The green port toolbox: A comparison of port management tools used by leading ports in Asia and Europe

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THE GREEN PORT TOOLBOX: A COMPARISON OF PORT MANAGEMENT TOOLS USED BY LEADING PORTS IN ASIA AND EUROPE

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ABSTRACT
The paper attempts to fill the literature gap and the much desired industry needs by researching on green port development from the policy and management perspective. This study aims to investigate the port management tools that port/public authorities have at their disposal and then to analyze to what extent the tools are used to enforce or encourage green port development at various activities of port operations and development. We conduct an analysis based on two axes: on one hand the range of tools available to port authorities (i.e. pricing, monitoring and measuring, as well as market access control and environmental standard regulation) and on the other hand the functional activities in ports (i.e. ships traffic, cargo handling and storage operations, intermodal connection, industrial activities and port expansion). The situations in the leading ports in Asia and Europe, namely Singapore, Shanghai, Antwerp and Rotterdam are studied and compared. Findings show that the ports are particularly mature in exercising environmental standard regulations which reveals that the enforcement approach is more prevalent. The most focused functional activity is ship traffic which reflects that the ports are driven by the advisory from the International Maritime Organisation. The respective port authorities in Antwerp and Rotterdam have a higher level of influence on devising green port policy in comparison to the two Asian ports due to a relatively open geopolitical culture in Western Europe. The analytical framework and policies investigated in the paper would be a useful toolbox for green port development.

Keywords: Green Port, Port Management, Port Development, Port Policy, Asia, Europe

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1. INTRODUCTION

The past years have seen an increasing attention on the environmental impact of port operations and development. As there is a high price associated to climate change and global warming, the port industry is subject to closer scrutiny in terms of environmental regulatory compliance. The focus on environmental issues is especially felt at the level of vessel and cargo handling operations, industrial activities in ports, port planning and extension initiatives and hinterland accessibility. Ports are also facing higher pressure from the public in terms of performing their social responsibility. Ports must demonstrate a high level of environmental performance in order to ensure community support. Ports need to comply with ever higher regulatory and societal requirements in the fields of environmental protection which can have an impact on the further space/room for the ports to grow, not only in terms of hectares, but also in terms of the so-called environmental space. This challenges seaports to minimize emissions of existing and future activities in the port areas and the wider logistics area. Environmental aspects also play an increasing role in attracting trading partners and potential investors. A port with a strong environmental record and a high level of community support is likely to be favoured. As such, port management in light of green port development is a topical issue which deserves much research work. However, the literature to-date has yet to fulfill the much desired industry needs.

This study aims to fill the gap by investigating port management tools that port/public authorities have at their disposal and then to analyze to what extent the tools are used to enforce or encourage green port development at various functional activities of port operations and development. The analysis will cover a comprehensive scope of port management tools including pricing, monitoring and measuring, market access control as well as environmental standards. Efforts are especially devoted to study and compare the situations in the leading ports in Asia and Europe, namely Singapore, Shanghai, Antwerp and Rotterdam due to the high shipping traffic and cargo volume handled, and ongoing and recent port extension projects. These major ports are more comparable and, given the substantial amount of cargo and ships handled, would generate higher environmental impacts, hence they are highly relevant for the research topic. The paper thus serves as one of the first studies to compare the Asian and European perspective and attempts to link the use of specific environmental management tools to local governance and regulatory settings.

The paper is organised as follows. After reviewing the background about the growing awareness on the environmental impact of port operations and development, an overview on port management tools and policies with a focus on green concerns will be given. Then the paper moves on to examine and compare the port management tools in the four leading ports as stated above. A detailed discussion on the research findings, policy implications and recommendations for the ports in the study and in general will then be presented. The last section concludes.

2. ENVIRONMENTAL IMPACTS GENERATED BY PORTS

The past years have seen increasing concerns on the environmental impact of port operations and development. One of the major environmental impacts generated by ports is air pollution, particularly greenhouse gas (GHG) emission which leads to global warming since GHG traps heat (Lashof and Ahuja, 1990). This in turn distorts the natural ecosystem. There are also health effects impacting the residents of the local community surrounding ports which include asthma, other respiratory diseases, cardiovascular disease, lung cancer and premature mortality (Bailey and Solomon, 2004). Ships that call at ports are a major source of air pollutants such as CO_2, SO_2, NO_x, PM_{10}, $PM_{2.5}$, HC, CO and VOC. Coastal passenger shipping, as opposed to cruise shipping, was found to be the dominate contributor of emissions in the passenger port of Piraeus in Greece (Tzannatos, 2010). As for Barcelona in Spain, the highest polluters are auto carriers among all other ship types (Villalba and Gemechu, 2011). In another empirical analysis taken on Taiwan (Berechman and Tseng, 2012), tankers and container ships were found to be the first and second largest groups of ships emitting such pollutants in Kaohsiung Port. It can be seen that the sources of emissions in terms of ship types are port activity-based. Land side activities, particularly cargo operations at terminals, form another source of airborne emission. Emissions of dust from bulk cargo handling, electricity consumption, and gases from cargo handling equipment and trucks adversely affect air quality (UN, 1992; Villalba and Gemechu, 2011). To take a broader view, cargoes handled at ports have to be connected to the hinterland and therefore generate GHG emission due to inland transportation. Liao et al. (2010) analysed the impact of using Taipei Port in Taiwan on the carbon dioxide emissions CO_2 of inland container transport. Via activity-based method, the estimation results showed that there are greater reductions in CO_2 when transhipment routes are changed from other major ports in Taiwan to Taipei.

Another major environmental concern is water pollution and the effects on marine ecosystems. Ng and Song (2010) assessed the environmental impacts generated by routine shipping operations on ports, and conducted an empirical analysis on Port of Rotterdam. Water pollution comes from ballast water, fuel oil residue and waste disposal from ship operations as well as cargo residue. There would be even more severe adversity and immediate impact if there is accident causing oil spill. These marine pollutants are harmful to natural habitats located around port waters which would upset marine and coastal ecology, as well as lead to the damage and loss of coastal ecology and fishery resources (UN, 1992). Furthermore, accommodating ever larger vessels requires upgrading and maintenance of the maritime access infrastructure. The need for navigation channel deepening and widening works would lead to contaminated sludge from dredging. There may also be a need to alter the sea floor and natural geographical feature causing disruptive impact on marine ecosystems due to dredging and civil works (Peris-Mora et al., 2005).

Waste disposal from port operations, industrial activities, construction and expansion projects causes another major category of environmental externality. This includes all kinds of solid, liquid and hazardous wastes. Industrial wastes would be toxic so should be handled with considerable care. Wastes from construction activities are mainly spoils generated by dredging. Waste lubricant, oily mixtures, solid waste (garbage), wastes from cargo operations, daily administration and buildings would also create pollution. Disposal of these contaminated materials on land may cause destruction of plants, leakage of contaminated materials, odour, unpleasant sight and other nuisances to the local community. Disposal in water would cause problems identified in the above paragraph. Hence improper waste control and treatment can be a great strain on the natural environment surrounding the port area.

Ports are major sources of the above environmental impacts given the concentration of a large number of industrial and logistics activities in port areas and the strong reliance of ports on freight mobility over land and via the sea. However, the clustering of activities in a port area can also exert strong environmental advantages. For example, 'ecologies of scale' (Rietkerk et al., 2002) are achieved in the large (petro)chemical industries of ports such as Singapore, Rotterdam and Antwerp by which companies utilize each others' waste material or by-products such as heat. It would be far more difficult to achieve this when the plants concerned would be spatially scattered. Next to potential economies of scale, large port clusters can thus also benefit from 'ecologies of scale' advantages.

The increasing focus on the environmental impacts of ports is not only associated with existing port, ship and hinterland transport operations. From an environmental perspective, port development and extension should ensure sustainable development. Hence, environmental sustainability of port projects has become as important as economic and financial viability. This often demands a more systematic approach in which the impacts of ports and port projects are placed within wider coastal management and environmental policies.

The growing concern about environmental impacts of ports implies that port authorities can no longer take broad public support for port operations and development for granted. Resources such as land are becoming scarcer and environmental concerns increasingly challenge the economic function of seaports. Without proper environmental tools and policies in ports, there is an increased risk of having a clear imbalance between the benefits and costs of ports for the local community. Such imbalances potentially form a breeding ground for major socio-economic confrontations related to port development (Benacchio and Musso, 2001; Notteboom and Winkelmans, 2003).

3. PORT MANAGEMENT TOOLS AND POLICIES

Port authorities around the world are pursuing a greening of port management in view of safeguarding their 'license to operate' and increasing their economic and environmental competitiveness. Port policy charts a port's strategy and development as well as regulates port activities.

Pricing strategies can be used to boost port's competitive positions such as lowering charges (port dues or terminal handling charges or both) in order to compete against other ports. Ultimately the pricing scheme should correspond to market conditions and to counter competition, stimulate market growth and improve profitability (Yap et al., 2011). In view of the direct relationship between hinterland access and port performance, port pricing should also take hinterland capacity into consideration. De Borger et al. (2008) found that profit-maximising ports internalise hinterland congestion as far as it affects their customers. Port pricing can promote the efficient use and enhance the utilisation rate of the facilities. Started in recent years, pricing can also be used as an environmental management tool in ports. A pioneer example is the Port of Long Beach which implemented the Green Flag Speed Reduction Program. By slowing down, ships can reduce airborne emissions and shipowners in return get discounted fees the following year as an incentive, hence the scheme combines environmental protection with economic benefits (Port of LB, 2009). However, since prices paid by shipping companies and other port users affect their commercial behaviour and decision, price regulation is more prone to spawn market distortions than access regulation.

Access regulation is to control how terminal operators access the facilities they need to compete in the market. It promotes competition among the operators and has lower intervention costs (Defilippi and Flor, 2008). In relation to market access regulation, a terminal concession or a grant by a government or port authority to a (private) operator for providing terminal operation services has become a popular governance tool in the port industry. The design of concession agreement, its regulatory and tariff regimes, as well as the way the concession is awarded are structured to conform to the priorities of public authorities (Notteboom, 2007). Ferrari and Basta (2009) argued that concessions are effective in boosting competition in ports only if they are granted to the most efficient port operator. European Sea Ports Organisation (EPSO) is in the process of producing a good practice guide which is primarily aimed to help port authorities improve their contracting methods and instruments in order to gain more value from a governance perspective (Notteboom et al., 2012).

Concession policy can also be used to direct port services in fulfilling environmental requirements (Notteboom, 2007). For example, the Port of Rotterdam sets sustainability as a key criterion in the assessment of concession competitive bidding. In the request for proposals for the Maasvlakte 2 expansion project, candidate terminal operators were asked to focus on minimising the share of road transport with the aim to achieve an ecologically favourable modal split using higher proportion of barge and rail transport (De Langen et al., 2012). ESPO/ITMMA survey conducted in 2008 and ESPO Fact Finding Report survey conducted in 2011 show that concession contracts of European ports often take the form of performance-based agreements to create incentives for terminal operator to meet the objectives of the port authority. The most common clauses in the contracts contain minimum throughput requirements, environmental performance and renewal and extension details (Notteboom et al., 2012). Hence, environmental governance via the mechanism of terminal concession agreements is already quite common in European ports. An example on other port services besides terminal operations is the Clean Trucks Program adopted by the ports of Los Angeles and Long Beach. The ports authorize trucking firms to access the port through offering a limited number of concessions that will be granted to those that can meet certain criteria including deploying vehicles that meet the 2007 US Environmental Protection Agency's standard (Goodchild and Mohan, 2008).

Ports also increasingly implement *environmental management system (EMS)* which is a systematic approach to manage a port's environmental programs for pollution prevention, protection and control (Florida and Davison, 2001). It in essence is a documented process that describes a structure for the management of environmental impact processes and continuous improvement (for example, environmental risk assessment and management actions to address those risks). For instance, the Valencia Port Authority in Spain commenced the ECOPORT project since 1997 and developed a system of indicators in order to implement a sustainable environmental management for industrial harbours and ports (ECOPORT Valencia, 2000). Peris-Mora et al. (2005)'s study proposed a set of environmental indicators for sustainable port management to be used by any port authorities. They also applied the environmental indicators to the port of Valencia. Gupta et al. (2005), with a case study on the Jawaharlal Nehru Port Trust in India, suggested that port and habour projects should have an environmental management plan which includes information on the generation and treatment of solid waste, liquid and gaseous effluents, details of safety measures around the project, and details of the safety organization including key personnel. Monitoring is one of the important aspects in EMS. The UK ports sector responded to environmental legislation with the focus on monitoring mechanism for ports and harbours in maintaining their environmental sustainability. Biological indicators such as presence/absence of individual marine species and abundance of dominant species for monitoring purpose were suggested (Wooldridge et al., 1999). Also related to monitoring, Darbra et al. (2009) studied 26 European ports' requirements for environmental information via interviews. The major environmental parameters that ports required to be monitored were marine related issues, water quality, meteorological parameters, turbidity and sediment processes. Indirect effects such as altered transport patterns and increased energy use due to larger built environment should be taken into account in strategic environmental assessment of transport infrastructure investment (Jonsson and Johansson, 2006).

The above studies have led to a better understanding of ecological issues in ports and port management policy with some relation to green port development. However, academic research on green ports from the policy and management perspective is scarce. Also, the few studies on environmental policy related to ports mainly provide a local perspective and typically provide a fragmented discussion on environmental challenges to ports. With regards to empirical investigation or case study, it is observed that prior studies are mostly devoted to a local situation or at best regional focus, e.g. Darbra et al. (2009)'s analysis on Europe. There are only very few studies on Asia which presents an urgent need for investigation due to the tremendous growth of seaborne commodity trades handled via ports and port development projects. To the best of the authors' knowledge, there are no empirical comparative studies devoted to green port policy at an international scale.

4. CASE ANALYSIS AND DISCUSSION

When it comes to sustainability, the ports considered in this study, i.e. Singapore, Shanghai, Rotterdam and Antwerp, have recognized at various points in time the necessity to carefully consider environmental issues in their strategic planning and behaviour, and to communicate actively with the entire range of stakeholders. We will demonstrate in this section that they have taken measures to show their environmental concerns and their reliability in taking care, and have started to implement the concept of sustainability. While differences can be observed among the ports considered, port authorities had to go through 'learning by doing' experiences in developing green policies and in dealing the best they can with international and national environmental regulations and spatial planning restrictions.

The effectiveness of a port on environmental issues depends largely on the various green port policies and tools adopted by port/public authorities. Different ports may adopt different policies considering local regulatory, geographical, economic and political background. Various policies and tools are classified into three main categories, namely 1) pricing, 2) monitoring and measuring, and 3) market access control and environmental standard regulation. Pricing control is further divided into penalty pricing and incentive pricing. We propose an analysis based on two axes: on one hand the range of tools available to port/public authorities and on the other hand the functional activities in ports (i.e. ranging from ships traffic, cargo handling and storage operations, intermodal connection, industrial activities and port expansion) to represent the logistics chain perspective. In order to derive the patterns across the four ports, the policies are compared according to various port functional activities. The analysis is based on comprehensive literature review, data and information collected from library and credible internet sources, and years of correspondence and interactions with the four ports. The findings are illustrated in table 1 and the interpretation and implications are discussed below.

Table 1: Green port tools in the 4 ports

Tools used by port authority/ public regulator

Port functional activities

	Penalty pricing	Incentive pricing	Monitoring & measuring	Market access control & environmental standard regulation
Ships traffic	Surcharge to docking fees RTM Fines on marine oil spill ANT RTM SHA SIN	Ships meet Environmental Ship Index scores get discount on GT section ANT RTM Reduction of port dues SIN	Ship GHG emission ANT RTM SHA SIN Sustainability report ANT	- Sulphur fuel cap, GHG emission RTM ANT SHA SIN (IMO MARPOL VI) - Regulation on oil pollution casualties RTM ANT SHA (IMO INTERVENTION Convention 69) - Regulation/control on pollution damage to marine environment by vessels ANT (co-signed document by shippers, terminal operators and port authority) SHA (Regulations of China[1]) SIN (Regulations of Singapore[2])
Cargo handling and storage	-	-	Crane GHG emission ANT RTM SIN Vehicle GHG emission ANT RTM SIN Sustainability report ANT	- Cargo handling vehicles with Sulphur fuel limits ANT (Antwerp Port Authority) RTM (Municipality of Rotterdam[3]) - Terminal concession criterion on sustainability RTM (Port of Rotterdam Authority), ANT (future) - Regulated operation activities SHA (Regulations of China[1])
Intermodal connection	Fines for non-compliance with agreements on modal shift RTM	-	Monitoring and analysis of policy developments ANT Sustainability report ANT	Agreement on modal shift RTM (agreement between terminal operators and port authority)

Tools used by port authority/ public regulator (cont'd)

Port functional activities	Penalty pricing	Incentive pricing	Monitoring & measuring	Market access control & environmental standard regulation
Industrial activities	Fines on pollution damage to the marine environment by dumping of wastes SHA	Financial incentives for companies that carry out energy audit ANT	Quality of dock water ANT Oxygen and nutrient concentrations monitoring RTM Sustainability report ANT	- Regulation on marine pollution by dumping of wastes RTM ANT SHA (IMO London Convention Protocol 96) SIN (Regulations of Singapore[2]) - CO2 reduction RTM (Rotterdam Climate Initiative)
Port expansion	Fines on pollution damage to the marine environment by coastal construction projects SHA	-	Ecological port design and construction ANT RTM SHA SIN	- Regulation on pollution damage to marine environment by coastal construction projects ANT (Flemish Port Decree[4]) RTM (Municipality of Rotterdam[3]) SHA (Regulations of China[1]) - Approval from government authorities SIN (Singapore government[5])

Note: ANT= Antwerp, RTM= Rotterdam, SHA= Shanghai, SIN= Singapore
[1] Regulations of the People's Republic of China on the Prevention and Control of Marine Pollutions from Ship
[2] The Environmental Public Health (Toxic Industrial Waste) Regulations 1988
[3] The city of Rotterdam Port Management Bye-Laws (version: September 2011)
[4] Flemish Port Decree, 1999 (Official Gazette No. 99/992)
[5] Committee for Marine Projects consisting of the National Environment Agency, Urban Redevelopment Authority and Maritime & Port Authority of Singapore
Source: see references in section 4

4.1 Pricing policy

Motivating or giving an incentive pricing to the good doers and punishing or giving a penalty pricing to the wrong doers is viewed as an effective tool to promote environmental awareness in transportation sectors (De Borger et al., 2004), including the port. Pricing control is observed in all the four ports. They use penalty pricing as the 'stick' approach or incentive pricing as 'carrot' or both approaches to reduce pollution and improve the environmental performance of port users and developers. In terms of port's functional activities, pricing control is most commonly used in ships traffic, followed by industrial activities at ports. Environmental-based pricing is not found in cargo handling and storage. This is probably due to the fact that cargo operations are controlled by terminal operators and they are service providers who should take the responsibility of protecting the port environment as a pre-requisite. Thus market access control and other regulatory measures to be discussed later are used instead.

In the area of ships traffic, RTM, ANT and SIN are the most active in pricing control as observed. Penalty pricing and incentive pricing are used simultaneously in these ports. Port of RTM imposes a 10% surcharge to docking fees for barge operators using fuel with sulphur levels near the upper limit (Port of Rotterdam, 2011). A rewarding scheme is also in place. Together with the port authorities of Amsterdam, Le Havre, Hamburg and Bremen and in cooperation with International Association of Ports and Harbors (IAPH), the ports of RTM and ANT participate in the Environmental Ship Index. Shipping companies can register their ships for this index on a website. On the basis of the data entered, such as fuel consumption and emissions, each ship is a given a score from 0 to 100 (from highly-polluting to emission-free). The ports themselves decide what advantages to offer participating ships. The Environmental Ship Index is a clear example of incentive pricing at the level of port dues. Since July 1, 2011, seagoing ships with a score of 31 or more will be a granted a discount of 10% on tonnage dues in ANT. The Antwerp Port Authority guarantees this discount for a period of at least three years, so offering continuity for shipping companies that invest in improving the ESI score of their ships (Port of Antwerp, 2012). RTM started to implement the new financial incentive plan in January 2011. Also here, clean seagoing ships which score 31 points or more on the Environmental Ship Index will receive 10% discount on the GT section of their harbour dues in Rotterdam (Port of Rotterdam, 2011).

In a similar manner, burning clean fuels with low sulphur content beyond MARPOL requirements within SIN can enjoy a 15% reduction on port dues payable (MPA, 2011). Maritime and Port Authority of Singapore has earmarked S$100 million to boost clean and green shipping in Singapore and aims to promote green port by financial incentives (MPA, 2011). The common and most established penalty pricing policy is imposing fines on marine oil spills which is implemented by the four ports. This reflects the ports' directive to prevent the potential disastrous damage of oil spills on coastal and marine environment and wildlife as discussed previously. Uniquely in RTM, the port fines for non-compliance with agreements on modal shift (Port of Rotterdam, 2011). The pricing initiatives in SHA are mostly penalty schemes. By fining the wrong doers stated in laws and regulations, SHA adopts the principle of letting the polluters pay for pollution. Marine Environment Protection Law states clearly under what circumstances should polluter pay for what amount covering both port industrial activities and port expansion (PRC, 2000). As for ANT, in addition to fines on marine oil spill, the port also provides financial incentive for companies and concession-holders that carry out energy audit (Port of Antwerp, 2010).

4.2 Monitoring and measuring

Ports are extremely vulnerable to unfounded claims of environmental damage and to deflect such claims, ports need quantifiable and detailed information on the impacts of their operations on the adjacent environment. Ports should communicate how environmental impacts associated with port operations are being effectively managed. If a port starts a dialogue with the local community only in response to a problem, negative perception by the community can be the outcome. Examples of environmental reporting are environmental impact assessment studies associated with port expansion, reports related to dredging impacts and monitoring of natural resources such as wetland conditions and bird population and migration.

By monitoring the air quality, water quality as well as policy development, the port authority could keep track of the port's environmental performance, subsequently formulate or modify its targeted strategies and policies. While such tool is common in all port activities, it is most often adopted in two functional areas, one is in ships traffic to monitor GHG emissions and another is in port expansion to monitor the design and construction process as observed in all the four ports. Apart from these, monitoring could also cover policy development as in ANT for intermodal connection (Port of Antwerp, 2012), or stipulated in law given legal enforcement as in SHA (PRC, 2000), though not commonly observed in all ports.

All four ports monitor their own carbon footprint (greenhouse gas emissions, expressed in CO_2-equivalent) and take it as a starting point where future measures could bring the port closer to the concept of "sustainable port". ANT's monitoring scheme is comprehensive and extensive which covers the port area as a whole and the inward and outward logistics chain as the port authority intends to act as a "responsible householder" to monitor the overall situation and will take corrective actions wherever possible (Port of Antwerp 2010). RTM's monitoring expects an aggressive outcome. The port authority's ambition is for its own activities to be climate neutral by 2012 (Port of Rotterdam, 2008). SIN adopts a systematic footprint-monitoring project including three steps: determining emission baseline year, collecting emission data and tracking emissions over time (Goh, 2010). As for SHA, monitoring the port's carbon footprint is highlighted in the green port guide information, however, we do not see very specific measures implemented yet mainly due to the relatively recent commencement in 2012 (China ACC, 2011). ANT and RTM also take active initiatives in monitoring the water quality. RTM monitors oxygen and nutrient concentrations (Port of Rotterdam, 2011) whereby such measure is not seen in the other three ports.

Under monitoring and measuring policy, the Environmental Management System (EMS) is worth mentioning which serves as a documented system to help organizations comply with environmental laws and prove their commitment to improve environmental performance. It can be regarded as a benchmark of environmental sustainability (Gudmundsson et al., 2005). ANT, RTM and SIN adopt the ISO 14001 as the standard for their EMS. Matters such as air quality, energy consumption, waste and transport have been included in the EMS. Stages include monitor, measure, evaluate and record performance, conduct audits and correct problems. European port authorities are encouraged to develop suitable environmental management programmes by the European Sea Ports Organisation's Environmental Code of Practice, since the port authorities would entail substantial investment in time and money to develop programmes on their own (ESPO, 2010). Such system is not observed in SHA.

In early 2012, ANT for its first time published a sustainability report for communicating the progress and results of its environmental monitoring and performance to stakeholders. Antwerp Port Authority and the Left Bank Development Corporation (for the public sector) and Alfaport Antwerp (representing the private sector) are the main driving forces behind the report. The report forms the basis for developing a sustainable port of and for people and identifies new joint projects and areas for further study and research. Using a range of interviews, photographs and moving images, readers obtain an in-depth view of the actions taken and the investments made by stakeholders within ANT in order to ensure sustainability as part of a future-oriented policy for the port. Such sustainability report, or such comprehensive form of reporting, is not found in the other three ports.

4.3 Market access control and environmental standard regulation

Regulatory control is a mandatory tool used to restrict market access control and stipulate environmental standards, which works together with the previous tools and set a baseline for port activities. For international conventions, like the International Convention for the Prevention of Pollution from Ships (MARPOL) adopted at the International Maritime Organisation (IMO), each signatory nation has the accountability to enact domestic laws to implement the convention and effectively pledges to comply with it. The status of accession to the conventions by the four ports' countries varies. According to IMO, ANT, RTM and SHA conform to the three IMO conventions related to green ports, while SIN has ratified one of the three IMO conventions which is MARPOL Annex VI on air pollution (IMO, 2012). SIN uses national laws as regulatory control on the other two areas, namely oil pollution casualties and dumping of wastes.

Other than international regulatory control, legislation is at various levels depending on the country/port which could be a stated law by the national government (as is the case in SHA and SIN), a law stipulated by the municipality (like in ANT and RTM), certain rules set by the port authority (e.g. in ANT and RTM), or a mutually binding agreement between the port authority and market players such as the agreement on modal shift in RTM (De Langen et al., 2012). It is observed that in ANT and RTM the port authority has a higher level of influence on devising green port policy in comparison to the two Asian ports (it is noted that SIN is a small city state so it is impractical to separate port's rules from the national level). ANT and RTM have more freedom to set rules and develop incentives which would be helpful to tackle local ecological issues. The credit of this approach is that the localised policies tend to be more flexible and specific. This would be attributed to a relatively open geopolitical culture in Western Europe, a not-so-systematic policy process for environmental legislation in the EU and a decentralized legal system in each European country as compared to many Asian countries (Hovden, 2002; Stevens, 2004).

The content of the control could cover a prohibition as is the case in SHA where certain activities causing damage to the marine environment are prohibited by the Regulations of the People's Republic of China on the Prevention and Control of Marine Pollutions from Ships (PRC, 2000), an upper limit of certain pollutants such as GHG emission from sulphur fuel, or licenses issued only to 'clean' trucks which means cargo handling vehicles meeting sulphur fuel limits (Port of Rotterdam, 2011). Winebrake et al. (2009) showed that low sulphur fuel mandates can effectively reduce human premature deaths which provide support for the associated port policy. From 2010, the fuel of ships at the quays of European ports may not contain more than 0.1 per cent sulphur (Port of Rotterdam, 2011; Notteboom, 2011). In Singapore, the reduction of sulphur fuel is on a voluntary basis. In China, the relevant implementation legislation is by national law. Although the regulations are strict, the enforcement is relatively slow and weak due to a lack of local legitimacy caused by conflicting interests of stakeholders (Van Rooij, 2006; Wang, 2007). As a whole, market access control and environmental standard regulation is very common across the range of port functional activities, except for intermodal connections where only RTM adopts this approach.

RTM is a clear example of a port authority involved in the objective to improve and develop sustainable transport. The port of Rotterdam is at the forefront of the fight against climate change, it designs and implements a set of policies organized in cooperation with local authorities. The city of Rotterdam has established a program called the Rotterdam Climate Initiative, whose aim is to "create a movement in which governments, organizations, companies, knowledge institutes, and citizens collaborate to achieve a 50% reduction of CO_2 emissions, adapt to climate change, and promote the economy in the Rotterdam region" (see site Rotterdam Climate Initiative). This program is developed as part of the global cooperation group C40 Climate Leadership Group, which is an international body aggregating several large cities wishing to fight against climate change. The objective of the Rotterdam Climate Initiative is to halve the CO_2 emissions of the Rotterdam agglomeration in 2025 compared to 1990. In order to achieve that objective, the program involves in an integrated way the different important local actors: the municipality of Rotterdam, the local association Deltalinqs, the environmental protection agency DCMR Milieudienst Rijnmond and the Rotterdam Port Authority. The port of Rotterdam adheres to this general policy and acts on two of these five axes: sustainable transport and sustainable energy port. Its main actions are aimed at the emissions of vehicles and ships used by the port authority, by implementing a "green fleet"-program. In 2008, the port has signed a convention to limit the sulphur emissions of its ships. Land-based vehicles will in the future use engines that are less polluting. Moreover, the port of Rotterdam supports the program to develop service stations in the city that provide bio-fuels (biodiesel, bio-ethanol, bio-gas). RTM has an ambitious program for capturing and storage of CO_2 under the North Sea. Critics say that the whole future CO_2 footprint of the port and thus its expansion possibilities are very much tied to the success of the CO_2 storage scheme. Any failure in this area could jeopardize future development potential of the port.

ANT and RTM both make agreements with shippers and terminal operators. For instance, both port authorities use (RTM) or consider using (ANT) environmental criteria in the granting of land to private terminal operators. For example, the land lease agreements between the port authority and terminal operators APM Terminals and the Rotterdam World Gateway Consortium contain specifications on the modal split of hinterland transport of containers from Maasvlakte 2 in favour of barge transport and rail transport (De Langen et al., 2012). ANT is adopting a similar policy for future concession agreements in the port. In this aspect, the two ports get ahead of the two Asian ports (SHA and SIN) as their regulatory control is more comprehensive which might be attributed to the background that Europe started green port initiatives earlier.

Environmental targets can also be enforced through licensing. For instance, environmental licenses in RTM are awarded to industrial companies by the regional DCMR Environmental Protection Agency. Environmental criteria are also used in private law contracts between the port authority and industrial partners, in order to go beyond environmental laws in the Netherlands and the EU (OECD, 2010). However, the discretionary powers of port authorities in environmental matters have their limits. It is generally not the port authorities of

RTM and ANT that impose environmental regulations on the companies (concessions being an exception to this rule), but the municipal and regional authorities.

In 1995 the National Ports Council (Nationale Havenraad) in the Netherlands and the Flemish Ports Commission (Vlaamse Havencommissie) in Flanders-Belgium initiated a comparative study between the strictness of environmental law in Belgium and the Netherlands. The results showed that environment was not a competitive issue in the ANT-RTM rivalry (NHR/SERV, 1998).

While the environmental level playing field continues to be considered, attention has concomitantly shifted to the need to cooperate, both nationally and internationally. For example, all Dutch seaports, so including RTM, have agreed to adopt a uniform policy for maritime shipping and barging, with a particular focus on, among others, cleaner maritime shipping and barging. The ports will thus not compete on environmental policy, but share knowledge. Also, RTM and ANT have been instrumental in enhancing cooperation among European ports. The Eco-Information project (1997–1999) and its follow-up Eco-Ports (2001–2004) were the first steps towards a port-specific environmental management system or standard for European ports. It was also the start of the Ecoports foundation which is now under the umbrella of the ESPO. RTM and ANT played a key role in the establishment of the Ecoports foundation.

The idea of cooperation on environmental performance is also found back in policy documents of the ports. In its port vision 2030, the Rotterdam Port Authority in essence advocates a further intensification of so-called ‘ecologies of scale’ in the (petro-)chemical industry on a regional cross-border scale (i.e. in relation to ANT). RTM focuses a lot on becoming a sustainable energy port, which is translated into three different objectives: development of energy efficiency, renewable energies and the capture and storage of CO_2. For example, between 2009 and 2020 the energy produced by windmill parks will be doubled from 151 MW to 300MW. Off shore windmills further away from the coastline are in particular being considered. Also ANT has developed a similar interest in supporting the establishment of additional windmill parks in the port area and in stimulating logistics companies in the port to use the flat roofs of the many port warehouses as platforms for solar panel parks.

4.4 Overall Comparison and Recommendation

In the case studies, we analyzed the various green tools used by the port authorities and public regulators of the selected leading ports in Asia and Europe according to the port functional activities and find that the more integrated the tools are used, the more effective the green port will be. Among the four ports, the most focused activity is ships traffic, followed by cargo handling and storage, port expansion and port industrial activities. This reflects that ports are driven by the advisory from IMO as the international conventions put higher weight on pollution from ships. We do not see many initiatives in intermodal connection. The most active port authority in this area is RTM, closely followed by ANT. While intermodal connection is not really applicable to SIN due to its small size and focus on transhipment, other countries can spend more effort in promoting modal shift through regulatory tools. Specifying ecologically favourable modal split as a requirement in terminal concession as in RTM would be a good reference for other ports when they direct towards greener port hinterland. The overall recommendation is that it is indispensible for ports to combine various tools together. Regulations and penalty may be too harsh and financial incentives alone may be too “sweet”.

Only by using technology innovation and making the necessary green infrastructures and facilities available, then adopting pricing and regulatory control to alter the operators' and market players' behaviour, meanwhile monitoring the environmental performance in the whole port area and taking timely corrective actions, can the port has a better chance of achieving the goal of sustainability. It should also be noticed that port/public authority could improve port's environmental performance by covering a wider range of functional activities, like intermodal transport and port industrial activities, which guarantees sustainability along the entire logistics chain.

5. CONCLUSIONS

The study is an original attempt to analyse green ports from the policy and management perspective. The analytical framework to structure green port management tools into three categories on one axis with regards to the policy nature (i.e. pricing, monitoring and measuring, as well as market access control and environmental standard regulation) and on the other axis according to the functional activities in ports (i.e. ships traffic, cargo handling and storage operations, intermodal connection, industrial activities and port expansion) represents a systematic approach. The case studies compared the situations in the leading ports in Asia and Europe, namely Singapore, Shanghai, Antwerp and Rotterdam. Our research has revealed the similarities and differences among the four ports' status and approaches with regards to green port development. In general, the port authorities and public regulators of the four ports are active in using the three categories of port management tools to enhance the environmental performance of the respective port. We observe that the ports are particularly mature in exercising environmental standard regulations which reveals that the enforcement approach is more prevalent. It is understandable as policy makers wish to achieve a greener status in a controllable time frame, especially in view of closer scrutiny in environmental regulatory compliance and public criticism from the international community. However, encouragement to go beyond the minimum environmental standard requires incentives and support from the government. The incentive pricing schemes as discussed in the analysis can provide financial benefits to the market players, thus adeptly combine ecological objective with economic returns in achieving sustainability. In terms of port functional activities, the most focused area is ship traffic which reflects that the ports are driven by the advisory from IMO as the international conventions put higher weight on pollution from ships.

The paper also serves as an exploratory study to compare the Asian and European perspective and has accomplished to link the use of specific environmental tools to local governance and regulatory settings. In sum, the respective port authorities in Antwerp and Rotterdam have a higher level of influence on formulating green port policy in comparison to the two Asian ports due to a relatively open geopolitical culture in Western Europe. Antwerp and Rotterdam have higher flexibility to set rules and develop incentives which would be instrumental in tackling local ecological issues. While there is merit in this localized approach, ports are recommended to be mindful of the possible complication and conflicts among the guidelines and rules at the local, state, national, regional and international levels. In particular, port stakeholders have diverse interests and needs, but they must collaborate as a whole for the port's sustainable development. Such collaboration could be formed through joint projects and technological innovation which are preferably coordinated and supported by public policy makers who play a central role in strategic planning and development.

As a whole, the paper generates useful insights and policy implications for port/public authorities and the stakeholders concerned, not only for the four ports in this study but also for other ports as they formulate and review green port policies. The policies that we analysed would be a useful port toolbox for green port development. The research therefore contributes to both research and practice in an increasingly important topic. Going forward, although the four port cases are regarded as leading examples, more ports from other countries can be studied in the future. Also, other methods can be employed for empirical investigation in future studies. For instance, empirical tests can be done in a larger scale facilitated by surveys. Theorisation of the findings would be a future research direction worth pursuing. For example, institutional theory may be explored to examine the behaviour of the port/public authorities in devising green port policy. Furthermore, since green port policy on intermodal connection is relatively less developed, more research can be performed to contribute to green port hinterland development. It would be interesting to combine this research topic with dry/inland port study.

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