Exploring Ship Emissions Mitigation Strategies for the Port of Shanghai

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Abstract: Over the last two decades, China has developed into a global export/import powerhouse. As one of China's most important gateways for foreign trade, the Port of Shanghai handles huge container throughput and serves the economy of its hinterland. The increasing port operations in recent years have called for the establishment of more shipping lines, stevedore firms and port authorities, which, in turn, has resulted in negative atmospheric emissions. This paper adopts an initial qualitative approach to explore managerial strategies to mitigate emissions in the Port of Shanghai. From the policy perspective, this paper conducts in-depth interviews with port operators and port officials based on grounded theory. Three mitigation strategies, namely, shore power, fuel regulation and ship speed reduction, are provided and discussed. Finally, conclusions with policy implications are drawn.

Key Words: Port of Shanghai; Emission; Mitigation strategies

I. Introduction

Fueled by the boom in China's economic development from the 1990s, the Asia-Pacific Rim's port cities have seen a tremendous increase in their container throughput, causing these cities to become key shipping hubs.[1] Nowadays, the Nor-

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1 Ding Ding and Chung-Piaw Teo, World Container Port Throughput Follows Lognormal Distribution, *Maritime Policy and Management*, Vol. 37, No. 4, 2010, pp. 401~426.

thern Trans-Atlantic and Trans-Pacific are the busiest trading routes in the world.[2] Large containerized imports/exports in China have resulted in changes to the ranking of the world's container ports, especially after mega-containerships with a carrying capacity of 12,000 twenty-foot equivalent units (TEUs) were adopted when they were proved economically feasible in the 1990s.[3] Port activities, like cargo load/unload and truck movement, however, bring air pollution problems and affect human health in coastal areas. Health impacts include asthma, respiratory diseases and lung cancer. Indeed, due to cost considerations, some ships burn low-quality residual fuel that contains high amounts of sulfur and heavy metals. These negative outcomes should be avoided through effective policy regulation.

The Port of Shanghai, the world's largest container port since 2010, has witnessed remarkable growth in container throughput and inevitably brought a substantial amount of adverse environmental side-effects, such as atmospheric emissions, especially the emissions of nitrogen oxide (NOx), carbon dioxide (CO_2) and sulfur dioxide (SO_2). Further, all of these adverse impacts may potentially cause port-community conflicts. Indeed, such negative externalities in the production of port service in Shanghai have become serious, especially in port congestion and the accompanying ship waiting time, and are worthy of investigation. The relevant external costs encompass an impact on human health, the environment, and the climate of the coastal community. Within the shipping industry, the concept of green port emphasizing corporate social responsibility is a disputed one that requires port operators, shipping lines and port policy makers to discuss for cost consideration and achieve a multi-win-win situation. In this context, the Port of Shanghai authorities should develop response and adaptation strategies to solve these externalities problems.

A growing number of studies have investigated a port's environmental impacts

2 Anthony T. H. Chin and Joyce M. W. Low, Port Performance in Asia: Does Production Efficiency Imply Environmental Efficiency, *Transportation Research Part D: Transport and Environment*, Vol. 15, 2010, pp. 483~488.

3 Kevin Cullinane, Mahim Khanna and Dong-Wook Song, How Big Is Beautiful: Economics of Scale and the Optimal Size of Containership, in *Proceedings of the International Association Maritime Economists 1999 Conference*, 1999, Halifax, Canada.

and sustainable policies in the past decade.[4 5 6] For example, some researchers have analyzed the growth patterns of the four busiest container ports of Shanghai, Singapore, Hong Kong and Shenzhen and examined the implications of their sustainable policies via a longitudinal approach.[7] In order to control emissions to air from ships, limits on sulfur oxide (with a maximum sulfur content of 0.1% for fuel) and nitrogen oxide emissions are required by International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI.[8] Also, fuel brokers and suppliers are not allowed to sell fuel with a sulfur content higher than 0.1%. Such strict standards of MARPOL, a marine environmental convention, might, however, increase the operation expenses of seagoing vessels. Taking liner and tramp shipping as cases, some researchers have estimated the cost impact of the environmental regulation in the sulfur emission control areas.[9] Cost assessment and sensitivity analysis have been tested via a stochastic linear model with scenario variables, such as fleet data, number of slots and demand patterns, being considered.

There is also some literature that has investigated green port policies, such as those in Kaohsiung port.[10] The results of such investigations revealed that the strategy of reducing the ship speed to 12 knots was highly effective in cutting fuel consumption, costs and also emissions. Yet, in addition to ships, air pollution at

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4 Peter V. Hall, Thomas O'Brien and Clarence Woudsma, Environmental Innovation and the Role of Stakeholder Collaboration in West Coast Port Gateways, *Research in Transportation Economics*, Vol. 42, 2013, pp. 87~96.

5 Michele Acciaro, Thierry Vanelslander, Christa Sys, Claudio Ferrari, Athena Roumboutsos, Genevieve Giuliano, Jasmine Siu Lee Lam and Seraphim Kapros, Environmental Sustainability in Seaports: A Framework for Successful Innovation, *Maritime Policy & Management*, Vol. 41, Issue 5, 2014, pp. 480~500.

6 Adolf K.Y. Ng, Shu-Ling Chen, Stephen Cahoon, Ben Brooks and Zaili Yang, Climate Change and the Adaptation Strategies of Ports: The Australian Experiences, *Research in Transportation Business & Management*, Vol. 8, 2013, pp. 186~194.

7 Wei Yim Yap and Jasmine Siu Lee Lam, 80 Million-twenty-foot-equivalent-unit Container Port? Sustainability Issues in Port and Coastal Development, *Ocean & Coastal Management*, Vol. 71, 2013, pp. 13~25.

8 International Convention for the Prevention of Pollution from Ships (MARPOL) first adopted in 1997, and entered into force on 19 May 2005. The revised Annex VI entered into force on 1 July 2010, at http://www.marpol-annex-vi.com/marpol-annex-vi/, 31 August 2014.

9 O. Schinas and Ch. N. Stefanakos, Cost Assessment of Environmental Regulation and Options for Marine Operators, *Transportation Research Part C: Emerging Technologies*, Vol. 25, 2012, pp. 81~99.

10 Ching-Chih Chang and Chih-Min Wang, Evaluating the Effects of Green Port Policy: Case Study of Kaohsiung Harbor in Taiwan, *Transportation Research Part D: Transport and Environment*, Vol. 7, 2012, pp. 185~189.

ports obviously comes from other sources such as trucks, locomotives, and off-road equipment used for moving cargo. In the US, several strategies have been introduced to reduce ship emissions, including the use of low-sulfur diesel fuel, shore-side power for docked ships, and alternative fuels.[11] In the meanwhile, cold ironing and speed reduction are viewed as useful policies to reduce emissions near to and inside ports.[12] Furthermore, a recent comparison of the green port policies in four leading ports showed that Antwerp and Rotterdam maintained a higher level of influence on devising green port policy than Singapore and Shanghai.[13] In addition, a gradual trend has been seen in the investigation of marine environmental awareness and attitude toward marine air emissions. For instance, one Swedish study has conducted a survey among Swedish ports, aiming to find their attitudes towards regulations of the shipping sector's emissions of CO_2, and the findings indicated that ports were generally positive towards an implementation of a mandatory CO_2 differentiated port dues scheme (97%), a technical standard (92%), a CO_2 taxation (84%) and an inclusion in the EU ETS (The European Union Emissions Trading Scheme) (74%).[14]

With regard to the formulation of more international maritime regulations, the International Maritime Organization (IMO) has discussed both technical and market-based measures to reduce greenhouse gas emissions from shipping, such as lowering ship speed or replacing rubber tired gantry crane with rail mounted gantry cranes.[15] The MARPOL Annex VI Regulations for the Prevention of Air Pollution from Ships, which entered into force on 1 January 2013, regulates energy efficiency for ships to make the Energy Efficiency Design Index (EEDI) mandatory for new ships, and the Ship Energy Efficiency Management Plan (SEEMP) mandatory for

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11 Diane Bailey and Gina Solomon, Pollution Prevention at Ports: Clearing the Air, *Environmental Impact Assessment Review*, Vol. 24, 2004, pp. 749~774.

12 Thalis Zis, Robin Jacob North, Panagiotis Angeloudis, Washington Yotto Ochieng and Michael Geoffrey Harrison Bell, Evaluation of Cold Ironing and Speed Reduction Policies to Reduce Ship Emissions near and at Ports, *Maritime Economics & Logistics*, Vol. 16, 2014, pp. 371~398.

13 Jasmine Siu Lee Lam and Theo Notteboom, The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe, *Transport Reviews*, Vol. 34, No. 2, 2014, pp. 169~189.

14 Anna Mellin and Hanna Rydhed, Swedish Ports' Attitudes towards Regulations of the Shipping Sector's Emissions of CO_2, *Maritime Policy and Management*, Vol. 38, No. 4, 2011, pp. 437~450.

15 International Maritime Organization, at http://www.imo.org/Pages/home.aspx, 20 January 2015.

all ships.[16] In the U.S., the Environment Protection Agency (EPA) is tightening the part of Clean Air Act governing marine vessels and U.S. waters have been designated a SOx emission control area.[17]

Further, emissions of the Port of Shanghai and their external costs have been assessed in several recent studies. For example, total marine emissions of ships for NOx, SO_2, PM, HC, and CO_2 in Shanghai port in 2003 were estimated to be 58,160, 51,180, 6960, 4560, and 3,012,800 tons, respectively.[18] Also, a recent study has estimated the in-port ship emissions inventory and the emission associated social cost in Shanghai Yangshan port.[19] The result of the study showed that the amount of in-port ship emissions of CO_2, CH_4, N_2O, PM_{10}, $PM_{2.5}$, NOx, SO_X, CO and HC in the Yangshan port area was 578,444 tons, 10 tons, 33 tons, 1,078 tons (PM_{10}, inducing $PM_{2.5}$), 859 tons ($PM_{2.5}$ only), 10,785 tons, 5,623 tons, 1,136 tons, and 519 tons, respectively. The total social cost was estimated to be around $287 million, accounting for 4.4% of the total port revenue. With regard to air pollutant concentrations, the average hourly SO_2 and NO_2 concentrations in Shanghai Port were respectively 29.4 and 63.7 $\mu g\ m^{-3}$. Average daily concentrations of total suspended particles (TSP) and $PM_{2.5}$ were 114.39 $\mu g\ m^{-3}$and 62.60 $\mu g\ m^{-3}$ with seasonal $PM_{2.5}$/TSP ratios ranging from 0.49 to 0.64.[20]

However, to date, the research on managerial policies with the purpose to reduce the emissions mentioned above by adopting a qualitative approach is scant. This paper attempts to help fill this gap by exploring the potential challenges and barriers to the adoption of emissions mitigation strategies and conducting in-depth interviews with port operators, governmental officials and other key stakeholders. Based on the interviews and relevant analysis, the paper provides some effective and feasible strategies to reduce emissions. The following parts are structured as

16 Energy efficiency and the reduction of GHG emissions from ships, at http://www.imo.org/MediaCentre/HotTopics/GHG/Pages/default.aspx, 20 January 2015.

17 Richard Hildreth and Alison Torbitt, International Treaties and U.S. Laws as Tools to Regulate the Greenhouse Gas Emissions from Ships and Ports, *The International Journal of Marine and Coastal Law*, Vol. 25, 2010, pp. 347~376.

18 Yang D. Q., Kwan S. H., Lu T., Fu Q. Y., Cheng J. M., Streets D. G., Wu Y. M. and Li J. J., An Emission Inventory of Marine Vessels in Shanghai in 2003, *Environmental Science & Technology*, Vol. 41, No. 15, 2007, pp. 5183~5190.

19 Su Song, Ship Emissions Inventory, Social Cost and Eco-efficiency in Shanghai Yangshan Port, *Atmospheric Environment*, Vol. 82, 2014, pp. 288~297.

20 Minjiang Zhao, Yan Zhang, Weichun Ma, Qingyan Fu, Xin Yang, Chunlei Li, Bin Zhou, Qi Yu and Limin Chen, Characteristics and Ship Traffic Source Identification of Air Pollutants in China's Largest Port, *Atmospheric Environment*, Vol. 64, 2013, pp. 277~286.

follows. Section II briefly introduces the background of the research site. Section III describes the methodology of this study. Section IV is a summary and analysis of the results. Sections V and VI are discussion and conclusion. Specifically, managerial policy implications, including challenge and barriers, are explored in the conclusion.

II. Site Background

The Port of Shanghai, located in the downstream area of the Yangtze River, is an international gateway at the land-sea interface where huge volumes of export/import containers are transported into and out of China. Being a super hub port and one of the fastest growing container ports (with a throughput of 33.6 million TEU in 2013) in the world, the Port of Shanghai plays a crucial role in the development of global economy.[21] The port is under the jurisdiction of the Shanghai Municipal Government and the Shanghai International Port Group (SIPG), a holding company in charge of the overall operations of the port.[22] In this port, corporatization and joint venture have become the hallmark of its development, attracting much foreign investments mainly from ocean carriers like CMA CGM group, and global terminal operators such as APM and PSA. Further, considering that large containership deployments are subject to water depth restrictions, Shanghai has invested in a deep water (over 15 m) container port project at Yangshan located in Hangzhou Bay since December 2001, aiming to attract a greater flow of containers from global carriers and play the role of a transshipment hub as well as an integrated logistics and industrial center in the Asia-Pacific region.[23]

According to *Shanghai Municipal Transport and Port Authority Yearbook 2013*,[24] 67,715 ships called at Shanghai port in 2012. Among these ships, ships with a length of or above 250 m and a draft of or above 11 m numbered 14,897 and 7,632, respectively. In accordance with the Shanghai Transport & Port Research

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21 Shanghai Transport & Port Research Center, *Shanghai Modern Shipping Service Industry Development Report (2014)*, Shanghai: Shanghai Pujiang Education Press. (in Chinese)

22 Changqian Guan and Shmuel Yahalom, China's Port Reform and Development, *Transportation Research Record*, Vol. 2222, 2011, pp. 1~9.

23 Theo Notteboom, Challenges for Container River Services on the Yangtze River: A Case Study of Chongqing, *Research in Transportation Economics*, Vol. 35, 2012, pp. 41~49.

24 Shanghai Municipal Transport and Port Authority, *Shanghai Municipal Transport and Port Authority Yearbook 2013*, Shanghai: Shanghai People's Publishing House. (in Chinese)

Center,[25] the air pollutants concentration in Shanghai Port for PM_{10}, SO_2 and NO_2 were 93 $\mu g\ m^{-3}$, 20 $\mu g\ m^{-3}$, and 32 $\mu g\ m^{-3}$, respectively. Noticeably, the concentration of PM_{10} was higher than national environment standard for air quality (second level).[26] Since the water depth of the Yangtze River tends to be rising, the port authorities loosened the restrictions on large size ships calling at Shanghai port. Obviously, such a policy consequently would attract more ship calls, yet at the same time will bring more air pollution problems if an appropriate regulation policy is not adopted in this port area. In fact, port development and extension should arguably adopt a more sustainable approach.

In China, the regulation policies followed by port administration and management authorities can be found in the Ports Law and Ports Operation and Management Rules of China.[27] These legislations focus on port administration, planning, construction, maintenance, operation, management, safety and other relevant activities. In order to avoid port pollution and maintain port sustainability, the Marine Environmental Protection Law of the People's Republic of China has clearly laid down the principles to regulate polluters and reduce environmental damage. The scope of its application includes marine environment monitoring and management, marine ecology protection, prevention of pollution from coastal/ocean engineering construction, waste regulation, and prevention and control of marine pollution from ships.[28]

III. Methodology

A port's development is related to port service/facilities and government's port policies. During June to July 2014, qualitative semi-structured interviews with key stakeholders, including shipping lines and port authorities, were conducted

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25 Shanghai Transport & Port Research Center, at http://www.shjt.org.cn/Main/Index.aspx, 20 January 2015. (in Chinese)

26 The upper limit of second level for PM_{10}, SO_2 and NO_2 are 70 $\mu g\ m^{-3}$, 60 $\mu g\ m^{-3}$, and 40 $\mu g\ m^{-3}$, respectively.

27 Ports Operation and Management Rules, at http://www.moc.gov.cn/zhuzhan/zhengwugonggao/jiaotongbu/jiaotongbuling/200912/t20091208_641489.html, 20 January 2015. (in Chinese)

28 Marine Environmental Protection Law of the People's Republic of China, at http://law.shmsa.gov.cn/smls/WebPages/Law/LawDetail.aspx?CatalogId=15692&&Keyword=%E6%B5%B7%E6%B4%8B%E6%B1%A1%E6%9F%93&&TreePath=100000020020&&typelang=LangType, 20 January 2015. (in Chinese)

to explore their insights and perspectives concerning emission mitigation policies in the Port of Shanghai. Transcripts were coded and analyzed using a constructivist grounded theory approach to search for emerging themes, which were categorized appropriately subsequently.[29] Main verbatim quotations were highlighted and extracted from the transcripts via Nvino 8 and would be later summarized in the research conclusions. The interviewees were selected chiefly based on their backgrounds and involvement in the topic being researched. The content of interviews includes questions regarding the potential barriers, limitations and problems that may arise during the implementation of emission mitigation strategies, *inter alia*, environmental problems, technical/standard problems, and issues pertaining to policy acceptance, waste control and treatment, and cost evaluation. Ethical approval for these interviews was granted from the appropriate bodies, and all participants' anonymity was ensured. This paper totally interviewed 8 port operators in Shanghai with an average of 20 years' professional experience, ranging from 15 to 28 years, and their job types included vice president, assistant vice president, junior general manager, and manager. The author also interviewed 5 government officials averaging 15 years of experience, ranging from 8 to 28, and their job types included director and senior engineer.

IV. Results

The interview results are categorized by the following themes: shore power, fuel regulation and vessel speed reduction.

A. Shore Power

Shore power is the delivery of shore side electrical power to a ship at berth while its engines are turned off. According to previous studies, shore power offers

29 Kathy Charmaz, Grounded Theory Methods in Social Justice Research, in Norman K. Denzin and Yvonna S. Lincoln eds., *The SAGE Handbook of Qualitative Research*, Thousand Oaks, Calif: SAGE Publications, 2011, pp. 359~380.

at least three benefits.[30 31 32] First, it could reduce pollutant emissions. In the case of Kaohsiung port, it could reduce CO_2 emission and PM (particulate matter) by 57.16% and 39.4%, respectively.[33] Second, it lowers fuel consumption and energy costs on board. Finally, it increases the operation life of a ship's diesel engine and auxiliary units. Shore power has been successfully utilized for many years by some North American ports, including Los Angeles, Long Beach, Juneau, Vancouver and Seattle, as well as some European ports such as Gothenburg, Lubeck and Antwerp.

However, the Port of Shanghai may face potential barriers to the adoption of shore power. Firstly, voltage requirements can vary considerably for different types of ships, such as 60 Hz for US and Japan and 50 Hz for China and Europe. Therefore, standardized plugs, power transmission by low voltage (frequency-variable on-shore power supply system) and receptacle connectors are needed to allow ships to connect at different ports. Secondly, the costs of retrofitting existing ships along with ship-side facilities pose another potential barrier. Thirdly, electricity charges must be standardized and fair to all types of ships.

Currently, cost estimation is difficult and challenging since it involves the costs associated with the construction and maintenance of shore power infrastructure. The setting of electricity charge standards would require further negotiations with related authorities, including power suppliers and port authorities. In this connection, it is suggested that port authorities should help to reduce the costs of using shore power by providing subsidies if ship operators, such as cruise ship operators, use shore power for their ships at berth.

B. Fuel Regulation

With regard to the fuel that ships consume, regulations should be made to

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30 X. Yang, G. Bai and R. Schmidhalter, Shore to Ship Converter System for Energy Saving and Emission Reduction, 8th International Conference on Power Electronics-ECCE Asia, 30 May - 3 June 2011, The Shilla Jeju, Korea.

31 W. Hall, Assessment of CO_2 and Priority Pollutant Reduction by Installation of Shore Power, *Resources, Conservation and Recycling*, Vol. 54, 2010, pp. 462~467.

32 Thalis Zis, Robin Jacob North, Panagiotis Angeloudis, Washington Yotto Ochieng and Michael Geoffrey Harrison Bell, Evaluation of Cold Ironing and Speed Reduction Policies to Reduce Ship Emissions near and at Ports, *Maritime Economics & Logistics*, Vol. 16, 2014, pp. 371~398.

33 Ching-Chih Chang and Chih-Min Wang, Evaluating the Effects of Green Port Policy: Case Study of Kaohsiung Harbor in Taiwan, *Transportation Research Part D: Transport and Environment*, Vol. 7, 2012, pp. 185~189.

compel ship owners to switch to cleaner fuel when approaching the port, e.g., from high to low sulfur fuel. Admittedly, a sulfur content policy would add extra costs to ship operators since low sulfur fuel is more expensive. In order to resolve this issue, a fuel cost subsidy is recommended to be given to ship operators if they adopt low sulfur fuel within 20~40 miles of the port. The implementation of such regulations requires techniques to monitor a ship's position and navigation. Further, this would be difficult to achieve in the short-term as it would need a consent and approval from IMO and may possibly increase fuel costs for ship owners. Also, ships are obliged to install appropriate pollution reduction equipment to reduce emissions, as required by the MARPOL. Accordingly, continuous sampling and monitoring by port authorities would also be necessary when ships are berthed at port.

C. Ship Speed Reduction

In order to collect accurate real-time data relating to ship speeds and routes, a modern Automatic Identification System (AIS) should be introduced in the port. For example, to reduce air emissions, emission control areas, reduced speed zones or designated coastal areas could be established for ships while at berth, maneuvering, and navigating in the Port of Shanghai. These methods have been discussed and examined in previous studies.[34] [35] A ship's basic data, including its maximum continuous rated engine power and maximum speed, and activity data like its actual speed, load factor of main engine, travel distance, moving and hotelling hours, can be used to estimate the in-port ship emissions inventory via AIS system.[36] Therefore, the port authorities should create a database of air pollutants, facilitating inspections of ships berthed within the port.

V. Discussion

To achieve a low emission target, port authorities should communicate proac-

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34 James J. Corbett, Haifeng Wang and James J. Winebrake, Impacts of Speed Reductions on Vessel Based Emissions for International Shipping, in *Proceedings of Transportation Research Board Annual Meeting*, Washington, DC., 2009.

35 Harilaos N. Psaraftis and Christos A. Kontovas, Speed Models for Energy-efficient Maritime Transportation: A Taxonomy and Survey, *Transportation Research Part C: Emerging Technologies*, Vol. 26, 2013, pp. 331~351.

36 Su Song, Ship Emissions Inventory, Social Cost and Eco-efficiency in Shanghai Yangshan Port, *Atmospheric Environment*, Vol. 82, 2014, pp. 288~297.

tively with the entire range of stakeholders during strategic planning and policy formulation. Such stakeholders include, among others, port operators, ship/equipment manufacturers, fuel suppliers, environmental protection authorities, legislators, regulators, customers and the local community.

Some barriers are clearly inevitable when developing a low emission policy, because the development of such a policy should also take into account the local governmental regulations and rules, and the relevant geographical, economic, financial and political background. Further, stakeholders should collaborate as a whole for the port's sustainable low emission development. Penalties or bans and incentive policies such as financial subsidies to achieve economic/financial viability are proposed to develop. Port authorities have to learn and follow international and domestic maritime and environmental regulations and timely correct port operators' and market players' improper behaviors, if any.

In the Port of Shanghai, institutional barriers would arguably delay the pace of the implementation of emissions regulation policies, despite the strictness of such policies. Loose connections between government departments, including port/maritime and inland transport (truck/railway) authorities, and inefficient procedures in dealing with cross-sectorial issues may lead to such barriers. Inter-institutional negotiations and a legal procedure developed by top government sectors, like the Ministry of Transportation of China and Shanghai Municipal Government, would facilitate the formulation of an effective policy framework to accelerate policy implementation. This work would involve the transportation, environmental protection, economic affairs, financial and local self-government sectors.

Additionally, port authorities should keep track of the port's environmental performance, e.g., atmospheric contaminant emissions and gas emissions with greenhouse effect, and gradually formulate or modify its targeted policy content. In the Port of Shanghai, regulatory enforcement is relatively slow and weak due to a lack of local legitimacy over many conflicts among stakeholders. Arguably, financial investment is essential to the construction of a low emission port, which usually entails the construction of advanced or cleaner facilities in the port. In this connection, how to balance air quality and economic feasibility is a key issue. For example, fuel regulation should be prepared based on the analysis of data associated with fuel consumption and emissions, together with the regulation standards for different ship types whose design specifications, ages, and maintenance conditions vary greatly. Further, port authorities should draft an air quality improvement plan to monitor the pollutants emitted within the port area by each source category.

Also, air monitoring stations should be installed to report air quality, *inter alia*, concentrations of key pollutants (e.g. CO_2, NOx).

VI. Conclusion

Using a grounded theory method, this paper conducts in-depth interviews with stakeholders to explore their perspectives regarding the ways to reduce emissions from port coastal regions. For port operators, emission mitigation policies were perceived to potentially affect their business operational costs negatively. For example, adopting low-sulfur fuel within the emission control area would increase fuel cost. In addition, shore power facility installment would raise the cost for ship owners. In contrast, government officials highlighted the importance of implementing emission regulation policies in the port. However, it was assumed that such policies could not be well and effectively implemented in all terminals due to inconsistent managerial mechanisms and terminal facilities. For instance, some public and large business-owned terminals are often well equipped with advanced facilities. Nevertheless, it is difficult to effectively regulate emissions in some bulk terminals due to a shortage of environmental facilities.

In sum, this paper suggests three mitigation policies: shore power, fuel regulation and ship speed reduction. It is hoped that stricter environmental policies for the port could be carried out by setting fuel quality and low carbon emission standards, using shore-side electricity for ships at berth and setting speed limits for ships entering the port. Governmental subsidies and budget planning/controlling should also be considered for sustainable development of the port. Meanwhile, the implications of such policies and the potential barriers that may arise during their implementation are also provided and discussed. The interviewees assert that legislative support is necessary for the successful implementation of a low emission port policy and an effective control of air pollution. Although the Port of Shanghai is investigated as an exemplar in this paper, the mitigation policies mentioned above may shed some light on the mitigation efforts by ports from other countries. Since the Yangtze River is a fast developing inland water market in China, one possible future research direction is to combine this topic with the concept of dry port to explore how to effectively develop a green water system. Also, economic interventions to reduce emissions, such as emission taxes and differentiated port and fairway dues, along with port facilities/trucks can be further assessed.