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ARTICLE

Sustainable development in seaports: a multi-case study

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Abstract Seaports are a vital part of the maritime transport industry and have a key role in integrated transport chains and regional economies. However, ports are also sites of environmental pollution originating from land-based activities, ship movements and ports' own activities. It is, therefore, increasingly recognised that economic growth in ports must be balanced with environmental protection and social progress. This has led to enhanced appreciation of the need for sustainable development (SD) in ports. Whilst much has been written about port environmental practices in European and American ports, there is limited synthesis and comparison of sustainable port practices from different parts of the world. Furthermore, in-depth case analysis and critical examination of the practices and challenges of sustainable port development in a globalised era is limited. This paper presents findings from a qualitative multi-case study that aimed to compare sustainable policies and practices of ports in four different continents and to understand the dilemmas, challenges and opportunities they face in attaining SD. This paper reports findings pertaining to the following research questions: (1) What policy frameworks do ports adopt to attain sustainable development? (2) What specific sustainable practices do ports utilise to manage environmental aspects such as air pollution, water quality, ballast water, dredging and disposal of dredged materials, waste disposal, hazardous substances and land/resource use? (3) What are the driving and constraining forces in achieving sustainable development in ports? Port authorities were studied by reviewing documents and secondary data. The following ports were studied: Port of Long Beach (USA), Port of Rotterdam Authority (The Netherlands), Sydney Ports Corporation (Australia) and Transnet Limited that owns and manages South African ports. Findings of the study demonstrate that the SD paradigm has gained momentum, albeit to differing degrees, in the functioning, organisation and the very ethos of case study ports. An important theme from all case studies is that, whilst there is definite progress towards SD, several practices deemed to be sustainable can be controversial

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and must be critically examined from the perspectives of different stakeholders including shippers, port-related businesses and the local and global community. Lack of data to monitor environmental impacts, economic costs of implementing sustainable practices and complexities of international, regional and national regulations were other constraining factors. On the other hand, reconciling differences between stakeholders and capitalising on economic opportunities, operational efficiencies and cost savings offered by environmental friendliness can advance port SD. Public–private partnerships and policies negotiated by involving all stakeholders were found to foster port sustainability. Most importantly, this study found that, with globalisation, environmental impacts of ports are not always localised. 'Sustainable' practices can have unintended consequences in other parts of the world. Therefore, globalisation necessitates a more critical and global analysis of port operations and environment practices in order to be truly sustainable. Although the scope of the research findings is limited to case study ports, the lessons drawn can be constructively applied to any port operating within an institutional system of structured SD.

Keywords Sustainable development · Seaports · Port environmental management · Port environmental practices · Globalisation

1 Introduction

With the acceleration of global integration, many countries have a growing dependence on water transportation. Seaports are an essential part of the maritime transport industry and have a key role within integrated transport chains (Cullinane 2002). Seaports have served as international trade gateways and crucial economic lifeline of nations by bringing goods and services to people around the world for hundreds of years. In the era of globalisation and the rapid expansion of world trade, ports are crucial links in contemporary supply chains and logistics processes, serving as transport hubs with their intermodal transport networks (sea, road, rail and inland shipping) (Pettit and Beresford 2009; World Bank 2001). Given their ability to handle and store bulky industrial raw materials such as oil, coal and iron ore, seaports are industrial zones with several industries, such as chemicals and steel (ESPO 2009a; de Langen 2004). Thus, the ports industry constitutes the greatest single business complex leading to corresponding impacts on coastal, marine and atmospheric environments (Hinds 2007; Juhel 2001; Project GRACE 2007).

With increasing international and regional regulations to control port pollution and intensified public debates, port communities can no longer avoid environment concerns (AIVP 2008; Oliver 2007). Concurrently, ports are also confronted with enhanced competition and pressure to increase services, modernise development and enhance economic efficiency (AAPA 1998; GreenPort 2009a). In order to balance these competing needs, it has become imperative for port authorities to manage port operations in a sustainable manner. The concept of 'sustainable development' (SD), therefore, has been gaining ground in the maritime transport sector in recent years.

Whilst literature on sustainable port development practices in American and European ports has grown (e.g. Gilman 2003; Houston 2007; MWGI 2006; Peris-Mora et al. 2005), there is limited synthesis and comparison of sustainable port

environmental practices from different parts of the world available in the English language. Port efforts towards SD require the institutionalisation of structured policy frameworks that can be deployed to assess, implement and monitor sustainability concerns. Notably, Comtois and Slack's (2007) study of 800 port authorities and 120 shipping lines provides a global overview of SD practices and environmental management systems in maritime transport; however, in-depth case analysis and critical examination of the challenges of sustainable port development are lacking. Given this gap, the present paper presents findings from a qualitative research that undertook case studies of ports in four continents to analyse and compare their sustainability policy frameworks and practices and investigate factors that promote or constrain successful implementation. The following research questions were addressed in the study:

1. What policy frameworks do ports adopt to attain sustainable development?
2. What specific sustainable practices do ports utilise to manage environmental aspects such as air pollution, water quality, ballast water, dredging and disposal of dredged materials, waste disposal, hazardous substances and land/resource use?
3. What are the driving and constraining forces in achieving sustainable development in ports?

The next section summarises existing literature pertaining to SD in seaports. The subsequent section elaborates the multi-case study research design, qualitative research methodology of document review and qualitative content analysis that was employed in this study. Research findings for each of the four selected port authorities—Long Beach, Rotterdam, Sydney and Transnet Limited that manages South African ports are presented and discussed next. The paper concludes with identifying future research directions.

2 Literature review

2.1 The conceptual framework of sustainable development

As early as the 1970s, the term 'sustainability' was employed to describe an economy in equilibrium with basic ecosystems (Stivers 1976). In the 1980s, the term 'sustainable development' was widely publicised by the World Commission on the Environment and Development (known as the Brundtland Commission), convened by the United Nations and led by Norway's former Prime Minister Gro Harlem Brundtland. The Commission adopted the following definition: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN 1987, p. 43). SD has since become central to the thinking on environment and development due to its holistic nature that embraces economic, environmental and social dimensions (Koppenjan and Enserink 2009; Strong 2009). Sustainability is also increasingly recognised as an essential part of long-term business strategies and corporate social responsibility (CSR) (Baker 2009).

2.2 Applying the sustainable development framework to seaports

The pressures to integrate with the global supply chain, the demand for greater port expansion, the urgent requirement to conserve natural resources and the increasingly

stringent international regulations necessitate that ports not just declare their intentions for environmental sustainability but also concretise and demonstrate innovative and sustainable practices (AIVP 2008; MISL 2009a; Tillman 2008).

The literature review demonstrates that the concept of sustainability is gaining awareness in the port industry, requiring them to attain new expertise and apply new practices (e.g. Balbaa et al. 2009; Comtois and Slack 2007; Darbra et al. 2009; Oliver 2007; Port Strategy 2008; Sletmo 2002). 'Port sustainable development' is defined as the situation in which the port is able to meet its needs without endangering its own future (Abbott 2008). Thus, for ports, sustainability implies business strategies and activities that meet the current and future needs of the enterprise and its stakeholders, whilst protecting human and natural resources. This means ports must balance their roles as coastal stewards, facilitators of commerce and transportation and members of their respective communities (Goulielmos 2000).

Addressing environmental implications of port activity and integrating actions into organisational decision-making processes and operations require structured processes and frameworks which outline the overall intentions and principles of the organisation's environmental commitment and performance (Paipai 1999; UKDfT 2009). Several ports have established policy frameworks that mandate port activities to be in tune with SD principles. Whilst the importance of different environmental aspects clearly depends on the characteristics of each port, ports face several common environmental issues such as air pollution,[1] water quality,[2] ballast water,[3] dredging and disposal of dredge materials[4] and storage, transport and management of hazardous substances.[5] In order to systematically analyse the SD paradigm employed by ports, it is essential to (1) identify policy frameworks launched by ports to attain

[1] Vessels berthed at ports use their auxiliary engines and sometimes their main engines to provide heating, cooling and electricity and for loading and unloading cargo, thereby generating significant emissions (Friedrich et al. 2007). Similarly, road and rail transport and industrial activities in port areas generate emissions of carbon dioxide (CO_2), nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter (PM) (Bailey 2004; ESPO 2009a).

[2] Sources of water pollution in ports include wash water of oil tankers, cabin water, gas stations on shore, repair and moving machinery; runoff water from storm drains and coal storage, wash water from terminal surfaces; port region and ship sewage and industrial wastewater; ship discharge (bilge water) which can contain water, oil, dispersants, detergents, solvents, chemicals, particles and more (EcoPorts Foundation 2006a; IAPH 1999).

[3] Ballast water is used by ships for maintaining stability when navigating with little or no cargo. Seawater is widely used as ballast material, and it is usual practice to get seawater from near the ship or the port of discharge. Local water, however, contains aquatic organisms and bacteria, which get transported with ballast water. When the ship reaches the next port for loading or discharging cargo, it ejects this ballast water into the local harbour, thereby introducing foreign organisms. The alien species released can survive and reproduce, often preying on native species or competing with them for food and/or space, and threatening local ecosystems (Reynolds 2004).

[4] Dredging consists of periodic removal of sediments from seabeds in port approach channels to maintain water widths and depths to ensure safe access for ships. The disposal of dredge materials can have adverse effects on biophysical health of lagoons and water quality due to acute chemical toxicity, increased suspended sediments and release of contaminants (Bolam et al. 2006; EcoPorts Foundation 2006b).

[5] In an increasingly globalised world, where goods are transported by sea in ever-increasing quantities, dangers of permitting hazardous substances to cross borders is escalating. Hazardous wastes (hazardous waste) constitute the biggest component: yearly trade in hazardous waste is estimated at $10–12 billion (D'Monte 2009). While hazardous waste and handling of hazardous goods are of concern, there is increasing trepidation about marine oil pollution and oil spills particularly after the grounding of *Exxon Valdez* that spilled 30,000 tons of oil in Alaska in March 1989 (queryFarthing and Brownrigg 1997).

sustainability, (2) understand their specific environmental concerns within the context of which SD practices are applied and (3) appreciate the challenges and opportunities faced in sustainable port development.

Most existing literature, however, has focussed on the impacts of port and shipping operations on the environment (e.g. Paipai et al. 2000; Carballo and Naranjo 2002; Pieters et al. 2002), whilst some articles evaluate and emphasise the need for SD in maritime transport (e.g. Callaghan 1998; Giaoutzi and Nijkamp 1993; Hilling 2001; IMO 2001; Saldanha and Gray 2002). Although these studies have enabled better appreciation of implementing appropriate legislation, they do not elaborate on the implementation and critical evaluation of sustainable practices and associated challenges and opportunities. Thus, there is a significant gap in terms of systematic studies that critically scrutinise the processes and practices of SD (Comtois and Slack 2007)—a gap that this study seeks to narrow.

3 Methodology

3.1 Research framework and design

Since business problems are complex and 'messy' because they relate to relationships between people, communities and organizations, this study employs interpretivist and phenomenological approaches that allow the search for details of the situation to understand complex reality. Interpretivism and phenomenological frameworks believe that reality cannot always be understood in terms of observable measurable criteria. These frameworks focus on meaning rather than the measurement of social phenomenon (Patton 2002). Instead of objectively measuring phenomenon or providing causal explanations as in the positivist approach, interpretivist researchers are more interested in exploring and understanding situations and giving plausible and acceptable accounts of them. Qualitative methods that draw upon interpretivism and phenomenological inquiry is particularly suited to this research that attempts to explore and make sense of certain phenomena (ports' approaches and actions towards SD) in context-specific settings.

Whilst quantitative researchers seek causal determination, prediction and generalization of findings, qualitative researchers seek illumination, understanding and extrapolation to similar situations. As the purpose of this study was not to achieve causal explanations or predictions, but rather to explore, identify, compare and critically analyse SD frameworks and practices, the qualitative approach was deemed to be most appropriate.

A multiple-case study design was employed in this study. Case studies are distinguished by their exclusive focus on a particular case (or several cases in a multiple-case study) (Creswell 2003; Holliday 2002). A case study can be described as 'the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances' (Stake 1995, p. xi). The 'case' can refer to an organization, program, activity, process or an individual that is bounded by time and activity (Neuman 2002). Case studies offer the researcher the ability to obtain rich data with high validity whilst situating and interpreting data within their wider context (Mitchell 1983). Case study designs do not claim generalisability;

rather, case studies allow researchers to compare and contrast research findings from each of the cases, thereby promoting theoretical reflections on the findings (Bryman and Bell 2007; Yin 2003).

3.2 Selecting case study ports

Keeping in view time and resource constraints, four cases were selected to enable a broad overview of the issues, yet allow their in-depth examination. To identify cases, academic literature, press reports and leading shipping journals were consulted. However, because most articles pertain to European or American ports, the selection of cases presented considerable challenge since the study was conceptualised as having a global character. Following Bryman and Bell's (2007, p. 68) suggestion, this research is not restricted to high-profile 'success stories' alone. For instance, although the award-winning Port of Long Beach (USA) (POLB) was studied, this research also involved ports that 'have made significant moves' (e.g. South Africa [SA]) towards SD. Thus, the following ports were selected:

1. Port Authority of Long Beach, USA;
2. Port Authority of Rotterdam, The Netherlands;
3. Sydney Ports Corporation (SPC), Australia; and
4. Transnet National Port Authority that manages South African ports.

3.3 Data collection

Since the purpose of this research was to critically analyse SD practices undertaken by ports, secondary data from a wide range of documents were deemed to be most appropriate to give a balanced view of port sustainable practices. Document reviews reveal what people/organisations do or did and what they value. This behaviour occurs in a natural setting, so the data have strong validity (Scott 1990). Documents were retrieved from various print and Internet sources, such as port websites, printed and online reports, manuals and handbooks, scientific literature including books and peer-reviewed journal articles, maritime magazines and journals and news reports. For each of the case study ports, a range of keywords was used to search for documents.[6]

3.4 Validity of data

To ensure validity, data obtained in this research were selected carefully. Articles or reports that were outdated were discarded, except when used to indicate an idea that was relatively constant. For Internet sources, editable sites (for example, Wikipedia), blogs and forums and non-copyrighted content and sites that accept open contributions were disregarded to ensure that data were factual. Data analysis incorporated all relevant evidence and included rival interpretations. Port documents (e.g. annual

[6] Keywords included port name and the following terms: sustainable development, environment management, air pollution, air quality, water quality, ballast water, dredging, dredged material disposal, hazardous materials management, hazardous waste, port expansion and port development.

reports) were not solely relied upon: both corroborating and contesting information from various sources were included.

3.5 Data analysis

Data were analysed thematically (van Manen 1998), where categories and patterns that contributed to the core theme of SD were identified. Following Strauss and Corbin (1990), each document was read repeatedly and significant statements relating to various aspects of SD in ports were identified and demarcated. Labels (codes) were assigned to these categories and later standardised across documents pertaining to each case study port. The goal was to create descriptive, multi-dimensional categories which formed a preliminary framework for analysis. The next stage of analysis involved re-examination of the categories to determine their interrelationships, a process called axial coding (Strauss and Corbin 1990). Axial coding puts data back together in new ways by making connections between categories. Categories that dovetailed together in meaningful yet distinct ways were then developed into core analytical themes.

4 Results and analysis

4.1 Case study 1: Port of Long Beach

4.1.1 Background

The POLB is a public agency managed and operated by the City of Long Beach Harbour Department. The port lands are owned by the City of Long Beach. POLB is a landlord port: it leases terminals to private shipping and stevedoring companies. POLB is the second busiest seaport in the USA (POLB 2011a). Over the past decade, POLB container traffic has risen to 108 % (Cannon 2008). Although POLB has been a trailblazer in environmental stewardship, winning several international awards (POLB 2011b; c), its rapid expansion has significantly impacted the environment and human health (Bailey et al. 2004).

4.1.2 Policy framework for sustainable development

POLB operationalises SD mainly through its Green Port Policy adopted in 2005, which mandates the port to drastically reduce negative port-related environmental impacts whilst maintaining the economic benefits of international trade (Musser 2008). The Green Port Policy directs the port to proactively foster an organizational culture of environmental enhancement, fiscal responsibility and community integrity. This culture extends beyond port staff to the port's customers and other stakeholders. The policy's five guiding principles are:

- protecting the community from harmful environmental impacts of port operations;
- establishing the port as a leader in environmental stewardship and compliance;

- promoting sustainability;
- employing best available technology to avoid or reduce environmental impacts; and
- engaging and educating the community (POLB 2011d).

The SD practices of all ports are summarised in Table 1.

4.1.3 Driving and constraining forces

Stakeholders Southern California has the dubious distinction of having the poorest air quality in the USA (Avol 2007; Joshi 2008; Sharma 2006). Hence, pressures from community and environmental groups have been a driving factor in POLB's environmental efforts. POLB has involved local communities, tenants and other stakeholders, including operators, port workers and regulatory agencies in its sustainable achievements (Houston 2007; POLB 2007; 2011k, l).

However, in an effort to publicise goals and announce deadlines, POLB has heightened expectations with the local community and environmental groups, resulting in failure and criticism (Bailey et al. 2004). For example, implementation of the Clean Trucks Program (CTP) was originally scheduled for July 2007, but has been rescheduled multiple times. POLB's failure to meet these deadlines also resulted in threats of litigation (McLaurin 2008; LB Report 2008).

Moreover, the CTP faces several controversies. Trucking companies are recouping their investment by charging higher drayage rates; consequently, retailers and other shippers are diverting shipments to other ports to avoid the fee (Mongelluzzo 2009a). Whilst environmental groups support CTP, in July 2008, the American Trucking Association (ATA) filed a lawsuit challenging CTP's plan to require truckers to obtain concessions and licenses to enter port facilities, giving the port authority to regulate truckers' business intricacies including hiring, truck safety, driver credentials, security measures and financial disclosures (Mongelluzzo and Nall 2008). These regulations have no connection to the environment (Page 2009). ATA claims that the port's plan, which could add more than a $1 billion per year to drayage costs, violates the US Constitution by hindering interstate commerce (Gallagher 2008). In 2009, the US Court of Appeals for the Ninth Circuit ruled in favour of ATA (CCJ 2009b).

Economic factors The costs of implementing the Clean Air Action Plan alone are huge (Cannon 2008). Shippers are diverting cargo to other ports because of the plethora of fees POLB charges to fund infrastructure and environmental programs (Mongelluzzo 2009c). Besides, with California facing a $29 billion budget deficit in 2009, there is little money for infrastructure projects to sustain POLB's economic viability (McLaurin 2008). Projects with huge investments have not kept up their promises. In 2001, the Alameda Rail Corridor, designed with $2.5 billion investment to move freight to a satellite terminal about 30 km away to reduce traffic congestion and air pollution, continues to operate under-capacity, without alleviating congestion (Bailey et al. 2004; GAO 2005a; Steinberg and Watson 2001).

Further, whilst liquefied natural gas (LNG) trucks cost almost twice as clean diesel trucks (Mongelluzzo 2009b), an LNG truck can save between $0.35 and 1.73 per gallon (Cox 2008). However, because 2010 model diesel trucks will be 98 % cleaner

Table 1 Summary of sustainable practices in case study ports and recommendations for investigating other port practices

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
1. Air pollution	San Pedro Bay Ports Clean Air Action Plan (CAAP) initiated in 2006 to reduce air pollution from port operations by 45 % by 2012. CAAP includes	Using natural gas for barges between port and inland destinations	Uses low-sulphur fuel that contains 10 % of the amount of sulphur in ordinary fuel	Prohibits ships from producing smoke within port confines, although reasonable amounts (not specified) are tolerated during engine start-up	Using alternative fuels
	Clean Trucks Program (CTP): Bans diesel trucks built 1998 or earlier. Truckers can apply for subsidies to finance truck replacement for a fee	Developing a sustainability shipping index to create financial incentives for clean ships that comply with the index	Dust monitoring and air sampling conducted prior to and during construction	Dust mitigation measures include conveyor covers, a sprayer system on stockpiles, online moisture analysers, surfactant sprays, paving of loading areas and using dust monitors	LNG
	Subsidised the purchase of trucks with liquefied natural gas (LNG) engines	Shore-based electricity facilities for inland shipping	Control measures, such as using water sprays, re-vegetating exposed areas and constructing wind breaks to prevent excessive dust during construction	Intermodal facilities are generally inadequate	Advantages: less NOx and SOx emissions
	Green Flag program: approximately $2 million a year in discounts and environmental recognition for vessel operators who slow their ships to 12 knots (22 km/h) or less within 32 km of the harbour, thus reducing emissions	Green Awards program rewards ship owners and managers who demonstrate environmental stewardship	Supports maximising the use of rail to transport cargo between ports to reduce air pollution from trucks	Recently, the government and Transnet promised greater use of SA's railways in transporting containers	Disadvantages: Needs R&D to curb GHG emissions of LNG trucks/locomotives
	Built new infrastructure to provide shore-side electricity[a] to container ships	PoR's own vessels have switched to low-sulphur fuels		Transnet has embarked on internal restructuring programmes, particularly in managing supply chains and	Low-sulphur fuel

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
				procurement processes whereby bookings can be captured and containers released from customers' own desks without their truck drivers waiting in queues in ports to collect containers, thereby reducing traffic congestion and air pollution	
	Green leases signed with terminal operators, which require cold-ironing, the use of clean fuels at berth and replacement of cargo-handling equipment to meet tougher standards of the Environment Protection Agency	Replaced hydraulic and truck diesel engines in AGVs (unmanned vehicles for transporting containers) with electric motors and small diesel engines, respectively			Advantages: SOx and PM reductions
	Cleaner vehicles	Feasibility study undertaken to use fuel cells in inland vessels			Disadvantages: unavailability, high cost, separate storage facilities
	$5 million investment to replace locomotives with cleaner units	Investing substantially in intermodal approach including transport by road, rail and inland waters and pipelines to reduce pollution			Biofuels
	Retrofitting diesel-powered maintenance equipment with diesel oxidation catalysts and clean diesel fuel mixed with biofuel/ethanol	Developing a Container Transferium, where container flows are combined and transported by barge between sea terminals and Rotterdam's immediate hinterland, to reduce			Advantages: uses renewable energy sources; biodegradable

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
		congestion and improve air quality			
	Replacing gasoline-powered fleet with CNG-powered vehicles	Encouraging the use of biomass in coal-fired power stations			Disadvantages: increases GHG emissions—further R&D required for GHG reduction technology; human rights issues due to diversion of arable land in food-insecure countries to biofuel feedstock production
	Developing a hybrid tugboat to reduce air pollution by 44 % and consume 30 % less fuel	Use of biofuels and innovation with regard to the next generations of biofuels			Shore-side electricity
	Requiring contractors to use ultra-low-sulphur diesel in construction equipment	Aims to capture, compress and transport CO_2 generated in biofuel production process via pipelines to greenhouses for growing plants and vegetables			Advantage: reduces non-renewable fuel consumption
	Promoting intermodal transport[b] to take trucks off road and reduce traffic congestion (e.g. Middle Harbour Redevelopment Project, Alameda Rail Corridor)				Disadvantages
					Costly
					Substantial CO_2 emissions from land-power grids
					Technical changes to vessels could be far more effective

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
2. Water quality	POLB's Storm Water Pollution Prevention Program goes beyond requirements of federal and state law	Measures dealing with water quality in the Rhine River are among the most rigorous in the world	As part of its Storm Water Management Plan, SPC has installed three storm water treatment devices to capture sediments, oil, grease and litter	Recent studies in South Africa have shown anthropogenic activities lead to heavy metal contamination of sediments within ports	Water management strategies in ports require more research to provide reliable and regionally comparable data on various aspects of water quality
	Requires contractors and tenants to follow best management practices to prevent soil erosion and pollutants from entering storm drains	Under the European Water Framework Directive, the Netherlands is required to set new standards for water quality by assessing ecological risks and developing remediation measures	All operators are required to treat storm water prior to discharge	An integrated harbour water quality management plan proposed to manage the sensitive marine ecosystem, particularly in Durban	
	Ensures tenants' compliance through inspections and training	Licenses for industry are being modified according to the new requirements of the Water Framework Directive, in which PoR is also involved	For Botany Bay expansion, SPC has implemented a Soil and Water Management Plan to control erosion of soil and sedimentation, besides ongoing water quality monitoring		
	Gathers information on potential pollutants, spills and control measures from each of the facilities to identify areas for improvement				
	But does not treat storm water				
	Link between toxic pollutants in storm water runoff and their impact on sediment and water quality not yet addressed				
	Uses mid-ocean BWE[c]				Mid-ocean BWE

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
3. Ballast water		No specific ballast water discharge regulations exist in the Netherlands although PoR is the largest ballast water exporter in the world at 14 million tonnes discharged in other ports annually	Ballast water discharges in Sydney's ports do not occur frequently	Developed a Ballast Water Management System awaiting approval of its Maritime Safety Authority	
	Given questions about efficacy of BWE, POLB is testing a new shipboard treatment system to remove oxygen levels of ballast water, thus destroying organisms	Most incoming ships exchange ballast water at high sea	Surveys by SPC show that dead toxic dinoflagellate cysts, which can potentially harm marine fauna and flora, are the only target marine pests found in Sydney ports	South Africa participated in IMO's Global Ballast Water Management Program (GloBallast) that is developing best-practice guidelines	Advantages: cost-effective
		Currently no information gathered by the Shipping Inspectorate from visiting ships	Mid-ocean exchange of ballast water is currently the most common way of handling ballast water in SPC	But uptake from and discharge of invasive marine species into the harbours continue to be major problems	Disadvantages
		Participates in ballast water testing programmes			Emptied tanks can contain invasive species (e.g. dinoflagellate cysts) accumulated at the bottom of the tank
					BWE can be hazardous since BWE process can compromise longitudinal strength if the ship is not so designed
					Need for researching 'safe' areas even on high seas
	With draughts ranging from 60 to 80 ft, POLB dredges more	Uses sea disposal as a relatively cheap procedure for less	Before the twentieth century, dredging was regularly	By law, marine disposal of dredged material is subject to	Disposing less contaminated dredge materials at sea

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
4. Dredging and dredge disposal	to create new terminal area than to enable deep-draught ships to enter	contaminated dredged sediments	undertaken and dredged sediment was used to reclaim mudflats or marshes, thereby creating additional useful waterfront land	the approval of the division of Marine and Coastal Management of the Department of Environment Affairs and Tourism	
	Removing, treating or rendering suitable for beneficial reuse contaminated soils and sediments required by POLB's Green Port Policy	More contaminated dredge material is stored at De Slufter, a confined isolated disposal site	Dredging is now intermittent and carried out largely to facilitate navigation for specific projects or minor maintenance to remove sediment from storm water drains	Dredging impact is minimised by ongoing monitoring at critical locations and regulation of the contractor's activities	Advantage: inexpensive
	Dredged sediments reused when channel dredging coincided with landfill construction for direct disposal from one to the other	Aims to ensure that all dredged material is sufficiently clean by 2015, so that it can be relocated at sea or beneficially re-used	Dredging required for Botany Bay expansion has led to several environmental measures, including the use of silt curtains to prevent sediment from flowing into the water	Dredge material is disposed off in designated marine disposal area	Disadvantages
	Over last 10 years, removed nearly 200,000 tons of contaminated soils and sediments from the environment and disposed them in approved landfills and recycling facilities				Ambiguous consequences
	Contaminated areas made productive—a process of beneficial re-use known as 'brownfield redevelopment'				Environmentalists maintain silt curtains as in Botany Bay can cause extensive environmental damage, e.g. tidal changes and disturbance of fish and bird breeding grounds

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
	Contaminated dredged sediment used as construction fill material to reduce the cost of imported fill				Possible toxic ecological effects need further investigation
	Sequesters contaminated sediments in a confined disposal facility capped with clean sediment, thereby preventing contact with the sediment surface and water column				Disposing dredge materials on land in approved landfills and confined disposal sites
					Advantage: inexpensive
					Disadvantages
					Environmental repercussions
					Contamination of groundwater
					Assessing sediment quality requires sufficient information about regulations, analytical methods, risk assessment and management
					Sediment reuse involves several engineering challenges
					Dewatering sediment in a holding pond or facility
					Pond design
					Sediment transport methodology
					Materials separation techniques, which requires expensive R&D.
					Monitoring systems

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
					Need for harmonising data from various testing procedures and systems to measure sand in the sediment
5. Solid waste disposal	Provides waste reception facilities	Worked actively in 2008 on developing the 'Enforcement Strategy for Shipping Waste'	Provides waste reception facilities for vessel waste	For ship waste, reception facilities are provided in each port	Ultimate goal of recycling—zero waste—yet to be attained
	Has state-of-the-art database for identifying potential pollutant sources	Waste reception facilities, financed by ship charges provided for all categories of wastes	Some of the waste is recycled; the remaining is disposed of in accordance with relevant statutory procedures	Implementation of waste minimisation options (e.g. recycling and composting) are infrequently implemented as they are more expensive than landfilling	
	Documenting waste management practices and tracking pollutants	For sludge and bilge water, processing costs are recovered from the fee, but shipowners have to pay for collection and transportation	Recycles and reuses construction waste—for example, sandstone is crushed for re-use in road construction		
	Requires port tenants to implement best management practices at their facilities to control litter		Recycled all waste materials from the demolition of a disused railway embankment for former wheat silos by reusing materials for constructing port expansion projects		
	Conducts routine street sweeping and catch basin clean-outs		Requires construction contractors to minimise waste generation		
	Construction projects are required to manage wastes appropriately		Adopted a Waste Reduction and Purchasing Policy to reduce office waste and give		

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
			priority to purchasing materials with recycled content		
	New facilities designed with storm water treatment devices that prevent litter discharge into the harbour				
	Attempts to reduce waste and throw-away packaging and increasing recycling programs				
6. Hazardous substances	California law prohibits discharge of any petroleum product, refuse liquid or solid and substances deleterious to fish, plant life or bird life	Has reception facilities for oily and chemical waste	Takes a proactive approach to prevent oil pollution incidents during refuelling operations	Transnet mentions care will be taken to identify sources, types and quantities of hazardous waste and to ensure that such waste is disposed off in accordance with policy	Adequate and effective procedures for handling land-based and operational oil dis charge are required
	Hazardous waste rules of EPA require facilities to properly store, label and seal hazardous waste containers	Requires immediate reporting of spills of hazardous materials	Ensures that an international ship-to-shore safety checklist is completed prior to every bulk oil, gas and chemical transfer	However, specific practices are not mentioned	Need to control illegal exports of hazardous waste
	However, US hazardous waste regulations do not cover exports—hazardous waste often illegally exported via POLB	Equipment is available to allow for speedy clean-up, with the 'polluter pays' principle[d]	Provides 24-h immediate emergency response unit, with well-equipped response equipment and staff for emergencies	In the Port of Saldanha, TNPA reached an agreement in 2007 with Oil Pollution Control South Africa to formalise oil spill response procedures, such as upgrading port control vessel tracking equipment and employing trained staff and well-maintained equipment	Develop greater monitoring and coordination between port customs officials and international organizations
		To detect hazardous waste, a powerful scanner was	SPC ensures that dangerous goods are transported in		

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
		introduced to detect the contents of containers travelling through PoR[e]	strict accordance with statutory requirements		Develop comprehensive and accurate database on waste shipments
		Images obtained are compared with the description of the product on the consignment note. If found suspicious, the container is opened for checking	SPC maintains a database of all dangerous goods imported to, exported from or transiting Sydney ports, in an Internet-based system known as ShIPS (Sydney's Integrated Port System)		
7. Land/resource use	Assisted in restoring and improving Southern California's wetlands and native wildlife habitats	PoR aims to achieve sustainable business operations	Targeting resource use and reducing energy consumption by 60 %	Sustainability practices are stated too soon to be adapted to minimise carbon footprint	Redevelopment of existing port land
	To mitigate expansion project effects on harbour marine life, POLB relocated the native habitat of the black-crowned night heron rookery	Aims to increase throughput by filling unused port basins, encouraging dual land use, co-siting[f], increasing terminal productivity and leasing back hidden reserves of companies	Installed solar-powered lighting for port signage and solar-powered navigational aids	Cleaner technologies and renewable energy resources to sustain business in the current environmental context will soon be explored	Advantage: can accommodate economic growth
	Recycling demolition debris create artificial reefs offshore to promote fish habitats	Maasvlakte 2 will promote sustainability by	Plans to purchase 10 % of its total power from renewable resources	Will continue to participate in the government's long-term mitigation planning process	Disadvantage: can increase capacities to limited extent, thereby constraining future growth, besides aggravating congestion around terminals
	Concrete piles from the demolished piers were used to build artificial reefs	Clustering businesses, whereby companies that can benefit from each other's residual products and residual heat are all within easy reach, resulting in energy and raw material savings	Major environmental challenge arises from terminal expansion at Port Botany. Hence developing a 47-ha Intermodal Logistics terminal at Enfield to accommodate 500,000 TEUs/ year, by significantly increasing	Efficiency targets have been set for resource utilization	

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
			cross-metropolitan rail transport of container freight		
	Steel and other metals were sold as used materials or recycled	Installing wind turbines	Also plans to minimise damage and enhance habitats by	Port expansion and construction of additional berths are subject to environmental management plans that include rehabilitation of disturbed areas, measures to control noise, waste avoidance and disposal, appointing environmental control officers to monitor compliance with regulations	
	Sustainable practices applied to all design and construction, operations and administration. Examples include	Intermodal transport: 45 % minimum requirement of waterborne transport to hinterland networks	Creating additional shorebird feeding and roosting habitat		
	Waste paper and container recycling in partnership with an NGO that educates and trains at-risk youth	Sustainability as part of tender procedures	Rock bund wall for the new terminal to provide a hard artificial surface as a valuable habitat for fish and other marine organisms		
	Landscaping projects	PoR has launched two nature compensation projects: establishing a soil protection area and the construction of 35 ha of new dunes (DPC 2000; PoR 2008a; c). PoR has also successfully relocated the endangered natterjack toad. A floating bird island has been created in De Slufter—the dredge spoil depot (PoR 2008c)	Treatment of storm water during operations		

Table 1 (continued)

Environmental issue	Port of Long Beach (POLB)	Port of Rotterdam (PoR)	Sydney Ports Corporation (SPC)	Transnet (South Africa)	Port practices that require further investigation
	Developing a pilot solar car port		Stringent erosion and sediment control measures		
	Sustainable purchasing/ procurement system		Landscaping to restore, enhance and reinstate existing native vegetation		
	Incorporating Green Building principles into new building design and saving utility bills				

Sources for POLB: Bonney (2007), CCC (2003), CCJ (2009a), Cannon (2008, 2009), CSQA (2003), Dibenedetto (2004), EPA (2008), Gibb (1997), GreenPort (2009b, c), Houston and Steinberg (2008), JoC (2009), Kanter, no date; Lukens (2000), Mongelluzzo (2006), POLB (2005, 2007, 2011e, f, g, h, i, j, k, l, m), Quinn (2007), Smith (2006), Steinberg and Watson (2001) and SWRCB and CEPA (2003). Sources for POR: Allan et al. (2005), Cannon (2009), Carpenter and Macgill (2005), de Langen and Chouly (2004), de Langen and Nijdam (2008), DPC (2009), Einemo (2007), Hill (2008), Hoebee (2009), Forstner and Heise (2006), GreenPort (2008a, b, c, d), PoR (2005, 2007b, c, 2008a, c), Heise and Forstner (2006), Oliveira (2008), van Niekerk (2008), van Niekerk and Adnitt (2004) and Veritas (2005). Sources for SPC: Carew (2002), CBB (2003), Comtois and Slack (2007), Jarrett (2008), Ling (2007), Martin (2004), Merz (2005), NSW Parliament (2006), Piyapatroomi et al. (2006), SPC (2003b, 2004b, 2007a, 2008a, c, 2011b), URS (2003) and Zin (2008). Sources for Transnet: de Boer (2008), Dohrman and Aiello (1999), Durban Metro (1999a, b), Fatoki and Mathabatha (2001), Khumalo (2003), Le May (2004), MISL (2009b), Naidoo (2007), PMG (2007), Patel and Holtzhausen (2008), Ports and Ships Maritime News (2008), TNPA (2009) and TPT (2008, 2011b)

[a] Shore power allows ships to shut their diesel engines at berth and plug into landside electricity grid to improve air quality

[b] Intermodalism implies moving from road transport to rail, inland and short sea shipping (van Ierland et al. 2000)

[c] Ballast water exchange consists of flushing coastal water from ballast tanks, replacing it with oceanic waters to reduce the concentration of coastal organisms since oceanic organisms are unlikely to colonize coastal habitats (GAO 2005b; Reynolds 2004)

[d] The 'polluter pays' principle requires those who are engaged in disposal or incineration at sea bear the cost of meeting the pollution prevention and control requirements for the authorised activities (Salomons and Gandrass 2001)

[e] Under the Basel Convention, implemented into legally binding EU law, exports of hazardous waste from the EU to non-OECD countries are prohibited (D'Monte 2009; Ermacora 1998)

[f] Co-siting involves making use of each other's raw materials, semi-finished and finished products. For example, companies that produce steam are connected to companies that need steam in their production process

than pre-1989 diesels, questions remain about the cost-effectiveness of POLB's LNG promotional efforts (Mongelluzzo 2009b). Moreover, critics emphasise that engine makers have overstated environmental benefits of LNG engines: although LNG emits less NOx and SOx, it releases more methane—a greenhouse gas (GHG) (Eason 2008). There is hope that the methane slip can be solved with further technological developments.

Globalisation Globalisation has led to increased trade and competition (McLaurin 2008). POLB predicts the need for 1,100 ac of new container cargo space and 400 ac of other types of terminal space to accommodate cargo volumes projected for 2020, which worries environmentalists (Bailey et al. 2004; LB Report 2008).

The US Government Accountability Office (GAO) noted that, with globalisation, hazardous waste is illegally being increasingly exported through many US ports (Stephenson 2008). There is inadequate data on hazardous waste exported specifically via POLB except for this GAO testimony that mentions an illegal shipment of cathode ray tube monitors originating from Colorado was intercepted in Hong Kong and returned to POLB in 2008.

On the positive side, globalisation has enabled international collaborations to exchange knowledge on sustainable practices. In 2007, POLB and Port of Shenzhen, China signed a formal agreement to exchange information on their best environmental practices. POLB has also signed similar agreements with ports in Mexico (POLB 2007).

Legislation/regulations US federal impetus on green initiatives has been a driving factor: port interests are encouraged by federal stimulus programs promoted by the Obama administration, which has linked green initiatives associated with infrastructure development projects as integral to the economic stimulus plan (Mongelluzzo 2009d). The US and Canada have proposed the world's largest emission control area. California has established its own emission standards to introduce these limits far sooner than the timetable proposed for the North American emission control area (Wallis 2009a).

4.2 Case study port # 2: Port of Rotterdam Authority, The Netherlands

4.2.1 Background

Port of Rotterdam Authority (PoR) is as an independent company with a professional executive and a non-executive board appointed on a commercial basis, as described in the Netherlands Corporate Governance Code. The Municipality of Rotterdam is a shareholder; yet, the city and port collaborate on major issues. Port land belongs to PoR that it leases to businesses (Paipai 1999; PoR 2007a).

PoR is the busiest seaport in Europe (PoR 2008a) with an annual throughput of more than 421 million tonnes of goods (de Langen 2004; PoR 2008b). Rotterdam is recognised as a European leader for cleaner technologies and efficient port practices (POLB 2009).

4.2.2 Policy framework for SD

PoR is guided by its Port Vision 2030 prepared along with clients, government departments, knowledge institutes and societal organisations. Building on Port Vision 2020 that aimed to develop PoR into a 'quality port', Port Vision 2030 envisages that, by 2030, Rotterdam will be Europe's most important port and industry complex with a strong combination of the Global Hub (logistics and industrial pillars of the port complex) and Europe's Industrial Cluster (largest, most modern and sustainable petrochemical and energy complex of Europe). Sustainability is envisioned as having the smallest ecological footprint in the world, achieved by sustainable transportation modes, clean fuels and efficient logistics chains (PoR 2011a). PoR has addressed environmental management through its CSR program that is an integral component of its Business Plan 2006–2010, which was refined further in 2007, making sustainability a priority goal. PoR believes that a healthy environment offers competitive advantages (Paipai 1999). Therefore, it emphasises combining economic objectives with the broad concept of 'liveability' encompassing environment, safety and quality of life aspects (Kolk and van der Veen 2002; PoR 2011b).

4.2.3 SD practices

With growing trade volumes, PoR is expanding the port area. Hence, Project Main Port Development Rotterdam was initiated, comprising three sub-projects—constructing Maasvlakte 2, developing 750 ha of nature and recreation area and improving the existing Rotterdam area (NMTPWWM 2009). Maasvlakte 2, the construction for which started in 1997, is a land reclamation project seawards to increase port size by 20 % (PoR 2008b; Visser 2007). Maasvlakte 2 will promote sustainability by clustering businesses, whereby companies that can benefit from each other's residual products and residual heat are all within easy reach, resulting in energy and raw material savings. Secondly, wind turbines will be installed on the solid sea defences. Thirdly, sustainable logistics has set 45 % minimum requirement of waterborne transport to achieve intermodal transport to hinterland networks. Rotterdam's location on the estuary of the rivers Rhine and Mass enables efficient and economic transport by inland vessel deep into the heart of Europe. Sustainability is also a part of tender procedures at Maasvlakte 2 (DPC 2009; PoR 2007b). PoR's sustainable strategies in various categories are listed in Table 1.

4.2.4 Driving and constraining forces

Stakeholder relations PoR has emphasised strengthening external and internal communications to garner support for sustainable operations (PoR 2007b). Recently, a 'PortCast' (an internal PodCast) discussed the issue of air quality. Port Infolink, funded by PoR, efficiently exchanges information with operators to improve terminals–hinterland interface for handling inland shipping, trains and trucks (de Langen and Chouly 2004; PoR 2008a). Besides, public–private partnerships (PPP) have played a key role. PoR initiated Quality Rail Rotterdam—a PPP—to optimise rail transport quality.

PoR adopts a consensus-oriented, rather than conflict-oriented approach (Deelstra et al. 2003). When negotiations for Project Mainport Rotterdam reached an impasse with non-governmental organisations (NGOs), the manager brought together all stakeholders to co-create a shared vision by expanding the project's objective towards a more integrated idea of PoR development. Maasvlakte 2 is an example of an alternative to top-down, 'expert'-driven port planning (Daamen 2007; Edelenbos et al. 2008; Kelly 2005).

Lack of data Lack of information on emissions from rail and ship engines running on low-sulphur fuel has hampered PoR's implementation and monitoring efforts (van Wee et al. 2003). Furthermore, although the fate of dredged materials is based on 'Chemical Toxicity Test' values, assessment of sediment quality is still prone to a number of uncertainties and insufficient information about regulation, analytical methods, risk assessment and management (Forstner and Heise 2006). Besides, there is need for harmonising data from various testing procedures of dredge materials, systems to measure sand in the sediment and long-term monitoring system in the Slufter (Alcock et al. 2003).

Economic factors The introduction of shore-side electricity is hampered due to concerns about the high costs required to install or retrofit and expand utility lines, substations and vessels. Lack of international standards for shore-side electricity increases the risks for investments in this measure. Two recent Dutch studies indicate that shore-side electricity at present is not viable for container vessels in Rotterdam due to high costs and the relatively low environmental benefits as well as uncertainty about future cold-ironing standards (Hammingh et al. 2007).

Globalisation Unbridled growth in trade with Asia continued unabated in 2007. This has created considerable pressure on the terminals and hinterland connections (PoR 2007b). PoR aims to become the European centre for biodiesel and bioethanol fuel production. However, geographical origins of raw materials for biofuels (e.g. coleseed, grains, palm nuts, soya beans, sugar cane, *jatropha* nuts) are in Asia, Africa, North and South America, Central Europe, Germany, France and Spain (GreenPort 2008d, e). This has created major controversies. For instance, *jatropha*, typically grown in India, is being introduced for cultivation in a large area of Rajasthan without any consultations with local people. Farmers have been encouraged to produce biofuel raw materials. Those who refuse are evicted without issuing notices despite holding valid documents for their land (The Hindu 2007). A World Bank report shows that the shift towards cultivation of biofuel raw materials has forced global food prices up by 75 % (Chakraborty 2008). However, globalisation has also led to international opportunities. Recently, PoR partnered with Senegal, West Africa to develop sustainable practices (PoR 2007b).

Legislation/regulations Progress in European port environmental activities has been driven by increasing the number of legislation. In June 2006, the European Commission released its *Maritime Policy Green Paper*, followed in October 2007 by an official action plan, called the *Integrated Maritime Policy for the European Union*, which creates a road map to facilitate continued growth in maritime activities whilst reducing their ecological footprint (Cannon 2009).

However, societal pressures and strict EU legislation often result in delays to port expansion projects, putting port authorities under constant pressure to defend their 'licence to operate' (Verhoeven 2009). Implementation of environmental legislation is also not consistent throughout the EU due to different interpretations by member states. This results in the distortion of competition because certain ports are subject to stricter conditions (ESPO 2009b; GreenPort 2008f). To level the playing field, Dutch seaports have undertaken 'self-regulation' and information exchange between European ports (Kolk and van der Veen 2002). The EU now officially recognises the problem and is developing guidelines to reduce confusion.

4.3 Case study # 3: Sydney Ports Corporation, Australia

4.3.1 Background

Australian ports were converted from departments of the State Maritime Boards to publicly owned corporations under the Ports Corporatisation and Waterways Management Act to ensure greater commercial and customer focus in port operations (Piyapatroomi et al. 2006; SPC 2004a).The SPC was established in 1995 as a state-owned corporation managing Port of Botany and Sydney Harbour Port that together handle one third of Australia's containerised trade (SPC 2011a). As a port corporation, SPC is a government-owned landlord port that leases port terminals and facilities to various companies.

4.3.2 Policy framework for SD

SPC views sustainability as fundamental to CSR (SPC 2003a; 2007a; 2011a). In 2006–2007, SPC developed its Sustainability Policy with the following objectives:

1. Making sustainability an internal philosophy integral to all business decisions;
2. Advocating and facilitating sustainable practices in planning, developing and operating port supply chain and influencing port operators to conduct sustainable business;
3. Decreasing SPC's consumption of resources including water and energy;
4. Creating mutual relationships between community, port and its operators;
5. Increasing employee satisfaction to ensure a healthy and safe workplace (SPC 2008a).

SPC has also developed 'Green Port Guidelines' to encourage port operators to adopt sustainable approaches and innovations in design and operations (GreenPort 2008g; SPC 2006; 2007b). Specific practices are summarised in Table 1.

4.3.3 Driving and constraining forces

Stakeholder relations SPC is committed to working with all stakeholders and local communities to minimise negative impacts of port operations. A range of initiatives exist, including sponsorship of local events and establishment of consultative committees and liaison groups (SPC 2008b; 2011c; 2011d). Although Carew (2002)

contends that Botany Bay development has been a pioneering exercise in collaborative relationships between different stakeholders, a commission of inquiry set up in 2004 to investigate controversial proposals found strong opposition from local councils, community groups and residents (Tull 2006). According to this assessment, port planning has been poorly integrated with city development and environmental impact inquiries have not consulted affected city populations.

Lack of data The lack of good quality and regionally comparable data in Sydney ports has hindered the development of appropriate management strategies and legislation for the coastal zone (Birch 2000).

Globalisation Strong consumer demand for imported products and a lower competitive Australian dollar have increased global trade in Sydney ports, necessitating port expansion to accommodate this growth with concomitant environmental problems (Martin 2003).

Legislation/regulations The House of Representatives (2007) in its report noted frequent delays in the government's approvals process on environmental issues, thereby often disrupting capital and maintenance projects. The report points to the lack of agreed mechanisms and coordination in setting standards between and within the Australian government and states/territories regarding dredging and dredge material disposal approvals. The report further mentions that the government's dredging and disposals review process raises the environmental bar for every subsequent application, leading to increasing costs and little overall benefit.

4.4 Case study # 4: Transnet National Ports Authority and Transnet Port Terminals, South Africa

4.4.1 Background

Transnet Limited is the state-owned South African transport business conglomerate which controls (1) Transnet National Ports Authority (TNPA) that has monopoly over the landlord function in all ports, (2) Transnet Port Terminals (TPT) that manages port operations, (3) Transnet Freight Rail, and (4) Transnet Pipelines—the national petroleum pipeline network (van Zyl 2005; Visser 2007). Transnet, established in 1990, is the successor of South African Transport Services (SATS), formed during the days of apartheid as a highly centralised organization. Transnet Limited's only shareholder is the state, which controls the core transport infrastructure (Mayer and Onyango 2005). TPT monopolises handling of most commodities, particularly containers (Thompson 2009). Private operators under leases handle only bulk commodities serving as niche markets without competing with each other or TPT.

4.4.2 Policy framework for SD

Transnet currently does not have a comprehensive sustainability policy, although its 2008 annual report included a sub-report on sustainability (TPT 2008). TPT believes

in integrating safety, health, environment and quality (SHEQ) within all spheres of its activities (TPT 2003; 2011a). Its principles include:

- Complying with legal requirements,
- Enhancing safety, health and environment of all stakeholders,
- Preventing pollution,
- Practicing and promoting good corporate governance,
- Promoting efficient use of energy and natural resources, and
- Promoting open dialogue with employees and other parties.

Limited information is available on sustainable practices in SA ports—this is summarised in Table 1. With growing trade, the number of containers conveyed by road has increased tremendously in recent years. Intermodal facilities are generally inadequate—SA does not have inland waterway transport (Khumalo 2003). The quality of rail services to the hinterland differs for bulk and container cargo. Transnet Freight Rail (earlier Spoornet) is the sole provider of train services mainly for handling bulk cargo. Container rail services are hardly developed; hence, most containers move by road. Spoornet's monopoly in the rail market has prevented entry of private firms (de Langen and Chouly 2004). Recently, the government and Transnet promised greater use of SA's railways in transporting freight (FinWeek 2008; Naidoo 2007).

4.4.3 Driving and constraining forces

Stakeholder relations Communities have opposed for many years the expansion of South Durban industrial zone. Despite the existence of new participatory frameworks of environmental management embodied in the National Environmental Management Act 1998, most government practices lack community involvement (Scott and Barnett 2009). TPT (2007) maintains that Transnet is committed to becoming a customer-centric organisation by providing effective customer service, enhancing customer engagement and input.

Lack of data Lack of reliable data regarding health consequences of pollution during the apartheid era hampered the development of effective legislation, which allowed companies to keep their data secret from public scrutiny for 'security' reasons (Scott and Barnett 2009). Consequently, environmental movements' dedicated efforts and journalistic reports on real-life stories of pollution effects, including increased levels of cancer in South Durban, laid the foundations for the Air Quality Management Act of 2004. An air quality monitoring programme was set up to produce and publish credible air quality data for all parties to inspect and verify (Scott and Barnett 2009).

Globalisation Since 1994, global economic integration and export-led growth strategy has led to exponential increase in container cargo throughput by an average rate of about 12 % a year over the last 5 years (Omar 2000; Rogerson 1998), thus necessitating port expansion. The size of container vessels calling at South African ports is increasing, with concomitant environmental consequences due to resultant channel deepening and expansion (Naidoo 2007; Visser 2007).

On the other hand, globalisation has promoted international collaborations. In 2009, SA hosted a conference of the Port Management Association of Eastern and

Southern Africa, which is proactive in bringing all African ports together to partner with international actors to foster sustainable practices (Mutonya 2009).

Legislation Past regulations regarding environmental management in SA have been fragmented both in implementation and responsibility. Over the past 5 years, international trends and public pressures have led to changes in environmental legislation in SA (van Koppen et al. 2005). However, some changes (e.g. waste regulations) are more suited to developed country conditions; these regulations have not been matched by adequate resources (Dohrman and Aiello 1999). Estimates suggest that 2.5 million tons of oil enter SA's coastal waters annually (DEAT 2001; Dittke 2000). Although TNPA (2009) mentions that hazardous waste will be disposed off with care in accordance with policy, specific practices are not mentioned.

Port governance The Legal Succession to the South African Transport Services Act 1989 that transferred all assets, liabilities, rights and obligations of SATS to Transnet Limited did not provide for the state's regulation of the monopoly inherent in incorporating both port ownership and operations in one company (van Niekirk 2000). SA's port sector is characterised by limited private sector participation (outside of road transport in the ports sector). In addition to market failures arising from this monopolistic structure, Transnet is both player and referee since it controls both the infrastructure (TNPA) and operations (TPT) (Mayer and Onyango 2005).

There is need for Transnet to promote competition; however, there is resistance to any change in the deeply entrenched state enterprise. Labour unions remain highly critical of increased private participation (Chasomeris 2003). Although the government does not intend to privatise state transport enterprises, it is willing to enter into PPP railway and port services (Fourie 2006).

5 Discussion

The findings of this study correspond with Wooldridge and Stojanovic's (2004) and Pinder and Slack's (2004) analyses questioning popular perceptions that ports are averse to environment protection. Whilst Wooldridge and Stojanovic's (2004) study pertained to Western European ports, this study underscores that, at the very least, several ports around the world show considerable concern for SD. Given their diversity, no two ports may follow similar trajectories of SD; however, within their diverse structures, several common frameworks, practices, challenges and opportunities were noted—the deliberation of which can benefit SD in other ports.

5.1 Policy framework for SD

Case study ports employ a range of policy frameworks to promote sustainability: the underlying premise is to promote all three arenas—environmental, economic and social sustainability. POLB's internationally recognised Green Port Policy mandates the protection of environment and communities from negative impacts, whilst promoting international trade. Both PoR and SPC have integrated sustainability within their CSR philosophy, making environmental protection, in principle, a core

component of business plans. PoR also believes that economic growth goes hand-in-hand with 'liveability' that covers environment, safety and quality of life aspects. Although Transnet has not articulated a sustainability policy, its SHEQ statement demonstrates it has embarked on the sustainability path. However, as Nagle (2008) notes, the challenge for all case study ports remains that of translating conceptual frameworks into actual practices.

5.2 SD practices

The findings of this study demonstrate that ports utilise a range of sustainable practices, although these are riddled with challenges and some with controversies.

5.2.1 Air pollution

Air pollution is the biggest environmental concern in all case study ports (except Sydney where water quality is the greatest concern). Case study ports have implemented or proposed three main strategies to reduce local emissions: alternative fuels (e.g. LNG, low-sulphur fuel and biofuels), shore-side electricity and intermodal transport. However, these strategies are not without controversies. Without further technological developments, GHG emissions of LNG trucks make them a questionable option (Eason 2008). Whilst low-sulphur fuel reduces SOx and particulate matter (PM) (Friedrich et al. 2007), limited availability of low-sulphur fuel, higher cost and lack of separate storage tanks to prevent contamination from diesel are major impediments (Eason and Joshi 2009; POLA 2005). Unlike POLB and PoR, the easy availability of low-sulphur fuel has led to much lower SOx emissions in Sydney compared to the national average (NSW Parliament 2006). However, the International Bunker Industry Association observes that a complete changeover to low-sulphur distillate would require oil refineries to process an additional 12 million barrels of crude oil a day (Bonney 2008).

Likewise, although biofuels reduce consumption of non-renewable energy sources and are biodegradable, they lead to different, not necessarily less, air pollution. Biofuels' implications of lower speed and larger bunker tanks, their GHG emissions and the relatively new GHG reduction technology need further investigation (GreenPort 2008h). Furthermore, scientific evidence suggests that corn-based ethanol production negatively affects the environment and communities (de Fraiture and Berndes 2009). Biofuel production increases GHG emissions relative to fossil fuels by transforming farming practices and taking away agricultural land earlier used for food crops, besides competing for freshwater that is increasingly in short supply. Biofuels have provoked increasing criticism about diverting land in food-insecure countries from food to biofuel feedstock production, with concomitant implications for food security, biodiversity and social justice (Howarth et al. 2009; GreenPort 2008c). Hence, sustainability benefits of biofuels have been increasingly questioned.

Whilst offering shore-side electricity obviously reduces fuel consumption by ships at berth, alternative energy is delivered by the land-power grid, which produces considerable CO_2 emissions (ESPO 2008; Friedrich et al. 2007). European Sea Ports Organisation (ESPO), representing common interests of ports in Europe, maintains that technical changes to vessels are far more effective in reducing

emissions at sea and in ports, since ships spend only limited time at berth. The average operating hours of engines per year at sea is 6,000 and only 700 at berth (ESPO 2008). Therefore, ESPO believes that shore-side electricity has limited advantage in improving air quality. Environmental benefits and cost-effectiveness of shore-side electricity need further evaluation. Meanwhile, utilizing low-carbon sources for shore-side power (e.g. solar and wind generators) and developing cost-effective energy storage technologies to achieve near-zero emissions have been suggested (Friedrich et al. 2007).

POLB and PoR have invested heavily in developing intermodal transport to combat air pollution. Each mode (rail, inland and short sea) has its economic and ecological trade-offs (Tull 2006). In 1995, it was decided to build a new rail link (Betuwe line) to transport goods from Rotterdam to other European places (van Ierland et al. 2000; van Wee et al. 2003). However, this has been strongly criticised by environmentalists since the rail link, whilst having some environmental benefits, will be accompanied by ecosystem fragmentation, visual pollution and noise. Studies show that Betuwe rail link contributes only modestly to reducing environmental problems and inland shipping is a better alternative (Annema et al. 2007; van Ierland et al. 2000). Whilst SPC aims to use rail transport to move 40 % cargo in Port Botany, the use of diesel freight trains without any regulatory framework defeats the purpose of using intermodalism to control air pollution. The NSW Government aims to implement a system to regulate diesel emissions from freight trains. Yet, inland and coastal shipping are cleaner alternatives (Comtois and Slack 2007; van Ierland et al. 2000). Moreover, a key characteristic of intermodal transport is the coordination between various components, requiring alliances between multiple actors. PoR plays a proactive role in the formation of such coalitions. In SA, such associations are hardly developed, mainly due to historical reasons. Whilst Rotterdam has a long tradition in cooperation in the port community, in SA, one public organisation (Transnet) has been dominant (de Langen and Chouly 2004).

5.2.2 Water quality

Water quality, sediment and storm water management plans have been proposed or implemented in all case study ports; however, all ports have yet to achieve sustainable water quality. POLB has yet to mitigate contaminated sediments and clean up toxic hotspots (Bailey et al. 2004). PoR is working on tackling soil and groundwater pollution (GreenPort 2008f). Past poor industrial practices have extensively contaminated the Sydney harbour (Birch 2000). Perhaps, this history of water pollution in Sydney harbour has propelled SPC to adopt innovative strategies such as treating storm water, reducing own water consumption and utilising rainwater tanks.

5.2.3 Ballast water

All four countries USA, Netherlands, Australia and SA are signatories to IMO's 2004 Ballast Water Management Convention. Mid-ocean ballast water exchange (BWE), allowed by IMO convention within 200 NM from the nearest port, is most commonly used by ships visiting case study ports. Gray et al. (2007) contend that BWE in only freshwater ports exceeds IMO's ballast water performance standards. Other scientific

studies have questioned mid-ocean BWE efficacy since most emptied vessels contain significant amounts of sediment with invasive species accumulated at the bottom of ballast tanks (e.g. Gollasch 1997; Hallegraeff and Bolch 1992; Reynolds 2004; Zhang and Dickman 1999).

5.2.4 Dredging and disposal of dredged materials

Of all the four ports, toxin-filled dredge from PoR dumped since the 1970s in the Rhine delta is the major issue (UNEP 2008). Rotterdam requires intensive maintenance dredging yielding 20 million m^3 of sludge annually (Alcock et al. 2003; PoR 2005). Both PoR and South African ports dispose less contaminated dredge materials at sea, the consequences of which are ambiguous. Dredged materials disposed offshore by PoR, for instance, comply with Dutch quality standards. However, studies show that dredged materials can have toxic ecological effects such as endangering the survival of oyster larvae (van den Hurk et al. 1997) and adversely affecting marine benthic resources by physical disturbances that may be caused by dredge disposal (Stronkhorst et al. 2003). Some studies (e.g. Bolam et al. 2006) suggest that consequences of dredge material disposal depend on site-specific variations (for example, ecological status, hydrographic profile) and variations in disposal activity (for example, quantity, timing, frequency and type of disposed material). Others (e.g. Bateman 1996; van den Hurk et al. 1997) maintain that sea dumping can lead to declining water quality and biological impacts (e.g. reductions and changes in marine biodiversity).

Disposing dredge materials on land in approved landfills and confined disposal sites, although cheaper and more flexible in their regional application than open water disposal (Heise and Forstner 2006; Krause and McDonnell 2000), can also lead to environmental repercussions, such as contamination of groundwater (Bateman 1996). POLB and SPC have used innovative practices such as recycling and beneficial re-use of dredged materials for 'brownfield developments', capping deepwater contaminated sediments and reclaiming mudflats and marshes. Remediation techniques for contaminated sediments are generally limited (Heise and Forstner 2006), although POLB has successfully used them as construction fill materials (Steinberg and Watson 2001).

5.2.5 Waste disposal

All case study ports provide waste reception facilities for visiting ships as per international conventions. Most case study ports have effective waste management programs. Available information shows that POLB and SPC have additionally implemented waste minimisation and recycling and reuse programs. Recycling, converting waste to beneficial reuse products (Offshore 2008) and waste reduction have been basic notions of sustainability. The ultimate goal of recycling, however, is zero waste (Goldstein 2002; Seldman 2003), a goal yet to be realised in all case study ports.

5.2.6 Hazardous substances

Oil spill responses and storage and transport of hazardous goods are well-developed in all case study ports. However, information on their procedures to manage land-

based and operational oil discharge is inadequate. This corroborates with existing literature (e.g. Reynolds 2004) that there is more information about marine pollution from accidental oil spills than from everyday operational oil discharges.[7] Export of hazardous waste, discussed in the subsection on globalisation, is of concern in POLB and PoR.

5.2.7 Land/resource use

Due to growth in trade volumes, case study ports are under pressure to expand their terminals to maintain economic sustainability; however, these projects face community opposition and are controversial for their negative environmental impacts. Ports have carried out environmental impact assessments of expansion and development projects and invested in ecological restoration and improvement, relocation of flora and fauna and nature compensation, besides landscaping and developing recreational facilities for the community. However, in the context of POLB, McLaurin (2008) notes that nonrevenue-generating projects (for example, beautification projects) consume the port's capital outlays, thereby jeopardizing financial sustainability. Nonetheless, new and expanded terminals also offer opportunities for sustainable practices by requiring terminal operators and businesses to adopt environmentally friendly approaches.

To accommodate economic growth, case study ports have undertaken redevelopment (POLB's Middle Harbour Redevelopment Project), development of satellite terminals in the hinterland (by POLB and PoR) and land reclamation (PoR's Maasvlakte 2 and SPC's Port Botany expansion). However, Slack (1999) notes that redevelopment can increase capacities to a limited extent, thereby constraining future growth, besides aggravating congestion around terminals. Lower land costs and land availability have encouraged growth of hinterland terminals, for which good access to the main terminal via inland transportation is paramount. This has led to intermodal transport development, which has economic and environmental benefits (e.g. air pollution reduction) (Notteboom and Rodrigue 2005). However, environmentalists stress that expansion and development proposals are unsound mainly because they would create a net increase in road traffic. For instance, SPC's environmental impact statement shows that Botany Bay expansion would double the number of trucks in the morning peak hour. Larger containers will be carried on trucks in larger numbers, despite the shift to rail. Critics charge that alternative sites for port expansion in less congested areas such as Port Kembla and Newcastle should be considered as options (Dick 2004).

In POLB, PoR and SPC, sustainability is also expressed in resource conservation and more efficient use of energy (e.g. through co-siting and clustering of businesses as in PoR), using renewable energy, and more environmentally friendly procurement policies and working practices (e.g. POLB, PoR, SPC) that can reduce overall negative impacts of port operations (Mneney and Yell 2008). These practices

[7] While public perceptions of marine oil pollution are associated with tanker groundings and collisions, in reality, accidents are responsible for minor proportions of marine oil pollution. Reynolds (2004) notes that only 20 % of ship-generated oil pollution results from accidents; the remainder is discharged during normal ship operations.

epitomise sustainability as using every single resource with careful thinking and respectful action (Baker 2009). POLB has the best land use efficiency of the ten largest ports in the USA (Bailey 2004). Ideally, sustainable practices should be implemented in design and construction, operations as well as in administrative practices throughout the port, as is aimed by POLB, PoR and SPC. PoR also reports on the sustainability of its own activities. As is clear from the discussion, several sustainable port practices are mired in controversies, which call for further research on their pros and cons (indicated in Table 1, last column). Additionally, study findings point to various related challenges and opportunities.

5.2.8 Driving and constraining forces

Stakeholder relations Community pressure to address environmental impacts has been both a driving and constraining factor in all case study ports. As these case studies suggest, enlisting public participation and effective communication with all stakeholders are cornerstones for SD. Creating port sustainability demands effective collaboration with communities, businesses and government agencies. Ports face challenges of reconciling different stances of the industry and public (GreenPort 2008i). For instance, in POLB, emission reduction measures have been viewed as chaotically quick by industry and agonizingly slow by the public (Avol 2007). PoR's consensus-based, rather than conflict-oriented, approach, which reconciles differences and offers an alternative to top-down, 'expert'-driven port planning, is imperative for SD, yet it is time-consuming.

Lack of data This research shows that sustainable port practices continue to be hampered by the lack and uncertainties of data. Data are required for monitoring environmental performance, besides assessing the effects of ports' biological, physical and chemical interactions within the ecosystem (Wooldridge et al. 1999). To address data limitations, Wooldridge and Stojanovic (2004) suggest that ports can forge links with local, regional, national and international regulatory authorities, NGOs and industry to gain access to their wealth of data. This is being increasingly undertaken: for instance, PoR participated in Eco-Information Project (1997–1999) that compiled significant baseline data from which port industry's environmental responses could be monitored (Paipai 1999). However, increased collaborations and greater investment of time and resources is required so that ports have adequate data and evidence to justify, plan, monitor and evaluate sustainable practices.

Economic factors Given the recent global economic recession, reducing environmental impacts of ports is a costly endeavour. For instance, the cost of low-sulphur fuel is estimated to be twice as much as residual fuel oil (Hammingh et al. 2007), mainly due to its limited availability. Shore-side electricity is another case in point, with infrastructure costs of about $4 million per container terminal (Mongelluzzo 2009c).

Nonetheless, as ports look for ways to increase market share or simply to survive (Meerseman and Van de Voorde 2002), they can capitalise on new sources of profit offered by pollution control and environmental management activities (Soriani 2004; Wallis 2009a, b). For instance, POLB and PoR, with their expertise in environmental management, have commercially marketable skills to improve coastal management in

other regions (Comtois and Slack 2007). Environmental stewardship of the port can also become a strong commercial argument (Alderton 1999). Besides, operating sustainably offers opportunities to implement state-of-the-art practices that enhance operational efficiencies and reduce costs (Tillman 2008). Thus, economic factors can become a driving force for SD.

Globalisation On one hand, globalisation has promoted exchange of information on sustainable practices across borders (GAO 1999; Comtois and Slack 2007). On the other, globalisation has created several challenges in case study ports. Growth in global trade has necessitated port expansion, creating major local environmental implications (Cleary and Goh 2004). Furthermore, in the globalised economy, ports are key interfaces in global logistics chains (Tull 2006). As the illegal exports of hazardous waste, often in the garb of 'recycling', via POLB and PoR demonstrate, inspecting every container is impractical. More than 5 million containers pass through PoR annually; about 80 a day are X-rayed (UNESCO 2000). The Dutch Environment Enforcement Agency observed that exporting waste through European ports has become common. There is no accurate database on waste shipments, unless such containers are detected and enforcement procedures are launched. In 2003, 51 containers were intercepted at PoR—these contained illegal electronic waste from Ireland en route to Indonesia, India and Singapore (Renout 2004). Substantial amounts of hazardous waste end up in countries without adequate disposal practices, thereby harming their workers and environment (Stephenson 2008). It is, therefore, imperative to develop greater monitoring and coordination between port customs officials and international organisations.

Another globalisation-related challenge revealed in this study is feedstock production for biofuels. PoR aims to become the European leader for producing biofuels. The raw materials for these are imported from developing countries. International organisations such as Oxfam contend that 'green policies' in developed countries are contributing to the world's soaring food prices, which have hit the poor hardest. It is estimated that EU's emissions reduction targets could multiply carbon emissions 70-fold by 2020 by changing the use of land (BBC News 2008). Thus, there is a need for holistic assessments about the potential impacts of biofuel programs (Howarth et al. 2009).

Clearly, practices deemed to be sustainable in one part of the world can degrade the environment in another region. Globalisation complicates the term 'community': whilst in traditional parlance 'community' refers to settlements surrounding the ports—or 'host communities' (Comtois and Slack 2007, p. 5), as the cases of biofuels and hazardous waste suggest, the impact of port 'sustainable practices' can create adverse effects, directly or indirectly, in far-flung communities that may not be easily discernible by port authorities at first glance. Findings of this study, therefore, refute Soriani's (2004) claim that, whilst their role in sustaining global economies is of global importance, environmental impacts of ports still remain largely localised. With globalisation, environmental impacts are no longer localised. A broader environmental view is required in which ports are recognised as part of larger global ecosystems, so that environmental pressures exerted by ports both locally and globally are addressed.

Legislation/regulations and their implementation Regulations and their implementation are both a driving and constraining factor. Whilst American and European

legislations have driven sustainable activity in the maritime industry, constraining forces include inconsistencies in interpretation and implementation among European member states, delays in approvals by Australian regulatory agencies and erstwhile fragmentation of SA's environmental regulations.

Furthermore, the complexity and divergence of international, national and regional/local legislation and frequent changes to these can hinder SD in ports (Roe 2009). For instance, in the EU, polices are interpreted from a higher international jurisdiction (for example, IMO), and then adapted by EU member states by national legislation, which is then applied through regional and local regulations. Problems can consequently emerge since the maritime sector operates within internationally competitive environments where vessel and port ownership, labour supply, finance, insurance, etc., are cross-jurisdictional. This can distort competitiveness of local entities due to stricter regional regulations (de Langen and Nijdam 2008; Roe 2009).

Port governance Except for SA's Transnet, all ports in this study are PPP in varying proportions. Whilst POLB and SPC are government-owned landlord ports with port operations being managed by private tenants, PoR is an independent company with the Rotterdam Municipality as its shareholder and several private companies as its tenants. Thus, unlike SA where port ownership and management is vested in one entity, the USA, Australia and Netherlands have avoided monopolisation by public or private corporations. Whilst conclusive evidence about causal relationships between port governance structures and effectiveness in managing environmental issues cannot be claimed from this research, the case studies point to a possible correlation between PPP and high degree of sustainability. This corroborates with existing literature that PPP in port governance enable ports to improve labour productivity and become more efficient and globally competitive (Omar 2000; van Niekirk 2000). PPP avoid disadvantages of state monopolies that can thwart competition on one hand and complete privatisation that can overlook public interests on the other. One advantage of this form of governance is ensuring access to massive funding required to invest in new projects and infrastructure (Comtois and Slack 2007; Pinder and Slack 2004), for instance, federal cost sharing for constructing dredged material disposal facilities in the USA (DPC 2006).

Overall, despite several challenges, POLB, PoR and SPC have moved from regulatory compliance to proactive environmental stewardship. South African ports too have embarked on the sustainable journey, which refutes, in part at least, the claim about the environmental 'priority gap' in transition and emerging economies (e.g. Pinder and Slack 2004). As Cleary and Goh (2004) note, although developing and transition countries prioritise economic development, the environment *is* on their agenda: pollution dangers have prompted a range of initiatives in these countries.

6 Concluding remarks

This study has synthesised and compared sustainable port policies and practices from four different continents, rather than being limited to European or American frameworks alone that have largely been the focus of much literature. Secondly, and more importantly, it has also critically analysed these practices from different perspectives,

highlighting the predicaments and controversies in their implementation. Thirdly, major forces that drive and/or constrain SD in ports have been examined with the hope that further deliberations on these factors will advance the cause of SD in ports.

This study has demonstrated that SD has gained momentum, albeit to differing degrees, in the functioning, organisation and the very ethos of case study ports. Award-winning ports incorporate activities that go beyond regulation requirements and rely on input from multiple stakeholders. Sustainability requires an integrated and holistic approach. Whilst there is definite progress towards SD in ports, several practices deemed to be sustainable can be contentious and must be critically examined from the perspectives of different stakeholders including shippers, port-related businesses and the local and global community. Lack of data about environmental impacts of ports and their sustainable practices, economic costs of implementing such practices and complexities of international, regional and national environmental regulations were other constraining factors. On the other hand, reconciling differences between different stakeholders and capitalising on economic opportunities, operational efficiencies and cost savings offered by environmental friendliness can further SD in ports. PPP and policies negotiated by involving all stakeholders can foster port sustainability. Most importantly, this study found that, with the advent of globalisation, environmental impacts of ports are no longer localised. Practices believed to be sustainable and environmentally friendly in one region of the world can have unintended consequences in other parts of the world (e.g. biofuels). Therefore, globalisation necessitates a more critical and global analysis of port operations and environment practices in order to be truly sustainable. Although the scope of study findings are limited to the case study ports, the lessons drawn can be constructively applied to any port operating within an institutional system of structured SD.

Port governance, critical to port SD, has undergone considerable restructuring with accelerated deregulation and privatization of ports. Whilst it has been well-established that PPP in ports results in enhanced efficiencies (Wooldridge and Stojanovic 2004; Soriani 2004), there is a need for more research on governance challenges in port PPP, such as transparency, accountability, legal and regulatory environment for PPP and conflicts within PPP. Further, with the development of hinterland networks in several case study ports, more research is required on their social and environmental impacts on inner cities, as is the need for rigorous evidence on implications of port expansion for port cities. Moreover, due to limited secondary data available for some case study ports (e.g. Transnet), this study did not cover noise pollution. Since noise has become an increasingly significant issue in many ports (NoMEPorts 2008) and is the first point of contention between port authorities and citizens, future research must address this aspect in different continents.

The present study was based on secondary data—that is, document reviews of print and Internet sources—rather than collecting primary data from port authorities and other stakeholders. However, extensive materials from a variety of sources/stakeholders were used that enabled not only information corroboration to ensure validity, but also allowed unbiased analysis of sustainable practices from a range of perspectives. Further research can include interactions with port authorities, government agencies, international organisations, environmental groups, port operators and businesses to provide a more complete picture on port SD as well as

dilemmas that need resolution. Particularly, more research is needed on various controversial aspects identified in this study, such as biofuels and shipment of hazardous waste in a globalised era. The essence of SD, after all, demands environmental stewardship both locally and globally.

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