huanqiu.com/roll/2015-03/5990681.html
[Accessed 18 8 2016].

39. ICF Internaitonal, 2014. *Maritime emission inventory development in Europe.*

40. Ifeng, 2015. *Jiangsu is leading in the Inland river vessel dismantlement.* [Online]
Available at: http://news.ifeng.com/a/20150917/44677813_0.shtml
[Accessed 17 8 2016].

41. IMO, 2014. *Third IMO Greenhouse Gas Study 2014,* s.l.: s.n.

42. IMO, 2016. *Ballast Water Management.* [Online]
Available at:
http://www.imo.org/en/OurWork/Environment/BallastWaterManagement/Pages/Default.aspx
[Accessed 28 7 2016].

43. IMO, 2016. *Emission Control Areas (ECAs) designated under MARPOL Annex VI.* [Online]
Available at:
http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Emission-Control-Areas-%28ECAs%29-designated-under-regulation-13-of-MARPOL-Annex-VI-%28NOx-emission-control%29.aspx
[Accessed 23 7 2016].

44. IMO, 2016. *Nitrogen Oxides (NOx) – Regulation 13.* [Online] Available at: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Nitrogen-oxides-(NOx)-%E2%80%93-Regulation-13.aspx [Accessed 24 7 2016].

45. IMO, 2016. *Prevention of Air Pollution from Ships.* [Online] Available at: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Air-Pollution.aspx [Accessed 23 7 2016].

46. IMO, 2016. *Prevention of Pollution by Sewage from Ships.* [Online] Available at: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/Sewage/Pages/Default.aspx [Accessed 28 7 2016].

47. IMO, 2016. *Sulphur oxides (SOx) – Regulation 14.* [Online] Available at: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx [Accessed 23 7 2016].

48. Jiang, J. & Yan, Y., 2015. The promotion of drafting and application of the Thirteenth Five-year plan. *Review of Economic Research,* Volume 60, pp. 5-10.

49. JSWMW, 2015. *Vessel dismantlement in Yancheng.* [Online] Available at: http://www.jswmw.com/9661/201511/t2494902.shtml [Accessed 17 8 2016].

50. Khan, M. Y. et al., 2012. Greenhouse Gas and Criteria Emission Benefits through Reduction of Vessel Speed at Sea. *Environmental Science & Technology,* 46(22), p. 12600–12607.

51. Lam, J. S. L. & Notteboom, T., 2012. *The green port toolbox: A comparison of port management tools used by leading ports in Asia and Europe.*

52. Lee, C.-Y., Lee, H. L. & Zhang, J., 2015. The impact of slow ocean steaming on delivery reliability and fuel consumption. *Transportation Research Part E: Logistics and Transportation Review,* Volume 76, pp. 176-190.

53. Lee, H., 2014. *The economics of slow steaming.* [Online] Available at: http://www.seatrade-maritime.com/news/americas/the-economics-of-slow-steaming.html [Accessed 20 7 2016].

54. Lister, J., Poulsen, R. T. & Ponte, S., 2015. Orchestrating transnational environmental governance in maritime shipping. *Global Environmental Change,* 9, Volume 34, pp. 185-195.

55. Li, Z., 2009. The problems in China's environmental governance. *China's Academy of Governance Paper,* Volume 4, pp. 108-112.

56. Maritime Safety Administration of Shanghai, 2016. *Working plan for limiting vessel emission in Shanghai.*

57. MEP, 2015. *Vessel engine exhausted gas emission standard.* [Online] Available at: http://www.zhb.gov.cn/gkml/hbb/bgth/201506/t20150604_302952.htm [Accessed 7 8 2016].

58. Mercator Institution for China Studies, 2015. *China's climate promises under economic pressure: scenarios and implications.*

59. MNW, 2015. *The port of Quanzhou 's throughput amounts to 110 million tonnes in 2014.* [Online] Available at: http://www.mnw.cn/quanzhou/news/915186.html [Accessed 12 7 2016].

60. Moon, D. S.-H. & Woo, J. K., 2014. The impact of port operations on efficient ship operation from both economic and environmental perspectives. *Maritime Policy & Management,* 41(5), pp. 444-461.

61. MOT, 2011. *Energy saving and emission control action plan during the Twelfth Five-year period.*

62. MOT, 2013. *Green Port Grade Evaluation.*

63. MOT, 2014. *The publicity of projects which receive the fund in 2014.* [Online] Available at: http://www.moc.gov.cn/zfxxgk/bnssj/zcfgs/201405/t20140520_1621573.html [Accessed 17 8 2016].

64. MOT, 2015. *Implementation Plan on Domestic Emission Control Areas in Waters of the Pearl River Delta, the Yangtze River Delta and Bohai Rim (Beijing, Tianjin, Hebei).*

65. MOT, 2015. *The action plan for preventing the pollution in shipping and port sector (2015-2020).*

66. MOT, 2016. *The notification about vessel waste reception and treatment,* s.l.: s.n.

67. NDRC, 2016. *Climate Change Department.* [Online]
Available at: http://qhs.ndrc.gov.cn/
[Accessed 4 8 2016].

68. NDRC, 2016. *National Energy Administration.* [Online]
Available at: http://www.nea.gov.cn/
[Accessed 4 8 2016].

69. NDRC, 2016. *Resource Conservation and Environmental Protection Department.* [Online]
Available at: http://hzs.ndrc.gov.cn/
[Accessed 4 8 2016].

70. New York Times, 2013. *Air Pollution Linked to 1.2 Million Premature Deaths in China.* [Online]
Available at:
http://www.nytimes.com/2013/04/02/world/asia/air-pollution-linked-to-1-2-million-deaths-in-china.html?_r=0
[Accessed 8 7 2016].

71. NoMEPorts, 2008. *Good Practice Guide on Port Area Noise Mapping and Management.*

72. Notteboom, T., 2011. *Current issues in shipping, ports and logistics.* Silhouet, Maldegem: UPA.

73. Notteboom, T. & Cariou, P., 2009. *Fuel surcharge practices of container shipping lines: is it about cost recovery or revenue-making?,* Copenhagen.

74. NPC, 2003. *Port law of the People's Republic of China.*

75. NRDC, 2014. *Prevention and Control of Shipping and Port Air Emissions in China.*

76. O'Brien, M., 2016. Oil spills in ports. *Ports & Harbors*, 7, pp. 34-35.

77. Patrik Ericsson, I. F., 2008. *Shore side electricity, A feasibility study and a technical solution for an on-shore electrical infrastructure to supply vessels with electric power while in port.*

78. People Network, 2015. *Promoting shore power in Jiangsu Province.* [Online] Available at: http://fj.people.com.cn/ocean/n/2015/1012/c354245-26756463.html [Accessed 16 8 2016].

79. People Network, 2016. *China's green ports.* [Online] Available at: http://sz.people.com.cn/n2/2016/0628/c202846-28575579.html [Accessed 14 8 2016].

80. People Network, 2016. *The shore power system comes into operation.* [Online] Available at: http://sh.people.com.cn/n2/2016/0715/c134768-28676467.html [Accessed 16 8 2016].

81. Port of Long Beach, 2015. *Green Flag Incentive Program.* [Online] Available at: http://www.polb.com/environment/air/greenflag.asp [Accessed 21 7 2016].

82. Port of Long Beach, 2015. *Vessel Emissions.* [Online] Available at: http://www.polb.com/environment/air/vessels/default.asp [Accessed 18 7 2016].

83. Port of Long Beach, 2016. *Green Ship Incentive Program.* [Online] Available at: http://www.polb.com/environment/greenship.asp [Accessed 26 7 2016].

84. Port of Rotterdam, 2009. *Proactive/reactive water pollution response in ports and economics go hand in hand.*

85. Puig, M., Wooldridge, C. & Darbra, R. M., 2014. Identification and selection of Environmental Performance Indicators for sustainable port development. *Marine Pollution Bulletin,* Volume 81, p. 124–130.

86. Schinas, O. & Butler, M., 2016. Feasibility and commercial considerations of LNG-fueled ships. *Ocean Engineering,* Volume 122, p. 84–96.

87. Shanghai Development and Reform Commission, 2016. *Notification for projects receiving the renewable energy fund in 2015.* [Online] Available at: http://www.shdrc.gov.cn/xxgk/cxxgk/22913.htm [Accessed 17 8 2016].

88. Shanghai Environmental Monitoring Center, 2014. *Emission inventory of Shanghai port and vessels in Shanghai area.*

89. Shenzhen Environment Committee, 2015. *Report of low sulphur fuel switching in Port of Shenzhen.*

90. Shipping Exchange Bulletin, 2016. *The use of LNG in vessels has not become a trend.* [Online]
Available at:
http://www.eworldship.com/html/2016/ship_inside_and_outside_0816/118655.html
[Accessed 17 8 2016].

91. Smith, A. B., 2010. *Gas fuelled ships: fundamentals, benefits classification & operational issues.*

92. SMPG, 2015. *Measures for control of vessel related pollution in Shanghai ports.*

93. Tan, P.-Q., Hu, Z.-Y. & Lou, D.-M., 2009. Regulated and unregulated emissions from a light-duty diesel engine with different sulfur content fuels. *Fuel,* 88(6), p. 1086–1091.

94. The Maersk Group, 2016. *Triple-E.* [Online]
Available at: http://www.maersk.com/en/hardware/triple-e
[Accessed 30 3 2016].

95. The Pearl River Maritime Management Bureau, 2016. *The model experiment for energy efficient vessel is passed.* [Online]
Available at:
http://www.moc.gov.cn/zizhan/zhishuJG/zhuhangju/tupianxinwen/201601/t20160127_1982316.html
[Accessed 17 8 2016].

96. The State Council, 2014. *National Climate Change Plam (2014-2020).*

97. The Statistics Portal, 2016. *Waterway cargo volume in China from 2005 to 2015 (in billion metric tons).*

98. Tongzon, J. L., 2009. Port choice and freight forwarders. *Transportation Research Part E,* 45(1), pp. 186-195.

99. Transport Department of Guangzhou, 2014. *The action plan of Guangzhou green ports construction (2014-2020).*

100. Transport Department of Jiangsu Government, 2015. *The publicity of projects which received energy saving fund in 2015.* [Online]
Available at: http://www.jscd.gov.cn/art/2015/8/26/art_18866_1082164.html
[Accessed 17 8 2016].

101. Transport Department of Tianjin, 2014. *The advise for Tianjin green port construction.*

102. Tzannatos, E., 2010. Cost assessment of ship emission reduction methods at berth: the case of the Port of Piraeus, Greece. *Maritime Policy & Management,* 37(4), pp. 427-445.

103. UK Marine Special Areas of Conservation, n.d. *Summary of the potential effects of oil on the environment.* [Online]
Available at: http://www.ukmarinesac.org.uk/activities/ports/ph6_2_1.htm
[Accessed 28 7 2016].

104. United Nations, 1992. *Assessment of the Environmental Impact of Port Development. A Guidebook for EIA of Port Development.*

105. Wang, J. J., Ng, A. K.-Y. & Olivier, D., 2004. Port governance in China: a review of policies in an era. *Transport Policy,* 11(3), pp. 237-250.

106. WHO, 1999. *Guidlines for community noise.*

107. World Port Climate Initiative, 2013. *Onshore Power Supply.*

108. Wu, X., 2016. *Set up the system "one waste receiving ship, one waste treatment facility and one operation system".* [Online]
Available at:
http://news.eastday.com/eastday/13news/auto/news/csj/20160503/u7ai5597547.html
[Accessed 17 8 2016].

109. Wuxi development and reform commission, 2015. *Installation of sewage handling system in Wuxi.* [Online]
Available at: http://dpc.wuxi.gov.cn/doc/2015/12/21/832917.shtml
[Accessed 17 8 2016].

110. Xinhuan Net, 2013. *The establishment of the "oil to gas" market.* [Online]
Available at: http://news.xinhuanet.com/fortune/2013-06/24/c_124899749.htm
[Accessed 12 8 2016].

111. Xu, M. & Chin, A. T., 2012. Port Governance in China: Devolution and Effects Analysis. *Social and Behavioral Sciences,* Volume 43, p. 14 – 23.

112. Zis, T. et al., 2014. Evaluation of cold ironing and speed reduction policies to reduce ship emissions near and at ports.. *Maritime Economics & Logistics,* 6, 16(4), pp. 371-398.