THE INTERNATIONAL COMMERCE & LAW REVIEW Vol. 48 DEC. 2010 pp.27~56

Article submitted on 2010. 11. 30.
Examination completed on 2010. 12. 07.
Publication accepted on 2010. 12. 18.

Air Pollution Reduction Strategies of World Major Ports

Han, Chul Hwan*

Ⅰ. Introduction

As a consequence of the global distribution of manufacturing sites and the increasing international division of labor, ship traffic is steadily increasing and is becoming more and more important as an origin of air pollution. Usually ocean-going vessels use residual oil, which is a byproduct of the refinery process and thus the least refined of the petroleum fuel, and consequently is

* Department of International Logistics, Dongseo University.
E-mail : chhan16@dongseo.ac.kr

much dirtier than other petroleum products.[1] Moreover, ships in port run their engines to generate on-board electricity during loading and discharging of cargo or during boarding and disembarking of passengers. Shipping companies use this kind of fuel because of its relatively low cost. However, the regulatory measure to reduce air pollution from ship, port-related transport modes and cargo handling equipments are less rigorous than land-based polluters in many countries. Local and regional air quality problems associated with ship emissions, especially in coastalAir Pollution Reduction Strategies areas, are a concern because of their public health impacts and greenhouse gas emission. Exposure to air pollution is associated with a host of health risks including premature death, cancer, heart and respiratory diseases.[2] Especially, air pollution emitted from port-related activities adversely affect the health of port workers, as well as residents of nearby port area, and contribute significantly to regional air pollution problems. Up to now, international regulations have been developed to address emissions from ocean-going vessels with the implementation of IMO's MARPOL ANNEX VI. However, this regulation is not effective enough to curb vessel emissions to meet local air quality concerns in several important port cities where port-related emissions contribute significantly to the air problems for these regions. Most port and maritime operations depend on the durability and strength of diesel engines in trucks, cargo handling equipment, locomotives, harbor craft and ocean-going vessels. These transport and cargo handling equipments use diesel fuel and serious amounts of diesel emission are occurred from port operation. During the burning process in diesel engines, these fuels can produce significant amounts of black smoke, particulate matter(PM), nitrogen oxides(NOX), unburned hydro carbons(UHC), sulfur oxides(SOX), carbon monoxide(CO), carbon

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1) Tally, W, Port Economics. 2009, p.164.

2) For more detailed information, see Bailey, D. and Solomon, G. "Pollution Prevention at Ports:Clearing the Air", Environmental Impact Assessment Review, Vol.24, 2004, PP. 752-756

dioxide(CO2), etc. These pollutants, which may deplete the ozone layer, enhance the green-house effect, and produce acid rain are detrimental to the health of living beings and have attracted a great deal of public concern.[3] Furthermore, the low-carbon port management increases the cost of port management and negatively impacts the port competitiveness in the short term. Adams et al(2010) argued that it might be justified for port operators and port authorities to invest in improving environmental performance as a mean to gain a competitive edge of a port in near future.

The main purpose of the paper is to review clean air strategies of the world major ports including six USA ports (Los Angeles/Long Beach, Now York/New Jersey, and Seattle and Tacoma), two European ports (Rotterdam and Gothenburg) and Busan Port and suggest some implications for Korean ports.

The paper consists of as follows: Chapter II examines emission reduction strategies of world major ports. And the existing clean air measures in Busan Port are also introduced in Chapter III. Chapter IV evaluates clean air measures by sectors, namely ocean-going vessel, cargo handling equipments, heavy duty diesel vehicles(truck) and rail and analyses advantages and disadvantages of each measure. In final Chapter, some implications and considerations on Korean ports' clean air action plan are also discussed.

Ⅱ. Literature Review

1. Domestic Studies

During the last decades, various domestic researches on port's environmental issues have been conducted. Choi et al(2001) suggested that environmental plan for port planning, construction and operation aspects. Jung et al(2004)

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3) Bin L, and Cheung-Yuan L. 2006. p.220

reviewed core economic concepts and methods relevant for assessing external costs in container port planning. Park(2004) introduced the self diagnosis method(SDM) for environmental management of Korean seaports according to the previous researches by ESPO(2001). The SDM is essentially based on a checklist which concentrates on the status of the port`s environmental management. KMI(2005) introduced current IMO and major countries' countermeasures and regulations on port air pollution. Song & Han(2007) examined various solutions to reduce port air pollution and suggests some implications to Korean ports to become a green port. Park et al(2009) reviewed the current international legal framework and instruments for air pollution prevention from ships. Recently, Cho(2010) analyzed the cost of low carbon port management of Busan and Los Angeles/Long Beach port for sustainable port management.

〈Table 1〉 Domestic Studies on Port Environmental Issues

Authors /Year	Title	Research Method	Main Contents
Choi et al (2001)	Study on Port's Environment Planning	Case Study	Suggestion on environmental plan for port planning/construction/operation
Jung et al (2004)	Environmental Issues in Container Port Development	Literature Study	Review core economic concepts and methods relevant for assessing external costs in container port planning
Park (2004)	A Study on the Self Diagnosis Methodology for Environmental Management of Korean Seaports	Literature Study	Introduction on the self diagnosis method(SDM) for environmental management of Korean seaports
KMI (2005)	Policy Implications and Regulations on Port Air Pollution	Literature Study	Introduction on current IMO and major countries' regulations on port air pollution
Song·Han (2007)	A Study on the Strategies for Reduction of Port Pollution	Literature Study	Examination on various solutions to reduce port air pollution and suggests some implications
Park et al (2009)	A Study on the International Instruments of Air Pollution Prevention from Ships	Literature Study	Review current international legal framework and instruments for air pollution prevention from ships
Lim (2010)	Establishment of Green Port cope with Environment Regulation in Port	Literature Study	Introduction of international organization and developed countries' green port strategies
Cho (2010)	Comparative Study on Low Carbon Port Management of Busan and LA/LB	Literature Study	Analysis on cost of low carbon port management of Busan and Los Angeles/Long Beach port

However, there are some limitation on domestics researches. First, most domestic researches are conducted from a legal point of view, especially focused on regulations of international organization. Second, domestic studies on green port have been simply introduced foreign ports' cases, so there is lack of empirical study on cost-effectiveness of each strategies for reducing environmental problems.

2. Foreign Studies

Gallagher & Talyor(2003) showed how international trade is affecting criteria air pollution emissions in the United States' shipping sector.[4] They found that the economic costs of SO2 pollution are estimated to be $1.1 billion or $126 million per year during the period 1993 to 2001. For NOx emissions the costs are $3.7 billion over the entire period or $412 million per year. Darbra et al(2004) introduced Self Diagnosis Method, which has been designed to assess the performance of the environmental management in sea ports.[5] Bailey & Solomon (2004) reviewed various environmental health impacts and suggested mitigation measures for port's air pollution measures encompass a range of possibilities from currently available, low-cost approaches, to more significant investments for cleaner air.[6] In addition, Bin Lin et al(2005) investigated possible strategies, which may be adopted by maritime countries such as Taiwan to conform to IMO convention in order to reduce the air pollution from ships.[7] NRDC & CCCA (2004a) assessed efforts at the 10 largest U.S.

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4) Gallagher & Talyor, *International Trade and Air Pollution: The Economic Costs of Air Emission from Waterborne Commerce Vessels in U.S, Global Development and Environment Institute Working Paper* No.01-08, Tufts University, *2003,* pp.1-12

5) Darbra, R., Ronza, A., Casal, J., Stojanovic, T., Wooldridge, D., "The Self Diagnosis Method: A New Methodology to Assess Environmental Management in Seaports", *Marine Pollution Bulletin*, Vol. 48, 2004, pp.420-428

6) Bailey, D., Solomon, G., "Pollution Prevention at Ports: Clearing the Air", *Environmental Impact Assessment Review*, Vol. 24, 2004, pp. 749-774

7) Lin, B., Lin, C., "Compliance with International Emission Regulations: reducing the

ports to control pollution, and provided an overview of policy and practical pollution mitigation recommendations.[8] In a follow-up report, NRDC & CCCA (2004b) discussed solutions to port pollution problems and reviewed the policies governing U.S. marine ports; and technical recommendations to port operators, regulatory agencies, and community-based environmental and health advocates.[9]

〈Table 2〉 Foreign Studies on Air Pollution from Shipping and Port

Authors /Year	Title	Research Method	Main Contents
Gallagher & Talyor (2003)	*International Trade and Air Pollution*	Empirical Study	Estimation of economic cost from air pollution in U.S shipping sector
Darbra et al(2004)	*The Self Diagnosis Method*	Literature Study	Introduction of Self Diagnosis Method
Bailey& Solomon (2004)	*Pollution Prevention at Ports*	Literature Study	Review various environmental health impacts and suggested mitigation measures for port's air pollution measures
NRDC & CCCA (2004a)	*Harboring Pollution; The Dirty Truth about U.S Ports*	Survey	Assessment 10 largest U.S. ports' air pollution control, and provided policy recommendations
NRDC & CCCA (2004b)	*Harboring Pollution; Strategies to Clean Up U.S Ports*	Survey	Technical recommendations for reducing emission
B. Lin et al (2005)	*Compliance with International Emission Regulations*	Literature Study	Strategies for conforming to IMO convention in Taiwan
ICCT (2007)	*Air Pollution and Greenhouse Gas Emission from Ocean-going Ships*	Literature Study	Regulatory, market-based, and voluntary approaches to reduce the air pollution and global warming
Tzannatos (2010)	*Cost Assessment of Ship Emission Reduction Methods at Berth: the case of the Port of Piraeus*	Empirical Study	Cost-effective analysis between shore-side electricity and low sulphur fuel

air pollution from merchant vessels", *Marine Policy*, Vol.30, Issue. 3, 2006, pp.220-225

8) Natural Resources Defense Council, *Harboring Pollution; The Dirty Truth about U.S Ports,* March 2004, pp.1-72

9) Natural Resources Defense Council, *Harboring Pollution; Strategies to Clean Up U.S Ports,* August 2004, pp.1-85

As a relatively recent study, ICCT(2007) discusses regulatory, market-based, and voluntary approaches to reduce the air quality and global warming impacts of ship emissions.[10] Tzannatos(2009) examined the problem of ship exhaust emissions at Port of Piraeus(Greece) and undertook the challenge of finding a cost-effective option for its reduction according to the upcoming requirement of the 2005/33/EU Directive, through analysis of port traffic data and the utilization of the experience gained previous studies. According to the study, the overall costs of shore-side electricity are around 25% lower than the use of ultralow sulphur fuel.[11] In conclusion, the main topic of foreign studies in this field is now changing from the researches on international regulation trends and case study on air pollution reduction measures in each country in the early stage to empirical study on assessment of cost-effectiveness in individual port.

Ⅲ. World Major Ports' Clean Air Strategies

1. Port of Los Angeles/ Long Beach : San Pedro Bay Clean Air Action Plan

To effectively integrate common goals for air quality in the South Coast Air Basin, Port of Los Angeles (POLA) and the Port of Long Beach (POLB) have developed the San Pedro Bay Ports Clean Air Action Plan in November 2006. This is the first clean air plan in the USA, linking the emissions reduction efforts and visions of the two ports.[12]

The vision of Clean Air Action Plan (CAAP) is designed to develop

10) ICCT, *Air Pollution and Greenhouse Gas Emission from Ocean-going Ships,* 2007, pp.7-15

11) Tzannatos, E. "Cost Assessment of Ship Emission Reduction Methods at Berth: the case of the Port of Piraeus", *Maritime Policy and Management*, Vol.37 No.4, 2010, pp. 427-445

12) Port of LA/LB, *San Pedro Bay Ports Clean Air Action Plan.* 2006. p.2

mitigation measures and incentive programs necessary to reduce air emissions and health risks while allowing port development to continue. CAAP is based on the following principles: i) the Ports will work cooperatively to implement these strategies, ii) the CAAP will be continually updated and improved, iii) the Ports will be open to new technologies and other advancements to accelerate meeting the vision expressed above, iv) The ports will achieve an appropriate "fair share" of necessary pollutant emission reductions. The most valuable aspects of this CAAP is that both Ports will combine resources and expertise to supplement the actions of federal, state, and local regulators as necessary to implement cleaner technologies for various source categories. The goal of the CAAP is to reduce port-related emission by about 45% over a 5-year period ending in 2012.[13)]

One of the main characteristics in CAAP lies in its implementation method. Two Ports agree on the incorporation of control measures into lease requirements and utilization of appropriate mitigation measures.[14)] Specific source category control measures by Clean Air Action Plan are as follows.

1) Heavy Duty Vehicles (Trucks)

By far the single most challenging component of the Clean Air Action Plan will be the implementation and funding associated with the mass turnover of frequent caller trucks calling at both Ports in order to meet the proposed "clean truck" standards. To accelerate the emission reductions from truck, the POLA introduced Clean Truck Program (CTP). The program is a bold initiative that will rapidly advance the improvement of air quality at the Port by accelerating the replacement of high-polluting trucks with cleaner trucks.[15)]

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13) OECD, *Environmental Impacts of International Shipping-The role of ports : a case study of the Port of Los Angeles and Long Beach,* 2010. p.16

14) The limitation of this strategy is that the timing of implementation will depend on the timing of lease negotiations. To make up for this limitation, the Ports will use targeted incentive funding to "encourage" early emissions reduction measures and other strategies such as tariffs changes wherever possible.

Since its commencement on October 1, 2008, the Port of Los Angeles Clean Truck Program has delivered an estimated 70% reduction in the rate of port truck emissions compared to 2007 average air emissions.

2) Ocean-Going Vessels

Another primary focus of the Plan is reducing the emissions from ocean-going vessels (OGV) during transit and hotelling at terminals. To reduce transit emissions, the Ports will utilize a combination of operational and technology strategies targeted at: 1) vessel speed reduction(VSR), 2) at berth emissions reductions, and 3) cleaner fuels in auxiliary and main engines. In 2001, the Ports of Long Beach and Los Angeles have participated in a very successful voluntary VSR program.[16] Since 2005, the POLB has further increased compliance by offering the Green Flag Program, which provides financial incentives to their vessel carriers that participate in the program. To comply with the VSR Program, vessels reduce their speed to 12 knots on arrivals and departures to the Ports. Speed reduction is an operational change that all vessels can make to reduce both NOx and PM emissions, and it doesn't require any modifications to the vessel.

The Clean Air Action Plan focuses on two primary approaches for reducing at berth emissions: shore-power and hotelling emissions reduction requirements through alternative technologies, for ships that do not fit the shore-power model.

The POLB's program is referred to as shore-side power or cold ironing, while the POLA' program for shore-power is called Alternative Maritime

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15) The schedule for banning older trucks from the Ports is as follows;
- October 1, 2008: All pre-1989 trucks are banned from entering the Port
- January 1, 2010: 1989-1993 trucks will be banned in addition to 1994-2003 trucks that have not been retrofitted
- January 1, 2012: All trucks that do not meet the 2007 Federal Clean Truck Emissions Standards will be banned from the Port

16) In 2009, more than 90% of vessels participated in the program, slowing their ships in the 20nm zone, while over 70% slowed down within the 40nm zone.

Power(AMP).[17] The POLB will develop shore-side electricity for ships at all container(15 berths) and one crude oil terminal until 2016; the POLA will facilitate AMP for ships at 15 berths(container and cruise terminals) until 2011. For vessels that do not fit the shore-power model, hotelling emission reductions will be required through alternative technologies that achieve equivalent emissions reductions. Some examples of these alternative technologies include: exhaust gas scrubbing technologies-capture vessel stack emissions while at berth and remove pollutants from exhaust streams either on-shore or on a barge, and emerging emissions reduction technologies such as sea water scrubbers, selective catalytic reduction, etc.

The third goal is to encourage to vessel operators to use low sulfur(0.2 percent sulfur or less) Marine Gas Oil(MGO) or Marine Diesel Oil(MDO) in their main engines during their approach or departure, out to 20 or 40 nautical miles from Point Fermin. To receive the incentive, vessel operators were required to be compliant with the vessel speed reduction program speed limit of 12 knots over the distance they wished to receive the incentive (40 nm or 20 nm) and use low sulfur fuel in their auxiliary engines while at berth. Under this program, which is called Vessel Main Engine Fuel Incentive Program, the ports will pay the difference between the price of bunker fuel and more costly low-sulfur distillate fuel for vessel operators who make the fuel switch within at least 20 miles-and as far as 40 miles-from the ports. Vessels also will be required to use low-sulfur fuel in their auxiliary engines while at berth in the port complex.

3) Dockside emissions treatment system

The POLB is reviewing an application by a terminal operator to conduct the first full-blown test of a dockside system that could treat air emissions from

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17) AMP technology is often referred to as “cold ironing” and has been used for naval vessels, Baltic ferries and cruise ships operating in Alaska. The Port of Los Angeles is the first port in the world to use AMP technology for in-service container ships in 2004.

ships at berth, reducing a major source of pollutants by more than 95 percent. The system consists of a "bonnet" that fits over the exhaust stacks of ships at berth. Through a network of ducts, emissions captured by the "bonnet" flow to a dockside treatment unit like those found at industrial plants. The treatment unit includes a multi-stage emission cleaning system, with a "scrubber" and selective catalytic reduction. POLB estimates the system would reduce harmful air pollutants such as PM and SOx by 99%, and NOx by 95%. Whereas cold ironing is not feasible for all ships, especially those that come here infrequently, this on-dock treatment system could be suitable option for infrequent calling vessels.

2. Port of New York/New Jersey

Port of New York and New Jersey (PANYNJ) published the first Clean Air Strategy report in 2009. The purpose of this strategy is to define a commitment by the PANYNJ and its partners to ensure that air emissions generated by mobile sources associated with marine terminal operations and activities decline even with anticipated future port growth over the next ten years. The actions identified in this ten year strategy are meant to address two primary emissions reduction objectives: One is to reduce maritime-related air quality impacts on human health and the environment from criteria air pollutants, especially those that come from diesel particulate emissions; the other is to reduce maritime-related contribution to greenhouse gas emissions associated with climate change.[18] The emission reduction goals of this strategy are annual 3% net decrease of criteria pollutants and annual 5% net decrease of green house gasses (GHGs). In creating this strategy, the port authority

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18) "Criteria pollutants" refers to the following pollutants: Oxides of nitrogen (NOX), an ozone precursor; Carbon monoxide (CO); Particulate matter less than 10 microns in diameter (PM10); Particulate matter less than 2.5 microns in diameter (PM2.5); Volatile organic compounds (VOCs), an ozone precursor; and Sulfur dioxide (SO2). Greenhouse gas emissions include Carbon dioxide (CO2); Nitrous oxide (N2O); and Methane (CH4).

worked with several partners, who collectively endorse this strategy and agree to continue a collaborative approach to reducing air emissions. The strategy lists actions for emissions reduction by source category, or sector of port operations. These five sectors are ocean-going vessels, heavy-duty diesel vehicles(truck), railroad locomotives, cargo handling equipment and harbor craft.

〈Table 3〉 Criteria Pollutant Emission Summary by Source Category

Source Category	PM_{10}	$PM_{2.5}$	SO_2	NO_X	VOC	CO
Ocean-Going Vessels	65%	32%	91%	47%	40%	22%
CHE	17%	19%	6%	18%	30%	32%
Truck	11%	12%	1%	25%	21%	39%
Rail	2%	2%	1%	4%	5%	3%
Harbor Craft	5%	5%	1%	6%	4%	3%
Total Emissions(tons/ year)	537	452	3,597	7,800	413	1,434

Source: The Port Authority of NY/NJ, A Clean Air Strategy, 2009. p.12

The details of emission reduction actions by sectors are shown in Table 2. The priority of implementing the actions provided within this strategy will be based upon their corresponding tons of emissions reduced, cost-effectiveness, available funding and localized area impacts.

〈Table 4〉 Clean Air Strategies by Sectors in Port of NY/NJ

Sectors	Actions
Ocean-Going Vessels	Environment Ship Index Vessel speed reduction incentive program Incentive program for switch to low sulfur fuel Green Flag Program Shore-power (“cold ironing”) capability Tax exemption for bunker fuel (future)
Cargo Handling Equipment	Use of Ultra Low Sulfur Diesel (ULSD) fuel Diesel particulate filters (DPF) on yard tractors Alternative power equipment (CNG, propane, electricity) Idle Reduction Program Wind turbines as alternative energy source (future)

Truck	SmartWay-type partnership[19] Appointment system for trucks Truck Replacement Program Develop near-Port truck parking areas with plug-in electrification technology to reduce idling emissions (future)
Rail	ExpressRail expansion ($600M) Anti-idling technology
Harbor Craft	Switch to ULSD in all harbor craft Engine retrofits/replacement Fuel efficiency(vessel speed reduction, vessel assignment planning)

Source : Compiled based on Port Authority of NY/NJ (2009)

3. Port of Seattle/Tacoma/Vancouver

Puget Sound Ports, which include Ports of Seattle/Tacoma(USA) and Port of Vancouver(Canada), developed a first cross-border clean air strategy, so called Northwest Clean Air Strategy in May 2007.[20] The strategy is the culmination of input from the three ports, major stakeholders, environmental groups and local citizens throughout the region. The overall goal of the strategy is to reduce diesel and greenhouse gas emissions in the region by achieving early reductions in advance of applicable regulations. It builds on emission reduction strategies already implemented, and establishes short and long-term performance measures for reducing emissions from cargo-handling equipment, rail, harbor craft, ocean-going vessels, and trucks.

Each of the ports, along with their customers and tenants, continues to work collaboratively with air and environmental regulatory agencies to reduce emissions through such initiatives as:

- Ships: Using low-sulfur distillate fuels at berth. Adding "green design"

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19) SmartWay is a voluntary program of USA EPA that establishes incentives for freight industry sectors to achieve fuel efficiency improvement and greenhouse gas emissions reductions.(http://epa.gov/smartway/index.htm.)

20) Port of Seattle, Port of Tacoma, Vancouver Port Authority, *Northwest Ports Clean Air Strategy*, 2007. pp.1-22

environmental features to ships, including diesel-electric motors that save up to 30 percent in fuel and significantly reduce emissions.

- Cargo-handling equipment: Using ultra-low sulfur diesel, biodiesel, and other cleaner-burning fuels in cargo-handling equipment
- Trucks: Setting targets to turn over older, less-efficient truck engines
- Rail: Installing anti-idling devices on rail-switching engines, as well as partnering on other innovative technological advances.

4. Port of Rotterdam

The Port of Rotterdam is famous for its efforts being sustainable port. The Green Award was one of the first voluntary programs to recognize ship environmental performance. It is granted to oil tankers and bulk cargo vessels that meet various safety and environmental performance criteria. Currently 202 vessels from 38 different owners are certified, representing about 7 % of the targeted vessel fleet. Green Award vessels benefit from reduced port dues in about 50 ports worldwide.

Recently Port of Rotterdam and its neighboring stakeholders have united in a partnership to develop a package of measures to mitigate air pollution in the Rijnmond region, called Rijnmond Regional Air Quality Action Program.[21] According to this program, Rotterdam Port Authority organized five task groups to focus on different source categories along with the participating administrative authorities and other parties such as members from the business community. The five task groups were divided into the following groups; road traffic, shipping, railway, industry and households. The following strategies relate to port/maritime activities.[22]

- Ship: Support for existing and future policies and legislation; shore side electricity; and development and implementation of emission control technologies.

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21) DCMR Rijnmond Environmental Agency, and ROM Rijmond, *Rijnmond Regional Air Quality Action Program*, 2006. pp.1-25

22) CITEAIR, *Air Quality Management Guidebook*, 2007. pp.6-7

• Trucks and Road Haulage: intelligent loading; clean vehicles technology.
• Rail: conversion of diesel to electric locomotives and cleaner EU emission standards for locomotives.

The Port of Rotterdam manages an extensive array of programs designed to reduce air pollution from port area, among them Environmental Ship Index(ESI) is introduced recently. ESI is a voluntary system, helping to identify seagoing ships that go beyond the current standards in reducing air emissions.[23] The ESI gives points for the performance of ships compared to the current international legislation, mainly IMO. ESI only takes the NOx and SOx emissions directly into account and awards documentation and management of the energy efficiency. The index is intended to be used by ports to promote clean ships, but can also be used by shippers and ship owners as a promotional instrument. Finally, all stakeholders in maritime transport can use the ESI as a means to improve their environmental performance and as an instrument to reach their sustainability goals. Port of Rotterdam has announced that in 2011 it will give the cleanest vessels a discount on harbor dues.

〈Table 5〉 Air Quality Measures in Port of Rotterdam

Sectors	Measures	Remarks
Sea-going vessels	Clean Fleet Program	use of clean engine and clean fuel
	Shore based power	ferries in progress feasibility study(container/cruise)
	Environment Ship Index	operation in 2011
Inland vessels	Shore based power	compulsory at the end of 2008
	Barge engine replacement program	engine replacement subsidy until 2025
	Barge speed reduction	under consideration
Rail	Hybrid shunting engine rail Betuwe line[24]	testing Service from 2007
CHE	Switch from hydraulic engine of AGV to electric motor	diesel-electric propulsion
Others	Transferium (Inland container terminal)	T/S point between Maasvlakte and eastern side of Rotterdam

Note : Compiled based on Port of Rotterdam (2007)

23) World Ports Climate Initiative, *Environmental Ship Index*, Dec 2009. pp.1-8

5. Port of Gotenburg

The Port of Gothenburg is continuously striving to reinforce its green port strategy including the introduction of environmentally differentiated fairway dues program and shore-side power and launch of its Railport concept.

1) Environmentally Differentiated Fairway Dues Program

This Program have contributed to reduce harmful emissions from ocean-going vessels since 1998. Under the program, baseline dues are levied proportional to each vessel's gross tonnage. Individual vessels can then qualify for reductions from the baseline dues based on their emissions performance. Since the program was designed to be revenue neutral,[25] baseline fairway dues were first increased so as to create room for fee reductions without an overall loss of revenues. Fee reductions for NOx performance are assessed based on vessel emissions in g/kWh as measured by an independent body. Fee reductions for SOx performance are assessed based on the sulfur content of the fuel used. NOx and SOx performance is certified for 3 years and periodically verified. The majority of vessels in the program have opted for installing SCR on their main engines to achieve NOx reductions; as a result, average NOx reductions totaled 87%.[26] This kind of local or national-based measures can have a significant impact on local emissions but their impact on global emissions is generally small since only the vessels calling at a few specific ports are affected.

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24) The Ports of Amsterdam and Rotterdam decided to invest (15% and 35% respectively) with Prorail (50%) in a dedicated high speed rail freight route - The Betuwe Line. Through this line, the ports would also achieve air quality benefits. (See Greenport Journal, *ModalShift:theroleofrail*,March2010).

25) Revenue neutral means that the higher costs incurred on the basis of environmental charges are offset by lower expenses incurred for the use of port facilities and services. Thus net effect is to increase the cost for high emitters, while environmentally sound ships face lower net costs.

26) International Council on Clean Transportation, *Air Pollution and Greenhouse Gas Emissions from Ocean-going Vessels*, 2007. pp.60-61

2) Onshore Power Supply

The Port of Gothenburg was the first port in the world to provide high voltage onshore power supply for cargo vessels. This was achieved at the Ro/Ro terminal in 2000, as a result of a successful collaboration with Stora Enso, one of the world's largest paper companies. In order to ensure that electrically connected vessels are as environmentally sound as possible, the Port utilizes two local wind turbines. From 2010 the EU's sulphur directive will come into force, which means that vessels have to use diesel with 0.1% sulphur content when they are in port. This will involve markedly higher fuel costs for the ship owners, so shore side electricity will also be a more attractive option from a financial viewpoint. To offer an important incentive for investing in this form of technology, the Swedish government is considering tax exemptions on electricity supplied to vessels using shore side connection s.[27)]

3) Rail Shuttle Service

The rail shuttle system is based on cooperation between the Port of Gothenburg, the Rail Port terminals, several rail operators, goods owners and the National Rail Administration. One of the important innovations is the development of the RailPort Scandinavia concept. RailPort Scandinavia is an integrated rail shuttle system linking the Port of Gothenburg with a large number of important consumption and production centers via Rail Port terminals all round Scandinavia. Through partner co-operation the inland hubs providing various services such as customs clearance, storage, and documentation. This enables the port to offer seamless and efficient rail links from the sea directly inland to its customers. Since 2002, rail transport to and from the Port of Gothenburg have increased from 6 to 26 daily shuttles. Container traffic by rail has seen a three folds increase since 2002 to 366 thousands TEU in 2009. In 2009, transporting freight by rail led to a

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27) Greenport Journal, *Gothenburg goes even greener*, November 2009. pp.34-35

reduction in carbon dioxide emissions of 50,000 tons compared with transport by road.

Ⅲ. Port of Busan's Clean Air Strategy

Korea's Ministry of Land, Transport, and Maritime Affairs (MLTM) established the National Green Port Project in 2009. According to this Project, Busan Port is trying to reduce air pollution through various strategies. First, Busan Port Authority (BPA) decided to convert oil-using RTGCs to electricity-driven RTGCs (e-RTGC). There are a total of 186 Rubber Tired Gantry Crane (RTGC) units at Busan North Port. The total conversion cost is about USD 400 thousand, half of that (USD 200 thousand) is for converting the engine system of the RGTCs, which is covered by operators, and the rest is for the construction of the electricity supply system, covered by BPA. A total of 73 units of RTGCs had been converted to e-RTGC until 2009 and 21 units will be converted to e-RTGC in 2010. BPA estimates that converting 94 RTGCs to e-RTGC reduces CO2 emissions by 28,000 tons, and saves USD 16 million in operating cost, annually.

〈Table 6〉 Number of RTGC converting to e-RTGC in Busan North Port

	2007	2008	2009	2010	Total
Units	9	35	29	21	94

Source: Busan Port Authority.

Second, from the beginning of the Busan New Port Planning, BPA decided to install Rail Mounted Gantry Cranes (RMGC), which is operated by electricity, not by fuel oil as RTGC. A total of 267 RMGCs will be equipped at the Busan New Port if a total of 30 berths are developed by 2015. BPA estimates that 267 units of RMGC reduce CO2 emissions by 80,000 tons and saves USD 80 million annually.

〈Table 7〉 Number of Rail Mounted Gantry Crane at Busan New Port

	Until 2009			After 2010				Total
Phase	1-1/	2-1	2-2	2-3	2-4	2-5	2-6	
Units	80	42	32	38	28	19	28	267

Source: Busan Port Authority.

Third, BPA has decided to change all of the old lighting systems of the Port of Busan to Light Emitting Diode (LED) systems. The total number to be changed is 22,723 (inside buildings: 22,450; outside buildings: 273). BPA estimates that the old lighting system consumes one unit of energy to produce 10% of lighting and 90% of heat; however, LED system consumes one unit of energy to produce 30% of temperature and 70% of lighting.

〈Table 8〉 Plan of Changing the old lighting to LED system

	2009	2010	2011	2012	after 2012	Total
Inside buildings	1,598	2,225	3,196	1,915	13,516	22,450
Outside buildings		49	28	78	118	273

Source: Busan Port Authority.

BPA estimates that the energy savings from using LEDs are 60% and the life-span of an LED system is about ten times longer than the old lighting system. BPA estimates that changing the old lighting system to LED will reduce CO2 emissions by 2,000 tons and save electricity worth USD 370,000 annually. Fourth, BPA uses solar energy at buildings in Phase 2-2 and other areas by constructing new solar energy systems on the roofs and windows. BPA estimates that solar energy will produce 10MW, which is about 10% of total energy consumed in the Busan New Port when the development of the Busan New Port Distripark is completed. BPA estimates that the new energy systems will reduce CO2 emissions by 300 tons per year. BPA will also spend

5 % of the total cost of every new construction project in new renewal energy systems from now on.

Ⅳ. Evaluation of Clean Air Strategies

In this Chapter, various measures to reduce emission from port are evaluated by sectors-ocean-going vessels, cargo handling equipments, truck and rail-, on the basis of categories such as reduction control technologies, operational changes and market-based measures. As far as ocean-going vessels concerned, vessel speed reduction and shore power supply are the most popular emission reduction measures in the world ports.[28] Shore power supply replaces onboard generated power from diesel auxiliary engines with electricity generated on-shore. It could also reduce the greenhouse gas CO2 to a minimum, if using renewable energy such as wind power. There are several advantages of using OPS: significant reduction of local air emissions, elimination of noise and vibration from the auxiliary engines while at berth, improved working conditions for both the people on board as well as those working on the quayside, and economic advantages for shipping lines when fuel prices are rising.

〈Table 9〉 Emission reduction efficiencies from shore power supply

Measure	% Emission reduction per vessel			
	NOx	SOx	PM	VOC
Shore power supply(vs 2.7% residual oil)	-97%	-96%	-96%	-94%
Shore power supply (vs 0.1% MDO)	-97%	0%	-89%	-94%

Source : http://ec.europa.eu/environment/air/pdf/task2_shoreside.pdf, page iii.

28) There are many names for the same technology: Alternative Maritime Power (AMP), Cold Ironing, Shore Side Electricity, Onshore Power Supply Shore Power.

The major concerns when implementing OPS are: no environmental benefits during the journey, ports and vessels have to be retrofitted, converting 60Hz/50Hz raises the cost significantly,[29] safety in handling high voltage cables, and none existing international standard.[30]

Vessel speed reduction measure reduces emissions from ocean going vessels during their to and from a port. This would include a speed reduction possibly down to 12 knots or lower when OGV's are within the coastal waters of a port or within the port area. The main advantages of this measure reduce all pollutants by mitigating the load on the main engines, which affects power demand and fuel consumption. However, vessel speed reduction measure causes the problems such as vessels' speed up outside the VSR zone to maintain their schedule and longer transit time to and from port.

Mitigation measures for cargo handling equipment are equipment replacement, use of clean fuel such as lower sulfur diesel fuel and emission control technologies. Replace older equipments with new ones that meet cleaner engine standards. Especially, e-RTG have significant fuel savings and emission reduction.

〈Table 10〉 Implemented Mitigation Options for Ocean-going Vessel

Measure Types	Measures	Advantages	Disadvantages
Clean Fuel (Lower Sulfur Fuel)	- Marine residual or bunker less than 1.5% - Marine distillate and gas oil less than 0.1%	- 44% SOx reduction, 18% PM reduction - over 90% SOx reduction, over 80% PM reduction	- Fuel contamination - Fuel tank cleaning
Emission Control Technologies	- Selective Catalytic Reduction (SCR) - Sea water scrubber	Exhaust after-treatment technology providing over 90% reduction in NOx, PM, CO, and HC	- Additional cost - Technical feasibility

29) The electricity frequency produced by the grid may not be compatible with the electricity required by the ships. Electricity supply in the USA and some parts of Japan has a frequency of 60Hz, while the rest of the world is offering 50Hz.

30) The ISO and International Electrotechnical Commission (IEC) have established working groups with the intent to develop "Publicly Available Specifications" for shore power supply, which will take care of the above mentioned concerns.

Operational Changes	Vessel speed reduction	Speed reduction reduces engine load and NOx production	- Speed up outside the VSR zone - Longer transit time
	Shore power supply	100% reduction in at-port emissions	- Emission at sailing - need to be retrofitted
Market-based measures	Environmentally differentiated fees	Emissions benefits depend on level of participation and implemented technologies.	- National based measure - Continuous adoption of technology and international rule

Note : Compiled by Author

However, e-RTG requires either rail-mounted electric supply buses or side mounted cable-reels. This reduces the flexibility of RTG operation by restricting them to a specific space of operation.

〈Table 11〉 Implemented Mitigation Options for Cargo Handling Equipments

Measure Types	Measures	Advantages	Disadvantages
Equipment Replacement	Replace older CHE Retrofit (e-RTG)	Emission reduction Fuel efficiency	High investment cost Additional infra
Clean Fuel (Lower Sulfur Fuel)	- Use of Ultra Low Sulfur Fuel - Emulsified diesel fuel - Biodiesel, CNG/LNG	- Reduce NOx, PM, GHG	Fuel availability High cost
Emission Control Technologies	- DOC, DPF - SCR	- Reduce NOx. PM, CO, and HC - Easy installation	High cost Require ULSD Require annual soot/ash removal

Note : Compiled by Author

And additional electric supply and transformers will be required. Another measure is the use of cleaner fuels with low sulfur content such as ultra low sulfur diesel fuel, emulsified diesel fuels, and biodiesel. And retrofit CHE with the best available emission control technologies such as diesel oxidation catalyst (DOC), diesel particulate filter (DPF), or selective catalytic reduction (SCR) have positive emission reduction. Challenges may arise with fuel availability and cleaner fuels often cost more than standard ones.

Equipment replacement for truck can maximizes emission reductions by replacing frequent caller older trucks that service the port with newer trucks that meet cleaner engine standards. Positive emission reduction benefits for PM, NOx reduction, but the costs of replacing engines and/or vehicles may be very expensive. Redevelop infrastructure and use technology, such as radio frequency identification (RFID) and optical character readers (OCR), to enhance the efficiency of gates and terminals, relieve congestion and reduce emissions. Some of these options involve capital investment; others could increase terminal operating costs. However, if designed and planned properly, can result in a significant return on investment due to enhanced operational efficiencies.

〈Table 12〉 Implemented Mitigation Options for Truck

Measure Types	Measures	Advantages	Disadvantages
Equipment Replacement	- Replace older truck - Alternative Fuel Vehicles	Emission reduction Fuel cost saving	- High capital cost - Additional infra
Operational Improvement	- Use of RFID, Optical Character Reader(OCR)	- Reduce NOx, PM, GHG - Operational efficiency	Capital investment and terminal operating cost
Emission Control Technologies	- Use of DOC, DPF and SCR	- Reduce NOx. PM, CO, and HC - Easy installation	High cost Require ULSD

Note : Compiled by Author

Effective strategies to reduce emissions from rail are equipment replacement, rail shuttle as means of modal shift, and idling-reduction program. New and cleaner locomotives could include electric or hybrid locomotives. However, locomotive replacement is costly and international availability may be a concern for some ports. In operational improvement, rail shuttle service from port to hinterland is the important measure in developed countries. Port of Los Angeles conducted feasibility study for Electric Cargo Conveyor System, which is the first container shuttle service by malgrev train.[31] Port of

Rotterdam opened Betuwe-line from Rotterdam to Germany in 2007 and now fully operational. Traffic volumes built to an average 250 trains per week in 2009 and are expected to reach 350 trains per week by the end of 2010, close to full capacity. Port of Gothenburg reduced significant amount to 50,000 ton of CO2 in 2009 by rail shuttle service. Container traffic by rail has seen a three folds increase since 2002 with close to 366,500TEU since 2009.[32) Idling-reduction system includes automatic engine stop-start controls(AESS), auxiliary power unit(APU), diesel-driven heating systems(DDHS), shore power plug-in unit and a hybrid switching locomotive. Eliminating idling time by using an idle-reduction technology greatly reduces emissions that would be generated from regular idling. Applying idle-reduction technologies to locomotives can yield significant fuel savings, which results in a significant cost savings.

Although most ports in advanced countries are using various measures to reduce air pollution in port area, clean air strategies of Busan Port is mainly focusing on cargo handling equipment such as e-RTG and RMGC and renewable energy resources in buildings and distribution centers. Thus, Busan Port is needed to introduce technologies-based measures (use of clean fuel, emission control technologies), operational changes (vessel speed reduction, shore power supply) and market-based measures (environmentally differentiated fees), which are prevailing in advanced countries.

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31) General Automics, *Conceptual Design Study for the Electric Cargo Conveyor System*, 2006. pp.1-11

32) GreenPort Journal, *Modal Shift; the role of rail*, March 2010. p.109

〈Table 13〉 Implemented Mitigation Options for Rail

Measure Types	Measures	Advantages	Disadvantages
Equipment Replacement	- Replace with electric or hybrid rail	Emission reduction Fuel efficiency	- High capital cost - International availability
Operational Improvement	Rail shuttle service	-Modal shift	Infra construction cost
Idling reduction technologies	- Automatic engine stop-start control - Auxiliary power unit - Diesel-driven heating system - Hybrid switching rail	- Reduce emission from regular idle - Fuel saving	High investment cost

Note : Compiled by Author

V. Conclusions

Ports and port users increasingly are challenged by the air pollution issue. Not only increasing rules and regulations but also the growing importance of port authorities and companies' social responsibility bring about the need to actively develop air pollution reduction strategies and measures. Many options for air reduction program are available. The selection of the most feasible actions will depend on many factors, such as laws and regulations, terminal set-up, the modal split of the port and the age of diesel engine equipment fleet, the cash involved.[33)]

There are some implications for Korea Ports. First, although Korean government recently established the National Green Port Project, there is no specific port's clean air plan. Thus, the more concrete Clean Air Action Plans for Korean ports are required as soon as possible. IAPH(2009) suggested six steps for overall methodology in developing and implementing a plan i) develop current inventory, ii) establish emissions baseline and forecast, iii) set

33) Ocean Shipping Consultants, *Container Port Strategy*, 2007. p.121

short/mid/long-term goals, iv) develop strategies, v) monitor progress, and vi) adaptation planning. Second, integrated approach is required to reduce emission effectively. Emissions reduction strategies in port can be classified in three categories: technological improvement(replacing or upgrading older engines and propulsion systems, use of low sulfur fuels, and exhaust after treatment such as SCR), operational changes(shore side electricity, improved fuel quality standards for auxiliary engines and voluntary speed reduction program) and market-based strategies(Swedish voluntary differentiation program). Each measure has its advantages and disadvantages. Thus, it is important to note that integrated approach among these three categories is the most effective way to reduce air pollution. And legal regulations and financial incentive/penalty approach should be integrated to foster emission reduction. Last but not least, most of emission reduction measures have been implemented on a local basis, such as vessel speed reduction program and shore side electricity. And the Swedish environmental differentiated fairway dues program is implemented on a national basis. However, the effect of port-related emission reduction can be maximized when various measures are conducted on a regional basis including neighboring ports. Furthermore, regional or global-based approach is useful to guarantee the level playing field among ports.

The limitations of this study and further researches are as follows. First, methodology for assessing the cost-benefit analysis of world major ports' emission reduction strategies should be developed in future research. Second, as Adams et al (2010) pointed out, most environmental initiatives having effects at a broader than a single port scale, further study for port collaboration and coordination in a certain region is needed. This is very important issue not only for effective emission reduction but also for ensuring the level playing field in certain port range. Third, clean air program for port operation should be implemented together with ship emission program. Because air pollution reduction measures will be more effective when they are conducted by both at sea and in port.

REFERENCES

Adams, M., Quinonez, P., Pallis, A., Wakeman, T. "Environmental Issues in Port Competitiveness", Center for International Trade and Transportation Working Paper 7, Dalhouse University. 2010.

Bailey, D., Solomon, G. "Pollution Prevention at Ports: Clearing the Air", Environmental Impact Assessment Review, Vol. 24, 2004.

Bin L., Cherng-Yuan L. "Compliance with international emission regulations : Reducing the air pollution from merchant vessels", Marine Policy, Vol 30. 2005.

Cho, Dong-Oh. "Comparative Study on Low Carbon Port Management of Busan and LA/LB", Journal of the Korea Society of Marine Environment & Safety, Vol.16, No.2, 2010.

Choi, Dong-Hyun, Study on Port's Environment Planning, 2001.

CITEAIR, Air Quality Management Guidebook, 2007.

Darbra, R., Ronza, A., Casal, J., Stojanovic, T., Wooldridge, D., "The Self Diagnosis Method: A New Methodology to Assess Environmental Management in Seaports", Marine Pollution Bulletin, Vol. 48, 2004.

DCMR Rijnmond Environmental Agency, and ROM Rijmond, Rijnmond Regional Air Quality Action Program, 2006.

Gallagher & Talyor, International Trade and Air Pollution; The Economic Costs of Air Emission from Waterborne Commerce Vessels in U.S, Global Development and Environment Institute Working Paper No.01-08, Tufts University, 2003.

General Automics, Conceptual Design Study for the Electric Cargo Conveyor System. 2006.

Greenport Journal, Gothenburg goes even greener, 2009.

, Modal shift; the role of rail, March 2010.

IAPH, Climate Protection Plan Development. 2009.

, Tool Box for Port Clean Air Program. 2008.

International Council on Clean Transportation, Air Pollution and Greenhouse Gas

Emissions from Ocean-going Vessels. 2007.
Jung, Bong-Min, "Environmental Issues in Container Port Development", KMI. 2004.
KMI, "Policy Implications and Regulations on Port Air Pollution ", 『KMI Issue Paper』 2005.
Lin, B., Lin, C., "Compliance with International Emission Regulations: Reducing the air pollution from Merchant Vessels", Marine Policy, Vol.30, Issue. 3, 2006.
Lim, Jong-Sup, "Establishment of Green Port cope with Environment Regulation in Port", Journal of Korea Port Economic Association, Vol.26, No.2, 2010.
Natural Resources Defense Council, Harboring Pollution; The Dirty Truth about U.S Ports, March 2004.
Natural Resources Defense Council, Harboring Pollution; Strategies to Clean Up U.S Ports, August 2004.
Tzannatos, E. "Cost Assessment of Ship Emission Reduction Methods at Berth: the case of the Port of Piraeus", Maritime Policy and Management, Vol. 37 No. 4, 2010.
Ocean Shipping Consultants, Container Port Strategy. 2007.
OECD, Environmental Impacts of International Shipping-The role of ports : a case study of the Port of Los Angeles and Long Beach. 2010.
Park, Ro-Kyung, "A Study on the Self Diagnosis Methodology for Environmental Management of Korean Seaports", Journal of Shipping and Logistics, Vol. 42, 2004.
Park Myung-Sup, Hong, Nan-Ju, Han, Neung-Ho, "A Study on the International Instruments of Air Pollution Prevention from Ships", Journal of Korea Maritime Law Professors Association, Vol. 21 No.2, 2009.
Port Authority of NY/NJ, A Clean Air Strategy. 2009.
Port of LA/LB, San Pedro Bay Ports Clean Air Action Plan. 2006.
Port of Rotterdam, Working Together; toward a sustainable port. 2007.
Port of Seattle, Port of Tacoma, Vancouver Port Authority, Northwest Ports Clean Air Strategy. 2007.
Song, Gye-Eui, Han, Chul-Hwan, "A Study on the Strategies for Reduction of Port Pollution", Journal of Korea Port Economic Association, Vol.23, No.1,

2007.
Wayne Tally, Port Economics, Routledge. 2009.
World Ports Climate Initiative, Environmental Ship Index, December 2009.
EPA,SmartWay(http://epa.gov/smartway/index.htm.)[8th October, 2010]

ABSTRACT

Air Pollution Reduction Strategies of World Major Ports

Han, Chul Hwan

Pollution emissions from international shipping and port activities have a significant impact on public health and global climate changes. The purpose of this paper is to review the status of pollution mitigation measures implemented to date in port industry and find out some implications for Korean ports. For this aim, the clean air strategies of the world major ports including six USA ports (Los Angeles/Long Beach, Now York/New Jersey, and Seattle and Tacoma), two European ports (Rotterdam and Gothenburg) and Busan Port were considered. Various measures to reduce emission from ports are evaluated by sectors–ocean going vessels, cargo handling equipments, truck and rail–, on the basis of categories such as reduction control technologies, operational changes and market–based measures. The policy implications of this paper are as follows. First, Clean Air Act Plans of Korean ports are required as soon as possible. Second, integrated approach is required to reduce emission effectively. Finally, the effect of port–related emission reduction can be maximized when various measures are conducted on a regional basis including neighboring ports. Furthermore, regional or global–based approach is useful to guarantee the level playing field among ports.

Key Words : Global Warming, Greenhouse Gas Emission, Air Pollution, Clean Air Strategy, Port Industry