Low Emission Port Development: The Policy Perspective

Po-Hsing TSENG*

Abstract: In this paper, an in-depth interview study of the practice within low emission port was undertaken to ascertain strategy implication for green port issues. Sixteen semi-constructed face-to-face interviews (including industry experts and governmental officers) were conducted in three main ports (Kaohsiung, Keelung, and Taichung) in Taiwan based on grounded theory methodology. The main focus of the study was streamlined to emissions (e.g. NOx, SO2, CO2, CO, PM, VOC) from ships and trucks. The findings show that stakeholders as for example port authorities, terminal operators and residents surrounding the ports should pay more attention to the port planning and development from a broad perspective. Moreover, the mitigation strategies of air pollution (e.g. shore power system, low sulphur fuel, carbon tax, reduced speed when arriving at the port, air quality standards within the port area, the implementation of international conventions like MARPOL, etc.) should be flexibly designed and managed to achieve resource use rationalization and environmental balance by adopting green port policies.

Keywords: Emission Ship Port Policy

1. INTRODUCTION

Every port has its positive and negative impact on the economy and the environment[1,2]. The expansion of international trade arising from globalization has resulted in a substantial increase in goods' transshipment between ports around the world. This phenomenon has led to increased emissions from ships in ports, and trucks traveling to and from ports, which, in turn, has produced significant external social costs.[3] The construction, operation and expansion of a port may produce air pollutants, climate change, acidification, eutrophication, health, traffic congestion, and noise. These negative external impacts are significant but have seldom been highlighted as being environmental implications of port development in the past. The International Maritime Organization (IMO) has debated both technical and market-based measures for reducing greenhouse

* TSENG Po-hsing, Assistant Professor of Department of Shipping and Transportation Management, Taiwan Ocean University. The author appreciates the fund provided by the Ministry of Science and Technology under grant number MOST 105-2410-H-035-030. Email:phtseng@mail.ntou.edu.tw.

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

[2] Po-Hsing Tseng and Pilcher Nick, Evaluating the Key Factors of Green Port Policies in Taiwan through Quantitative and Qualitative Approaches, *Transport Policy*, Vol. 82, 2019, pp.127~137.

[3] SusanaL ópez-Aparicio, Dag Tønnesen, The Nguyen Thanh and Heidi Neilson, Shipping Emission in a Nordic port: Assessment of mitigation strategies, *Transportation Research Part D: Transport and Environment*, Vol. 53, 2017, pp. 205~216.

gas emissions from shipping, for example, lower ship speed[1] or rail mounted gantry cranes (instead of rubber tired gantry crane). Moreover, Sustainable Eco-port in Europe is a key step to ensuring environmentally friendly maritime industry and at the same time help increase more trade and cooperation opportunity with other partners[2]. Today, it is important that the knock-on environmental impact of port development is considered and accounted for, since it has an influence on a nation's port planning and economic development.[3] In particular, it can affect the nation's overall carbon emissions, and is becoming more of an issue in tandem with the importance of such overall emissions[4]. These issues also have important impacts on stakeholders of the port, such as the community; from a health perspective, lower emissions have many implications, and from an economic perspective, any limitation of activity to reduce such emissions would also be significant.

To date, most studies into this area have been quantitative in nature rather than qualitative. Qualitative studies would complement the existing quantitative ones to present more in-depth 'human' perspectives[5] regarding stakeholders' perceptions of the policies and recommendations the quantitative studies have offered. This is important as it reveals how such policies are perceived, and therefore, ensures the potential success of their take-up and implementation, particularly when they may involve significant changes to existing practices, which may be resisted[6]. The results of this study provide policy implications for port stakeholders such as port authorities and shipping operators. The paper is organized as follows: Section 2 reviews and summarizes some existing studies related to green and low emission port. Section 3 presents the qualitative methodology that was used. The study results and discussion are shown in sections 4. Finally, Section 5 summarizes the research finding.

2. LITERATURE REVIEW

Many quantitative studies recognize the role of emission from ships during the combustion process in marine diesel engines, boilers, and incinerators as significant sources of air pollution and greenhouse gases, especially during the hoteling time of ship engines for loading/offloading operations.[7] The main pollutants resulting from ship

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1 *Haakon Lindstad, BjørnAsbjørnslett and Anders Strømman, Reductions in Greenhouse Gas Emissions and Cost by Shipping at Lower Speeds, Energy Policy, Vol. 39, 2011, pp. 3456~3464.*

2 *Gul Denktas-Sakar and CimenKaratas-Cetin, Port Sustainability and Stakeholder Management in Supply Chains: A Framework on Resource Dependence Theory, The Asian Journal of Shipping and Logistics, Vol. 28, No. 3, 2012, pp. 301~320.*

3 *Po-Hsing Tseng, Exploring Ship Emissions Mitigation Strategies for the Port of Shanghai, China Oceans Law Review, Vol. 22, pp. 333~334.*

4 *Mei Davies, Emissions Trading for Ships- A European Perspective, Naval Engineers Journal, Vol. 3, 2006, pp. 131~138.*

5 *Norman Denzin and Yvonna Lincoln, The Discipline and Practice of Qualitative Research. In Denzin, N.K., Lincoln, Y.S. (eds.), The SAGE Handbook of Qualitative Research. Thousand Oaks: Sage Publications, 2005.*

6 *Niccolo Machiavelli, The Prince. Florence: Antonio Blado d'Asolo, 1532.*

7 *Giovanni Lonati, Stefano Cernuschi and Shelina Sidi, Air-quality Impact Assessment of at-berth Ship*

exhaust emissions are, by mass, carbon dioxide (CO_2), Sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), particulate matter (PM), hydrocarbons (HC) and volatile organic compounds (VOC).[1,2] The negative effects of such pollutants might contribute to acidification of the environment and the formation of secondary inorganic aerosols which consequently cause air pollution in the port-city area. With the surge in shipping activities, port city authorities plan mitigation strategies against air pollution to achieve a sustainable balance in port and coastal development. Based on past studies[3], ship emissions at berth determine the concentration of exhaust emissions in ports which are between three to five times higher than from other activities in ports (e.g., maneuvering and cruising). Understandably, these emissions from ships at berth have become a great concern for port authorities.[4] These negative effects have brought serious health problems such as asthma, cardiovascular disease, respiratory disease, lung cancer and premature mortality to port operators and residents of local communities around the ports.

Maritime experts have attempted to provide effective strategies to reduce emissions from shipping in light of the fact that climate change is now a global environmental concern[5]. The port authorities are likely to face immense pressure in cargo traffic-handling given that cargo throughput is projected to increase in the future. For such reasons, various strategies have been presented within both academic and industrial fields. For example, it is argued that on-going advances in cargo-handling systems, terminal design and pollution abatement technologies could help to alleviate the pressures on land use and the environment.[6] Besides air pollution issues should be considered at the planning stage of port development.

In order to improve port environment, in California and Los Angeles, some pollution mitigation policies were implemented through new technologies and processes for handling and moving cargo, mechanisms for planning and policy making, as well as for financing, implementing, upgrading, managing and operating infrastructure systems.

Emissions: Case-study for the Project of A New Freight Port, *Science of the Total Environment*, Vol. 409, 2010, pp. 192~200. Gara Villalba and Eskinder Demisse Gemechu, Estimating GHG Emissions of Marine ports-the Case of Barcelona. *Energy Policy*, Vol. 39, No. 3, 2011, pp. 1363~1368.

[1] Warre Fitzgerald, Oliver Howitt and Inga Smith, Greenhouse Gas Emissions from the International Maritime Transport of New Zealand's Imports and Exports, *Energy Policy*, Vol. 39, No. 3, 2011, pp. 1521~1531.

[2] Emeston Tzannatos, Ship Emissions and their Externalities for the Port of Piraeus-Greece, *Atmospheric Environment*, Vol. 44, 2010, pp. 400~407.

[3] Cengiz Deniz, Alper Kilic and Gokhan Civkaroglu, Estimation of Shipping Emissions in Candarli Gulf, Turkey, *Environmental Monitoring and Assessment*, Vol. 171, 2010, pp.219~228.

[4] Joseph Berechman, Y. and Po-Hsing Tseng, Estimating the Environmental Costs of Port Related Emissions: the Case of Kaohsiung, *Transportation Research Part D: Transport and Environment*, Vol. 17, 2012, pp. 35~38. Kevin Cullinane, Po-Hsing Tseng and Gordon Wilmsmeier, Estimation of Container Ship Emissions at Berth

[5] Paul Gilbert and Alice Bows, Exploring the Scope for Complementary Sub-global Policy to Mitigate CO_2 from Shipping, *Energy Policy*, Vol. 50, 2012, pp.613-622.

[6] 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.

Using an inductive research approach.[1] In China, low-carbon ports were widely implemented in many ports and related policies included setting standards of low-carbon port emissions, exploiting clean energy and increasing the support of policy and finance.[2] In Sweden, projections of ship emissions in the Gothenburg port area for 2030 are made, and three scenarios (alternative fuel, ship design, and operation) have been analyzed. GHG emissions from ships in the port are projected to increase by 40% to 2030 in a business as usual (BAU) scenario. The highest reductions were seen in the 'Operation' scenario where GHG emissions were 10% lower than the BAU level.[3] In recent years, technological policies (lower sulfur fuel and selective catalytic reduction), operational policies (vessel speed reduction and shore-side power) and market-based policies (environmentally differentiated fee, and cap and trade system) were implemented in many advanced ports since it can effectively reduce port emissions and its external costs of maritime transport.[4,5] Also, liquefied natural gas and methanol could provide potential bridge to reach low emission ship transports. Asia (Singapore and Shanghai) and Europe (Antwerp and Rotterdam) were used to compare the green port performance through various management tools (e.g. pricing, monitoring and measuring, market access control and environmental standard regulation). Findings showed that Antwerp and Rotterdam have a higher level of influence on devising green port policy in comparison to the two Asian ports.[6] Recently, Emission Control Area policy was used to evaluate the effectiveness of reducing emissions (e.g. SO_2, $PM_{2.5}$, NO_x) from merchant ships in Shanghai port. Findings indicted that future ECA policies could bring a much greater decrease of pollutant emissions in water areas of Yangshan and Wusong.[7] In Lithuania, the Klaipeda Port was used as a case study and found that a decrease in emissions from ships could be achieved by conducting various methods, such as environmentally friendly fuels, electrical and hybrid vehicles, the improvement of port approach, inside navigational channels and optimization of the transport processes organization.[8]

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[1] Peter Hall, Thmos O'Brien and Clarence Woudsma. Environmental Innovation and the Role of Stakeholder Collaboration in West Coast Port Gateways, *Research in Transportation Economics*, Vol. 42, No. 1, 2013, pp. 87~96.

[2] Jian Li, Xiao Liu and Bao Jiang, An Exploratory Study on Low-carbon Ports Development Strategy in China, *The Asian Journal of Shipping and Logistics*, Vol. 27, No. 1, 2011, pp. 91~111.

[3] Hulda Winnes, Linda Styhre and Erik Fridell, Reducing GHG emissions from ships in port areas, *Research in Transportation Business & Management*, Vol. 17, 2015, pp. 73~82.

[4] Haakon Lindstad, Bjørn Asbjørnslett and Anders Strømman, Reductions in Greenhouse Gas Emissions and Cost by Shipping at Lower Speeds, *Energy Policy*, Vol. 39, 2011, pp. 3456~3464.

[5] Chul-Hwan Han, Strategies to Reduce Air Pollution in Shipping Industry, *The Asian Journal of Shipping and Logistics*, Vol. 26, No. 1, 2010, pp. 7~30.

[6] 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, 2016, pp. 169~189.

[7] Ku Shi, Jinxian Weng and Guorong Li, Exploring the Effectiveness of ECA Policies in Reducing Pollutant Emissions from Merchant Ships in Shanghai Port Waters, *Marine Pollution Bulletin*, Vol. 155, 111164, 2020, https://doi.org/10.1016/j.marpolbul.2020.111164

[8] Vytautas Paulauskas, Ludmila Filina-Dawidowicz and Donatas Paulauskas, The Method to Decrease Emissions from Ships in Port Areas, Sustainability, Vol. 12, No. 11, 2020, 4374. DOI: 10.3390/su12114374

In a quantitative study of Greek port, deposit–refund framework is confirmed as a useful method for the operation of ships in a more environmentally responsible manner regarding their waste based on user pay principle.[1] The deposit is refundable, and the system is aimed at rewarding the correct environmental behavior instead of polluters' punishment. With regards to international shipping studies, research found that a fuel tax of approximately $150/ton fuel would lead to 20-30% CO_2 reductions, and a speed reduction mandate targeted to achieve a 20% CO_2 reduction in the container fleet costs between $30 and $200 per ton CO_2 abated.[2] Similarly, in Taiwan (Kaohsiung Port), it is found that adopting the strategies of both reduced speed and cold ironing emissions control can reduce 71% and 91% emissions with a 20 nautical mile reduced speed zone.[3] It is thus suggested that, the port authorities and shipping companies should invest in shore power and related transmission equipment in order to fit the trend of international ports.

With regard to developing green ports, many ports have developed corporate social responsibility strategies. In Sweden, it is suggested to implement a differentiated green port through internalizing external costs in the transportation systems and analyzing the effects of the strategy by various stakeholders.[4] In Hong Kong, It is indicated that green management practices (GMP) consists (1) cooperation with supply chain partners, (2) environmentally friendly operation, and (3) internal management support. Also in Hong Kong, it was found that a positive relationship exists between the adoption of GMP and container terminal firm performance.[5] Recently,, the research of Netherlands found clean shipping target difficult to achieve through private governance institution due to an insufficient level of collaborative advantage within partnership with related political and legal issues.[6] For example, The Marine Environment Pollution Committee (MEPC),a sub-organization of International Maritime Organization, is responsible for drawing up relevant regulations to prevent ships from polluting the ocean and atmosphere. MEPC started examining ships' air pollution since year 1988 through the regulation of Prevention of Air Pollution from Ships or MARPOL. 73/78 Annex VI. In China, a general algebraic modeling system was tested in the green port project scheduling with comprehensive efficiency consideration and found that efficiency achievement is significant from

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[1] Dimitrios Georgakllos, The Use of the Deposit-refund Framework in Port Reception Facilities Charging Systems, *Marine Pollution Bulletin*, Vol. 54, 2007, pp. 508~520.

[2] James Corbett, HaifengWang and James Winebrake, The Effectiveness and Costs of Speed Reductions on Emissions from International Shipping, *Transportation Research Part D: Transport and Environment*, Vol. 14, 2009, pp. 593~598.

[3] 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. 17, 2012, pp. 185~189.

[4] Rickard Bergqvist and Niklas Egels-Zanden, Green port dues- The case of hinterland transport, *Research in Transportation Business & Management*, Vol. 5, 2012, pp. 85~91.

[5] Lun Venus, Green Management Practices and Firm Performance: A Case of Container Terminal Operations, *Resources, Conservation and Recycling*, Vol. 55, 2011, pp. 559~566.

[6] Lindey Wuisan, Judith van Leeuwen, C.S.A. and Kris Koppen, Greening International Shipping through Private Governance: A Case Study of the Clean Shipping Project, *Marine Policy*, Vol. 36, 12012, pp. 65~173.

economic and environmental perspectives.[1]

Evidently, the majority of these past studies mainly use quantitative approaches to survey the green port and related external cost issues, yet there is a paucity of empirical investigations that have collected stakeholder's opinion using qualitative studies, particularly in Asian countries. Despite this, qualitative approaches have been used in transport related fields, such as maritime safety[2] and bus transportation[3] and landscape and urban planning[4]. Nevertheless, ports, especially with regard to low emission port development, have seldom been investigated from a holistic perspective. The purpose of this study is to begin to fill this gap and present a comprehensive summarized finding after an empirical interview research.

3. METHODOLOGY

This study adopted qualitative approach to understand the perceptions of industry experts and governmental officers, and responses to address the complex and understudied phenomenon of low emission port policy. Based on grounded theory, qualitative analysis was used to obtain the intricate details about certain issues. To provide an in-depth understanding of low emission port development strategy, a qualitative study was undertaken in three international ports (Kaohsiung, Keelung, and Taichung) in Taiwan. The methodical approach considered interviewees' background in order to ensure their expertise (e.g. more than 10 years' work experiences or knowledge about the research topic). Interviewees were initially contacted via telephone, then selected through purposive sampling based on their ability to answer the interview questions. After confirming their participation in our research, interview location and dates were further arranged. Interviews were conducted from July 1- August 31, 2020. Every participant was sent a formal invitation letter stating that participation was voluntary and explained how the data would be used only for the purpose of the study, as well as ensuring anonymity and confidentiality. These interviews were digitally recorded and literally transcribed[5] using a self-chosen code[6], then sent to the participants for verification.

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[1] Wei Wang, Li Huang, Gu Jian and Liupeng Jiang, Green Port Project Scheduling with Comprehensive Efficiency Consideration, *Maritime Policy & Management*, Vol. 46, No. 8, 2019, pp. 967~981.

[2] Arben Mullai and Ulf Paulsson, A Grounded Theory Model for Analysis of Marine Accidents, *Accident Analysis and Prevention*, Vol. 43, 2011, pp. 1590~1603. U. M. Ikeagwuani and G.A. John, Safety in Maritime Oil Sector: Content Analysis of Machinery Space Fire Hazards, *Safety Science*, Vol. 51, 2013, pp. 347~353.

[3] Rui Carreira, Lia Patricio, Renato Natal Jorge, Chris Magee and Qi Van Eikema Hommes, *Transport Policy*, Vol. 25, 2013, pp. 233~243.

[4] Erin Heacock and Justin Hollander, A Grounded Theory Approach to Development Suitability Analysis, *Landscape and Urban Planning*, 100, 2011, pp. 109~116.

[5] Joseph Alex Maxwell, Understanding and Validity in Qualitative Research, *Harvard Educational Review*, Vol. 62, No. 3, 1992, pp. 270~300.

[6] Christina Davidson, Transcription: Imperatives for Qualitative Research, *The International Journal of Qualitative Methods*, Vol. 8, No. 2, pp. 35~62. Blake D. Poland, Transcription Quality. In Jaber F. Gubrium and James A. Holstein, *Handbook of Interview Research*. Thousand Oaks, Calif: Sage Publications, 2001.

Interviews were conducted in Chinese[1] and then translated using a decentering technique[2] or skopos approach[3] to render a translation that was as natural as possible. Data collection involved various observation and interviews (including sixteen interviewees). The participants were from organizations comprising Taiwan International Ports Limited Company (including Kaohsiung, Keelung and Taichung), Maritime Ports Bureau (including North Maritime Affairs Center, Central Maritime Affairs Center, South Maritime Affairs Center). To cover various factors of variability in low emission port development, the sixteen interviewees included director (2), port operation managers (6), terminal operators (6) and other interested parties (2) to better understand the policy implication.

Questions were both semi-structured and open ended[4] and based on key areas in the quantitative literature such as air pollution, regulation, international conventions, MARPOL, carbon tax, flag of convenience, port, terminal, shipping lines and shippers. These processes enhance the content of data analysis and theory development. Interview data was analyzed through initial and focused coding. The codes were developed to related themes and concepts, and selective coding further generated the formation of theoretical propositions. The interview coding brief and examples are shown in the Appendix.

4. RESULTS AND DISCUSSION

Policy actions for controlling and reducing air pollution can be grouped into regulatory requirements and market-based (or incentive-based) categories [5]. The perceptions of the interviewees from this study has been categorized into four mitigation strategies.

4.1 Adopt Economic Incentives to Mitigate Emissions

From an economic viewpoint, interviewees felt pollution externalities were social costs that should be borne by both suppliers and users of ships and trucks.[6] To internalize these costs a Pigouvian Tax[7] should be imposed on polluting activities thereby reducing

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[1] Martin Cortazzi, Nick Pilcher and Lixian Jin, Language Choices and 'blind shadows': Investigating Interviews with Chinese Participants. *Qualitative Research*, Vol. 11, No. 5, 2011, pp. 505-535.

[2] O. Werner and D. Campbell, Translating, Working through Interpreters, and the Problem of Decentering. In R. Naroll & R. Cohen (eds.). *A Handbook of Method in Cultural Anthropology.* New York: Natural History Press. 1970.

[3] Hans J. Vermeer, Skopos and Commission in Translational Action. In L. Venuti (ed.) *The Translation Studies Reader* (2nd edition), London: Routledge, 2004.

[4] William Foddy, *Constructing Questions for Interviews and Questionnaires: Theory and Practice in Social Research.* Cambridge University Press, 1993.

[5] Chengfeng Wang, C., James J. Corbett and James J. Winebrake, Cost-effectiveness of Reducing Sulfur Emissions from Ships, *Environmental Science & Technology*, Vol. 41, No. 24, 2007, pp. 8233-8239. Vytautas Paulauskas, The Method to Decrease Emissions from Ships in Port Areas, *Sustainability*, Vol. 12, No. 11, 2020, pp.11~15.

[6] Alvar Mjelde, Øyvind Endresen, Einar Bjørshol, Caroline Wang Gierløff, Even Husby, Johanne Solheim, Narve Mjøs and Magnus S. Eide, Differentiating on Port Fees to Accelerate the Green Maritime Transition, *Marine Pollution Bulletin*, Vol. 149, 110561. DOI: 10.1016/j.marpolbul.2019.110561

[7] A. C. Pigou, *Economics of Welfare*. London, UK: Macmillan and Co., 1920.

ships and trucks non-optimal activity, i.e., an activity whose marginal social costs exceed its marginal social benefits. Since a ship's emission depends on how long the ship is at berth, given technology, time is a key factor affecting the magnitude of pollution costs. The longer the time, the higher the pollution costs.

A key question in welfare economics is what should be done with these tax revenues. In general, revenues generated from charges could be allocated to two main purposes: The first is air quality improvement projects. For example, port authorities provide subsidies as incentives for ship owners to buy energy-efficient ship engines or to follow the rules of emission control areas (e.g. discount for berth fee). The second is to compensate a port's residents for health problems related to emission. In any case, the port authorities should impose these taxes on ship activity, which in turn will reduce pollution and provide ship owners with an incentive to reduce emission[1].

4.2 Use Shore-side Power to Replace Auxiliary Engines

The interviewees suggested that shore-side power should be comprehensively implemented to replace auxiliary engines. Currently, ships' diesel auxiliary engines continue to provide the basic power electricity for lighting, ventilation, pumps, cranes, and essential equipment while they are berthed[2]. One alternative to control ships' emissions is to provide the electricity supply with universal plug equipment from the land instead of from ship engines[3]. Several successful cases have been implemented in different ports where shore-side electrical power has achieved significant reduction in CO_2 emissions: 99.5%, 85.0%, and 9.4% in Norway, France and the U.S., respectively[4]. To encourage such a system, a port tax discount (or differentiated tonnage tax) could be implemented for ships when they use shore-side power. However, there are currently no compulsory rules that could guide ship owners to adopt shore power in Taiwan ports. Again, shore power is not installed in many old ships due to high expenses of ship-side equipment, hence such old ships cannot be deployed to advanced ports (e.g. US). Also, the adoption of shore power might sometimes depend on the rules of Flag of Convenience. The development pace is evident in Taiwan when compared to other advanced ports (e.g. Hong Kong, Singapore, Los Angeles, Long Beach). Ships currently being constructed are more likely to be equipped with shore power facilities so the adoption rate could increase in the future.

4.3 Improve Operation Efficiency in Port

A third strategy interviewees noted was to improve operations efficiency in port.

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[1] Celeste Ahi, Elaine Frey and Seiji Steimetz, The Effects of Financial Incentives on Vessel Speed Reduction: Evidence from the Port of Long Beach Green Flag Incentive Program, *Maritime Economics & Logistics*, Vol. 19, No. 4, 2017, pp. 601~618.

[2] Jihong Cheng, Tianxiao Zheng, Akhil Garg, Lang Xu, Sifan Li and Yijie Fei, Alternative Maritime Power application as a green port strategy: Barriers in China, *Journal of Cleaner Production*, Vol. 213, 2019, pp. 825~837.

[3] Markus Salomon, Recent European Initiatives in Marine Protection Policy: Toward Lasting Protection for Europe's Seas? *Environment Science & Policy*, Vol. 12, 2009, pp. 359~366.

[4] Willaim Hall, Assessment of CO_2 and Priority Pollutant Reduction by Installation of Shoreside Power, *Resources, Conservation and Recycling*, Vol. 54, 2010, pp. 462~467.

Since ship time at berth is an important factor that would affect its emissions in port, improving cargo operation efficiency (loading/unloading) by introducing advanced facilities such as container gantry cranes, rail-mounted gantry crane and container stacker at berth, could further mitigate the severity of air pollution and externality[1]. Currently, in order to achieve an efficient handling service, only few shipping lines use lease-dedicated berths in Taiwanese ports. Other shipping lines without berthing priority have to queue for a berthing at a public berth due to the cost implications. From a green port management perspective, the port authorities could provide more lease-dedicated berth projects with proper rent reduction to reduce ship times at berth if the ship operators were to adopt certain environmental policies; for example, using low Sulphur fuel instead of traditional maritime fuels when berthing at port[2]. Also, the container yard storage strategies for improving land utilization and operation efficiency should be well implemented in order to minimize the number of reshuffles/turnaround time to consequently reduce congestion in the yard.

4.4 Adopt Technological Innovations to Mitigate Emissions

Interviewees believed innovation in technology provides many potential opportunities to reduce ship and truck emissions. For example, natural gas is available as a fuel source for smaller ships (e.g., tugboats and commercial fishing boats) at berth[3]. Also, clean fuel (e.g., fuel cell, low sulphur fuel, biodiesel, liquefied natural gas) offers many advantages over existing diesel generators, such as low exhaust emissions (e.g., diesel oxidation catalyst and diesel particulate filter), improved thermal efficiency and electrification (e.g., automated vehicles and hybrid yard equipment). However, introducing new technologies (e.g. Internet of Things, big data[4]) might be costly for shipping operators with related bargaining power between port authorities and shipping operators.[5] In addition, autonomous ship might be a future trend and could significantly reduce emissions. However, besides higher construction costs, shipping laws for this technology has not been well organized by the International Maritime Organization (IMO), other internal stakeholders (e.g. member states, council, and committee) and external stakeholders (e.g. non-governmental organization). Therefore, it is necessary to integrate these advancing technologies into the existing regulation framework. Shipping operators can further collaborate and cooperate with other organizations in the region for innovation.

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[1] Yi-Chih Yang, Operating Strategies of CO_2 Reduction for A Container Terminal based on Carbon Footprint Perspective, *Journal of Cleaner Production*, Vol. 141, 2017, pp. 472~480.

[2] Ching-Chin Chang and Chia-Wei Jhang, Reducing Speed and Fuel Transfer of the Green Flag Incentive Program in Kaohsiung Port Taiwan, *Transportation Research Part D*, Vol. 46, 2016, pp. 1~10.

[3] Lei Yang, Yiji Cai, Yunlei Wei and Shou Huang, Choice of Technology for Emission Control in Port Areas: A Supply Chain Perspective, *Journal of Cleaner Production*, Vol. 243, 2019, 118105. https://doi.org/10.1016/j.jclepro.2019.118105

[4] Xing Sun, Zhe Tian, Reza Malekian and Zhixiong Li, Estimation of Vessel Emission Inventory in Qingdao Port based on Big Data Analysis, *Symmetry*, Vol. 10, No. 10, 2018, pp. 452-1~452-11. 10.3390/sym10100452

[5] Dong Bo, Dong Kangcheng, Chen Guang, Cao Huiyun and Ya Hongying, Carbon Emission Management System of Port Logistics based on Internet of Things Technology, *Agro Food Industry Hi-Tech*, Vol. 28, No. 1, 2017, pp. 1094~1098.

For example, shipping authorities could help IMO and regulatory bodies to ensure ships' energy efficiency requirements to meet the rapid technological changes. Also, automated guided vehicles and automatic yard cranes in automatic container terminal system will be future development trend, especially in hub ports.[1] Finally, there ought to be clear guidelines and work schedules for discharging and loading operation prepared for the stakeholders (e.g. shipping operators, terminal operators, shipping agents, etc.) with the utilization of carbon trading mechanism as a possible solution.[2]

5. CONCLUSION

In order to develop a low emission port, this study adopted a qualitative approach to collect and analyze various opinions for port stakeholders. Based on sixteen expert opinions, this qualitative approach allowed access to more in-depth perspectives and these were categorized into four mitigation strategies focusing on economic incentives, shore-side power, port operation efficiency (e.g. container yard storage strategies) and technology innovation (e.g. clean fuel, automatic operation system). It is suggested that port planning and development should consider three important stakeholders which are port/terminals, carriers and shippers. Furthermore, mitigation strategies of air pollution should be flexibly designed and managed from a broad perspective. For example, port taxes (carbon tax) should be levied by the port authorities and paid by the ship owners. It should as well increase stakeholder acceptance and provide initiatives (e.g. port tax reduction via adopting energy-saving methods) to achieve resource use rationalization (or resource sharing) and environmental balance.

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APPENDIX

Thank you very much for participating in this research project. I'll record the interview to enhance reliability. I don't know how long this will take but I estimate approximately 1 hour. Please feel free to ask questions at any time, and I may do same to help me appreciate your perspective as an interviewee. The brief coding contents are shown in Table 1.

Table 1 Coding and exemplar quote

Codified Category	Descriptions	Exemplar Quote
Conventions	Adopt international conventions (e.g. MARPOL) when	*"Shipping lines should autonomously follow international*

[1] Kap Hwan Kim and Jong Wook Bae, A Look-Ahead Dispatching Method for Automated Guided Vehicles in Automated Port Container Terminals, *Transportation Science*, Vol. 38, No. 2, 2004, pp.224~234.

[2] Yuxia Peng and Yanping Meng, Research on Carbon Emission Reduction Decisions of Ports with Low Carbon Preference under Carbon Trading Mechanism, *International Journal of Social Science and Education Research*, Vol. 3, No. 9, 2020, pp. 330~321.

	implementing Port State Control check	*conventions"*. Industry Expert 01.
Carbon tax	Polluters pay the pollution fees	*"It is reasonable that port polluter pay the carbon tax in order to reduce emission around the port area"*. Government Expert 01. "Carbon Trading Mechanism might be a future trend". Government Expert 02.
Regulations	Adopt emission mitigation strategies (e.g. low sulfur fuel, shore power, reduced speed) to achieve green port target.	*"Our company will follow pollution regulation rules of port authorities even it might add our operation costs."* Industry Expert 02.

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