The natural environment in port development
A 'green handbrake' or an equal partner?

Taljaard, S.; Slinger, J. H.; Weerts, S. P.; Vreugdenhil, H.

DOI
10.1016/j.ocecoaman.2020.105390

Publication date
2021

Document Version
Accepted author manuscript

Published in
Ocean and Coastal Management

The natural environment in port development: a 'green handbrake' or an equal partner?

Taljaard S[a,b], Slinger, JH[c,d], Arabi S[a], Weerts SP[a,e] and Vreugdenhil H[c,f]

[a] Council for Scientific and Industrial Research (CSIR), P O Box 320, Stellenbosch, 7599, South Africa
[b] Institute for Coastal and Marine Research, Nelson Mandela University, PO Box 77000, Port Elizabeth, 6031, South Africa
[c] Faculty of Technology, Policy and Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Jaffalaan 5, 2628 BX Delft, The Netherlands
[d] Institute for Water Research, Rhodes University, Artillery Road, Grahamstown, 6139, South Africa
[e] CRUZ and Department of Zoology, University of Zululand, Private Bag X1001, KwaDlangezwa, 3886, South Africa
[f] Deltares, Boussinesqweg 1, 2629HZ Delft, The Netherlands

Abstract

Rapid urbanization of the coast, growing global trade, stakeholder emancipation and ongoing depletion of natural resources mean that ports can no longer operate and develop without acknowledging and incorporating societal and environmental considerations. Drawing primarily on first-hand experiences in South African ports, supplemented with learning taken from international literature, this paper proposes a conceptual change in the position of the natural environment in port development from that of a 'green handbrake' to 'equal partner'. The argument for this conceptual change is developed in three stages. First, we merge two concepts emerging from the literature, namely natural capital (or natural infrastructure) and infrastructure systems, to embed the natural environment as an integral component or 'equal partner' in port development. We then identify practical avenues through which the profile (or value) of the natural environment can be enhanced in port development, drawing on concepts such as Building with Nature (BwN) and multi-use of natural capital. Finally, we build a framework for Integrated Port Management (IPM) by conceptually positioning and aligning environmental processes within the traditional port development cycle, as well as identifying the need for coordination across and continuity between individual environmental assessment processes.

In essence, bridging the disconnect between natural environmental issues and port development requires early consideration of the natural environment in port development, and an acknowledgement of multi-use benefits from natural capital. Further, in the operations and maintenance phases, environmental management systems in ports should not only focus on environmental performance, but also embrace multi-use valuation of the natural environment (ecosystem services) to give purpose to the need for environmental protection. However, crucial to effective implementation of an Integrated Port Management framework will be its integration in organisational processes, supported by collaborative institutional structures. Only then will the environment take its place as equal partner in port development.

Keywords: integrated port management, green ports, sustainable port development, environmental assessment, natural capital

1. Introduction

Over the past decades maritime trade and port industries have experienced phenomenal growth and as trade facilitators ports are crucial to the global economic system. In their simplest forms - the 1st generation ports - ports operated in areas of uncontested spaces, benefiting from seascapes in which they could be situated safely and cost-effectively without competition (Kaliszewski, 2018; Lee et al., 2018). However, society has evolved, with rapid coastal urbanization, growing global trade, stakeholder emancipation and depletion of natural resources (e.g. through physical alteration and destruction of habitat, pollution and unsustainable levels of exploitation) (Wolanski, 2006; Nichols et al. 2008; Burt, 2014; Güneralp et al. 2018; Riekhof et al., 2019). Port systems can no longer operate without acknowledging and incorporating societal and environmental considerations in their planning and management (e.g. 5th generation ports) (Kaliszewski, 2018). The port industry therefore faces increasing challenges in addressing societal and environmental considerations while at the same time having to provide adequate capacity and cost effective services to traders and associated industry clusters (Lam and Van der Voorde, 2012; Roh et al., 2016; Haezendonck and Langenus, 2019). These challenges stimulated the development of concepts such as 'Green Ports' with the key objective of balancing environmental challenges and economic demand (Bergqvist and Monios, 2019; Lam and Notteboom, 2014) and striving to establish sustainable ports by increasing both their economic and environmental competitiveness (Maritz et al., 2014). While Schipper et al. (2017) claim that green port management must include the broader topic of ecosystem protection, Lam and Van de Voorde (2012) argue that green ports ultimately will lead to positive outcomes on the economic performance of ports. However, with increasing public and regulatory pressures, port authorities around the world now are compelled to pursue 'greening' of their ports not only to grow their economic and environmental competitiveness, but also to safeguard their 'license to operate' (Lam and Van der Voorde, 2012; Roh et al., 2016). The concept of 'Sustainable Port Development' builds on 'Green Ports' by considering social sustainability, in essence advocating the need for port development to create a balance between economic growth, environmental protection and social progress so as to secure its long-term future (Hiranandani, 2014).

Environmental processes have been introduced successfully in port development, for example strategic environmental assessment (SEA) (e.g. Dublin Port Company, 2012a and 2012b), environmental impact assessment (EIA), environmental management planning (EMP) (e.g. Gupta et al., 2005), and environmental management systems (EMSs) (e.g. Darbra et al., 2004; Darbra et al., 2005; Hussain, 2018; Lawer et al., 2019). Still, as a result of the strong conventional economic focus in port development the natural environment is often perceived as a hindrance to port development. Natural physical forces of dynamic environments in which ports are located pose risks to port infrastructure. Protection against these forces requires expensive engineering intervention. In addition, prevention and mitigation of environmental impacts also requires costly intervention, and perhaps selection of 'less preferred' engineering designs. This leads to situations where the natural environment is viewed as an obstacle to economic efficiency (Acciaro et al., 2014). In developing countries particularly, economic prerogatives are sometimes viewed as more important than environmental considerations (Klemensits, 2019).

In the African context, acceptance of environmental assessment has been challenged by a post-colonial view that environmentalism is predominantly an externally (Western) imposed construct (Audouin et al., 2011). For example, divergent environmental and economic priorities have emerged in the decision-making about several proposed port infrastructural developments in Durban (South Africa). These have resulted in port development projects either not being approved, being delayed, or being subject to strict environmental conditions. This, and similar cases elsewhere in the world, has engendered a perception amongst some port development proponents that environmental assessments are a 'green handbrake' to development and growth. This need not be the case if environmental considerations are timeously acknowledged and incorporated as an essential component within the port development cycle (Audouin et al. 2011; de Boer et al., 2019). This may require a paradigm shift from viewing ports and the natural environment as conflicting entities, to one where innovative engineering and environmental principles are integrated into port development to ensure optimal utilisation and long-term sustainability (Slinger et al., 2017; de Boer et al., 2019). In this alternative view the natural environment becomes an asset, comprising natural 'stocks' (including geology, soil, air, water and all forms of life) from which a wide range of ecosystem services that contribute to wellbeing can be derived – supporting the concept of natural capital (e.g. Costanza et al., 2014; World Forum on Natural Capital, 2018) or natural infrastructure (e.g. Sutton-Grier et al., 2015; Van Ierland et al., 2000). In this scenario, port development is viewed as one of the beneficiaries of natural capital, together with local communities and others also gaining value from the natural environment.

Critical to the optimisation of natural capital in this multi-use setting is strategic, pro-active negotiation. Port development can also leverage the inherent benefits provided by natural physical processes (e.g. circulation and sediment dynamics), rather than only considering principles aimed at establishing and operating engineered infrastructure to withstand potential damage from such natural forces. This is supported by the concept of Building with Nature (BwN) (e.g. de Vriend et al., 2015; Slinger et al., 2016; Waterman et al., 1998; Waterman, 2010). We argue that by adopting this stance, the natural environment can emerge as an equal and valued partner in port development. Indeed, studies show that when the natural environment is considered in infrastructure design, costs often turn out to be lower on a life-cycle basis than when only traditional engineering design principles are adopted (e.g. de Vriend et al., 2015). Similarly, direct links have been demonstrated between good financial performance and sound environmental, social and corporate governance practices in business in general (IFC, 2019), including the ports sector (Roh et al., 2016) and ports industrial clusters (Haezendonck and Langenus, 2019). To achieve this in practice, planning and actions needs to be integrated into organisational decision-making processes guided by structured frameworks (Hiranandani, 2014).

This paper therefore aims to achieve a conceptual change in the position of the natural environment in port development from that of a 'green handbrake' to 'equal partner'. We undertake this in three stages. First, we combine two concepts emerging from the international literature, namely natural capital (or natural infrastructure) and infrastructure systems, to embed the natural environment as an integral component of a port infrastructure system. We then identify practical avenues through which the profile (or value) of the natural environment can be enhanced in port development, drawing on concepts such as BwN and the multi-use of natural capital (e.g. Costanza et al., 2014; de Vriend et al., 2015; Slinger et al., 2016; Waterman, 2010; World Forum on Natural Capital, 2018). Finally, we construct a framework for Integrated Port Management (IPM) by conceptually positioning and aligning environmental processes within the traditional port development cycle, as well as identifying the need for coordination across and continuity between individual environmental assessment processes.

2. Theoretical Background

2.1 Infrastructure systems

Ports are examples of infrastructure systems (or *infrasystems*), groupings of systems that provide critical functions to societies, including energy provision and distribution systems, communication systems and transport systems (Thissen and Herder, 2003). To address multi-disciplinary challenges, Thissen and Herder (2003) proposed a reference model for infrasystems comprising three layers, namely an infrastructure layer, an operation and maintenance layer, and a services layer. Design, construction and maintenance of the built infrastructure, executed by actors such as developers, designers and contractors, comprise the infrastructure layer. The operations and maintenance layer encompasses network operation and management processes and actors that deal with network control, capacity management and routing on the network. The service layer comprises the supply and use of infrastructure-based products and/or services. Within this context, Taneja et al. (2012) defined ports as complex, large-scale, multidisciplinary infrastructure models (or *inframodel*). In the case of port infrasystems, the complexity and extended design life (i.e. having to accommodate "today's needs and tomorrow's") create huge uncertainty that can best be accommodated by flexibility in planning and management processes within the system. Typically, planning and management processes within port infrasystems comprise six key stages: site selection, master planning, design, construction, operations and monitoring. GHD (2013) conceptualise these stages of planning and management and an adaptive management cycle, highlighting the importance of flexibility and the ability to accommodate incremental learning gained over time (Bornmann et al., 1999; Gray, 2006). However, port infrasystems are complicated by an emerging and growing focus on environmental issues. This complication demands that greater and more consistent attention is paid to environmental matters in port infrasystems, from the earliest stages of site selection through to ex-post monitoring and evaluation (de Boer et al., 2019; Taneja et al., 2012). The consequences of not accounting for environmental matters, and of non-compliance can be costly, and can even halt planned developments (Engelsman, 2014).

2.2 Concepts of natural infrastructure and natural capital

The World Forum on Natural Capital (2018) defines natural capital (or natural infrastructure) as stocks of natural assets that include geology, soil, air, water and all forms of life, from which humans derive a wide range of ecosystem services that contribute to their wellbeing. To create benefits to humans (i.e. support human well-being), ecosystem services from natural capital flow through social capital (i.e. communities), human capital (i.e. people) or built capital (i.e. built infrastructure) (Costanza et al., 2014).

Planning and management decisions often undervalue (or disregard) the benefits to humans from natural capital, resulting in unsustainable utilisation and destruction of natural resources (e.g. Hein et al., 2016). This is widespread and the need to actively start restoring or replenishing dwindling natural capital stocks is becoming increasingly evident (Blignaut et al., 2014). In 1992, the first United Nations Conference on Environment and Development (UNCED) recognised that steps had to be taken to start integrating ecological sustainability principles into economic management. From this emerged the concept of "ecosystem services" as a tool to be used across science, management and governance to explicitly link ecological infrastructure to benefits for societies and economies (e.g.

Villa et al., 2014). The natural capital of the world's oceans plays a significant role in supporting human well-being, through ecosystem services such as the provisioning of food, supporting of livelihoods and offering of recreational opportunities. However, ever-increasing human pressures are rapidly diminishing this natural capital. Most critically affected are coupled human-ocean systems such as coastal ecosystems (Halpern et al., 2012) where seaports are typically situated. Increasingly this strong coupling is recognised, as well as the urgent need to quantify and protect the multi-use benefits derived by humans from these ecosystems. One of the systems developed to better account for natural capital and its multi-use benefits, is the United Nations System of Environmental-Economic Accounting (SEEA). This is the first international statistical framework for the environment as a counterpart to the System of National Accounts (UN, 2014a and 2014b; UNEP, 2017).

2.3 Concept of Building with Nature

The concept of BwN emerged as an approach to the design of water infrastructure, in response to the port and dredging industries' growing environmental consciousness, as well as increasing pressures posed by environmental legislation (Vikolainen et al., 2014). The concept was proposed in the late 1970s by the Czech hydraulic engineer Svašek, and was introduced to the field of coastal management by Waterman (Waterman et al., 1998; Waterman, 2010). Central to this approach is seeking innovative infrastructure designs that meet socio-economic targets that are in harmony with the natural environment (Vikolainen et al., 2014). The concept of BwN requires the integration of environmental and societal systems as early as possible in the design stages (de Vriend et al., 2014; de Vriend et al., 2015; de Vriend and Van Koningsveld, 2012; Slinger et al., 2016; Vikolainen et al., 2015). It starts from the functioning of the natural and societal systems in which infrastructure is to be realised, and within this context innovative design emerges to meet societal infrastructural demands. The aim is not only to achieve environmental compliance, but more fundamentally to include the natural environment in infrastructure design so as to be flexible and adaptable to changing environmental conditions, as well as to provide complimentary functionalities and services that can be derived from these ecosystems (de Vriend et al., 2015). In essence, BwN underpins the concept of ecological engineering, which also emerged in response to the growing need for engineering practice to provide for societal welfare in a manner that still protects the natural environment and its benefits to humanity (Bergen et al., 2001).

2.4 Environmental assessment

Although rooted in rational planning theory developed in the 1950s, the specific notion of environmental assessment (EA) first emerged in the 1960s when the US Congress enacted the National Environmental Policy Act (Jay et al., 2007). Essential to effective EA is actor participation, appropriate process management (requirement for participatory management) and sound scientific knowledge (Taljaard et al., 2011). In practice, EA is undertaken at two levels (Fischer, 2003): at the level of an individual project, referred to as Environmental Impact Assessment (EIA), and at a policy, planning or program level, referred to as Strategic Environmental Assessment (SEA). In short, EIA can be described as a systematic process for considering potential impacts and the environmental consequences of a proposed project (or action) before the decision-making (Jay et al., 2007). The purpose of this anticipatory, participatory environmental approach is to supply decision-makers with an indication of the likely environmental consequences of proposed projects with the aim of supporting environmentally sound development (Fischer, 2003; Jay et al., 2007). SEA is typically applied earlier in the decision-making process, and as such is more pro-active than reactive, and deals with issues of sustainability of development scenarios rather than environmental impacts of individual projects. It provides a framework for understanding cumulative impacts and for articulation of individual projects in a complementary manner. As such SEA constitutes a powerful tool for sustainable development that can strengthen decision-making processes (Arce and Gullòn, 2000). However, the role of SEA is determined by its place in the decision-making process. For example, SEA can be used to assess a proposed policy, plan or programme that has already been developed, or it can be used to develop, evaluate and modify a policy, plan or programme during its formulation. SEA can be used to raise the profile of the environment or it can have an integrative role, where the focus is on combining environmental, social and economic considerations (DEAT, 2004; Kørnøv and Thissen, 2000). Effective implementation of SEA can create a roadmap for sustainable development, especially in developing countries where it can mitigate the lack of transparency, accountability and ineffective public participation often encountered in the development of policies, plans and programmes (Alshuwaikhat, 2005). The large economic, social and environmental footprints of ports often extend beyond their demarcated boundaries, and also need to be taken into account in broader spatial planning and development strategies (Wright, 2002).

Since the mid-1990s when the International Organization for Standardization (ISO) introduced ISO 14001, environmental management systems (EMSs) have received growing attention (Darnall and Edwards 2006). EMSs stem from the concept of continuous improvement (Deming, 1986), and refer to management systems that are put in place to continuously improve the condition of the natural environment, as per the concept of adaptive management (Bornmann et al., 1999). These systems typically consist of an environmental policy and stipulate evaluation processes to be undertaken in order to assess environmental impacts, to establish and implement goals, to monitor achievements, and to review planning and management practices (Lamprecht, 1997). Studies have shown the value of well-designed EMSs for environmental performance and technical and organizational innovation, but the degree to which these systems provide strong, competitive benefits, depends on the extent to which the EMS permeates into organizational planning and management frameworks (Iraldo et al., 2009).

Although rooted in ancient human history, sustainable development (SD) re-emerged as a paradigm in the early 1900s in response to failures in conventional development focussed only on achieving growth in gross domestic product (Printér et al., 2012; Villeneuve et al., 2017). An inability to distribute wealth fairly and detrimental impacts on the natural environment and society are key failures of the conventional economic development model, which might be addressed by sustainable development principles that consider environmental, social and economic issues in the light of cultural, historic and institutional perspectives (Waas et al., 2011). In 2015 the United Nations adopted the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDG) (UN, 2015). With the adoption and establishment of the concept, monitoring and assessment of progress in SD have become necessary, and the concept of sustainability assessment has emerged (Sala et al., 2015). Given the nature of SD, sustainability assessments are necessarily complex and multidisciplinary appraisal methodologies, and are conducted to inform decision-making and policy development (Sala et al., 2015, Villenieve et al., 2017). Various sustainability assessment tools have been developed including the Sustainable Development Analytical Grid, which is recognised by the

UN and is part of their SDG Acceleration Toolkit (UNDG, 2019), and the Sustainable Integrated Condition Index, an assessment methodology developed specifically for ports (Schipper et al., 2017).

Environmental monitoring to provide reliable long-term data and information is critical to all environmental assessments (or evaluations) (Kusek and Rist, 2004). Environmental monitoring and evaluation typically emerge in three generic forms, namely descriptive monitoring (aimed at gaining improved knowledge and understanding of environmental systems); regulatory monitoring (aimed at testing compliance against objectives as well as the effectiveness of policies and associated actions); and results-based monitoring and evaluation, aimed at evaluating the impact of projects, programmes, and policies against predetermined objectives (Harvey, 1984; Kusek and Rist, 2004; Taljaard et al., 2011; Wooldridge et al., 1999). It is advisable not to "monitor for the sake of monitoring". Instead, environmental monitoring strategies need to be comprehensive enough to measure performance in terms of agreed goals and objectives and coordinated enough to draw from the various environmental assessments and systems (Wooldridge et al., 1999).

3. Research Methods

In South Africa, the governance model is one of a public port or a landlord port with a mixed model of service delivery (Barnes-Dabban, 2017; Trujillo and Nombela, 2000). The country's eight commercial ports are operated by a state owned company (Transnet SOC Pty Ltd) through two of its five operating divisions, Transnet National Ports Authorities (TNPA) and Transnet Port Terminals (TPT). TNPA is primarily responsible for marine-related port operations and landlord functions in all of these ports, while TPT, together with private terminal operators, is responsible for cargo handling and landside operations. The National Ports Act (RSA, 2005) promotes sustainable and transparent port planning processes to achieve a fair and reasonable balance between port development, port operation and environmental protection. The importance of proactively integrating environmental aspects into all stages of port planning and operation, from the early planning stages through design, construction and into operation, is recognised. However, environmental assessment and monitoring programmes are mostly still executed in a fragmented manner with only limited feed-back to improve port operations. Large port infrastructural development projects, including environmental aspects, are managed by Transnet Capital Projects - a specialist embedded supporting business to Transnet SOC divisions. TNPA engineers are included in teams implementing large development projects but there is risk of a disconnect between environmental information flows, and lack of integration of environmental strategic and operational considerations at levels of visioning (TNPA), project design and construction (Transnet Capital Projects) and long-term operation and maintenance (TNPA).

It is within this context that our research is primarily positioned, strongly drawing on contextual knowledge (sensu Flyvbjerg, 2001) derived from past and ongoing engagement in port environmental assessment and monitoring in South Africa's commercial ports. Three of the five authors work for a national science council in South Africa and have a long history of engagement with the country's port authorities as service providers undertaking environmental studies on their behalf. The Supplementary Material provides a listing of key studies demonstrating the practical experience of the research team across most of South Africa's commercial ports. Through such studies, there is ongoing engagement with environmental and engineering staff in the various ports and exposure to the experience base and issues in port environmental management practice in South Africa.

Following Flyvbjerg (2001, 2006) and Delmar (2010), the research approach adopted in this study integrates the place-based experiential knowledge from South Africa with information from the review of international literature to identify sound practices with regard to the environment in ports. This integration is undertaken in three stages.

First, we position the natural environment as an integral component or 'partner' in port development, by merging two concepts emerging from the international literature, namely natural capital (or natural infrastructure) and infrastructure systems. Second, again drawing on the international literature, we suggest innovative, practical means whereby the role of the natural environment can be enhanced in port development, through concepts such as BwN and multi-use of natural capital. Third, recognising the component technical activities of port development (e.g. GHD, 2013), and the current fragmentation in environmental assessment experienced in South Africa, we move beyond (see Delmar, 2010) to pose a framework for Integrated Port Management (IPM), conceptualising the position and necessity for integration of environmental assessment activities within and across the port development cycle. Insight into the alignment of specific environmental assessment activities with components in the port development cycle is sourced from review of international literature (both scientific and grey literature). For instance, the alignment of SEAs with 'master planning' from Deloitte Inc. (2015) and the lessons learned in the recent expansions of the Ports of Rotterdam and Antwerp (Vellinga, 2018, Engelsman, 2014), through Pan-African analyses of coastal erosion near ports (e.g. de Boer, Mao et al., 2019), and stakeholder engagement and in-depth analyses of some West African ports (Barnes-Dabban, 2017, Slinger et al., 2017, Kothuis and Slinger, 2018, Slinger, 2018). We also draw on expertise in the theory and practice of Integrated Coastal Management (ICM) (e.g. Taljaard et al., 2011, 2012 and 2013) to connect the environmental assessment processes continuously across the integrated framework.

4. Results and Discussion

4.1 Embedding the natural environment in port infrastructure systems

Within the traditional concept of ports, capital comprises physical infrastructure; buildings, quay walls, equipment, superstructure and infrastructure (Gouleilmos, 2000). The natural environment can also be considered as a source of capital (Fisher, 1995 and Pearce and Atkinson, 1995 in Gouleilmos, 2000), although its current position in port development is more typically seen as one of constraining growth. If the natural environment is to be viewed as natural capital (or natural infrastructure), how can it be placed logically in the port infrastructure system?

Taneja et al (2012) described the port infrastructure system as comprising three interconnected layers: a physical infrastructure layer, an operational layer, and a services layer. We propose a logical forth layer to include natural infrastructure and complete the port inframodel (Figure 1). In this extended port inframodel, the components within the operation and management, and services layers also expand. Environmental management is explicitly recognised as an integral component of port management and operations, while services no longer only relate to shipping and added value activities from shipping, but also consider other ecosystem services that are made possible by the safe spaces and sheltered waters created by port infrastructure, and which provide benefits such as, recreation, fishing and serving as nursery areas to various estuarine and marine biota.

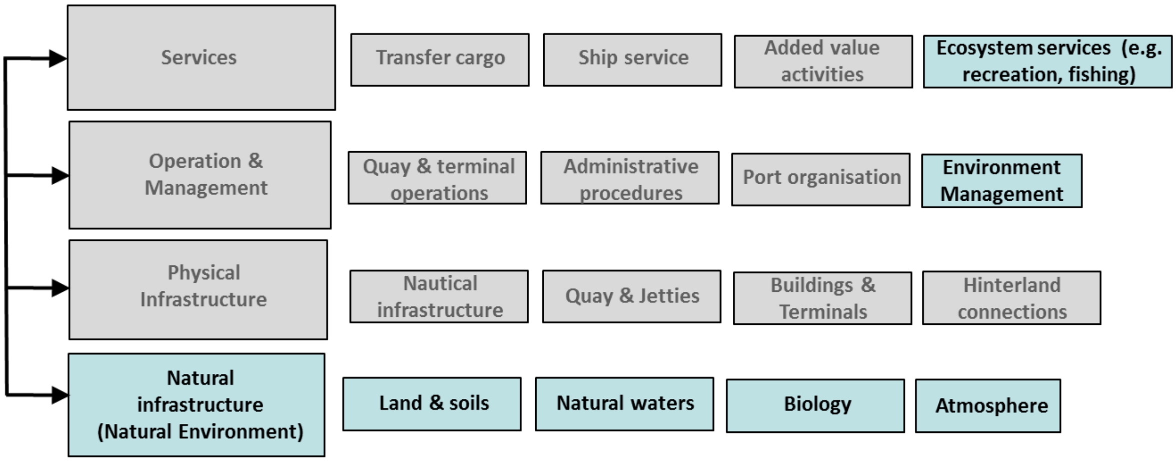

Figure 1: ***Positioning the natural environment (natural infrastructure) in the port inframodel (adapted from Taneja et al. 2012)***

A shift in the competitive environment in ports in recent years, from stability to increasing uncertainty, has necessitated new approaches to port planning and management (Taneja et al., 2012). Flexibility and adaptability are essential in the face of uncertainty. These attributes are no different from those required to handle uncertainties relating to the natural environment, as emerging from the BwN literature (e.g. de Vriend et al., 2014; de Vriend et al., 2015; de Vriend and Van Koningsveld, 2012; Slinger et al., 2016; Vikolainen et al., 2015). To deal with uncertainty and to be pre-emptively flexible and adaptable to changing environmental conditions, the natural environment must be considered and included in infrastructure design. The economic benefits of this have been demonstrated (e.g. de Vriend et al., 2015) and further strengthen the case for the inclusion of natural infrastructure as a layer in the port inframodel.

4.2 Raising the Natural Environment's Profile in Practice

In practice, the challenge of how to change the perception of the environment as being a 'green handbrake' to an 'equal partner' remains. We argue that two emerging concepts can contribute towards achieving this, namely BwN and natural capital.

4.2.1 Building with Nature

The concept of ecological engineering is no longer new, but recently it has gained increasing acceptance and real world application, including to marine infrastructure (Chapman and Underwood, 2011). Spatial scales at which it has been applied have grown with its development to include large scale ecosystem processes, including water flows (ecohydrology) (e.g. Elliot et al., 2016; Wolanski, 2007). BwN has evolved as an approach that seeks to completely integrate engineering and ecological principles into the planning and construction of infrastructure. It further considers societal aspects of the broader system (Van Slobbe et al., 2013). It has been increasingly applied in coastal systems, mostly in the Netherlands but also elsewhere in Europe, Africa, Middle East, Far East, the Americas and Australia (Waterman, 2007). Similar approaches are 'Working with Nature' and 'Engineering with Nature', developed by the World Association for Waterborne Transport Infrastructure and the US Army Corps of Engineers, respectively (Vikolainen et al., 2014). All inherently seek to align natural and engineered systems to achieve broader engineering, environmental and societal benefits.

BwN lends itself well to the integrated port planning and management implementation model proposed here. In considering large scale coastal areas and processes it is a valuable approach to strategic decision-making on issues such as site selection and early design criteria, but it can also be applied to guide engineering design at smaller scales and for specific developments, such port layout plans, breakwaters and quay developments. While environmental and societal benefits are a clearly understood benefit of the approach there is often opportunity in reciprocity in natural processes being used for engineering purposes. A mega-beach nourishment scheme in the Netherlands (the 'Sand Motor') relies on natural sediment dynamic processes to disperse sediments needed to protect the Dutch coast from flood risk (Stive et al., 2013). There are environmental and social co-benefits to this project, which has the objective of achieving coastline stabilization over an extended period of time. The 'Mud Motor' aims to achieve the opposite, using natural flows to direct disposed dredged material to salt marsh where it is bound rather than recirculating back towards areas which need to be dredged for the purpose of safe navigation. This has the benefits of reducing dredging costs for the port authority, enhancing salt marsh development, stabilizing foreshores and reducing dike maintenance costs (Baptist et al., 2019; Van Eekelen et al., 2016).

4.2.2 Co-benefiting from natural capital

An appreciation of the vast array of societal benefits that derive from the world's natural resources has coined the term *natural capital* - an extension of the more common economic notion of capital (e.g. Hein et al., 2016). Competition for resources and environmental space no longer affords the luxury of single-use exploitation of natural resources, and this is true in the case of ports (de Vriend et al., 2015). The acknowledgement of wider societal and environmental issues in port planning and management is reflected in the notion of 5th generation ports (Kaliszewski, 2018; Lee et al., 2018). The National Ports Authority of South Africa has embraced the concept of natural capital, already acknowledging it as one of its 'capitals' together with financial capital and human capital, amongst others (TNPA, 2017). However, the challenge lies in releasing the additional benefits offered by natural capital contained in ports, while still ensuring they fulfil their primary role as gateways to global trade.

In this regard the upsurge of waterfront revitalization occurring in port-cities across the world holds promise. These developments capitalise on the social heritage value and charm of refurbishing old port buildings next to the sea through urban renewal, entrepreneurialism, recreation and tourism (Hoyle, 2000; Hoyle, 2001; Oakley, 2005). Challenging local and global forces are at play but emerging multi-use benefits can be gained by re-kindling a lucrative, historical port-city intimacy, lost as a result of the global transformation in maritime technology (Hoyle, 2001; Oakley, 2005). Successful waterfront revitalization emerges from an appreciation of distinctive, place-based social and environmental matters. Although most waterfront revitalisation still is confined to advanced countries, successful developments in Cape Town (South Africa) and Lamu (Kenya) are some examples paving the way for the developing world to follow (Hoyle, 2001).

Ports play a major role in the fishing industry, providing access to essential services and supplies, as well as a place to land catches (Huntington et al., 2015). Fishing ports have lined the world's coasts for centuries, ranging from small harbours servicing local markets to major fishing ports supporting large commercial fishing vessels. As with their commercial sea-trading counterparts, fishing ports also are facing greater social and environmental challenges as competition for space increases (Sciortino, 2010). In mixed-use ports fishing industries co-benefit from sheltered coastal spaces together with other commercial port industries (Sciortino, 2010). A concern in the African context, however, is the tendency for large global companies to construct fenced, single-use commercial ports (e.g. dedicated to the oil and gas industry) with little or no recognition of meeting local societal or environmental needs (Kothuis and Slinger, 2018). However, exploring co-benefits for smaller fishing communities as part of these large port developments holds the promise of stimulating local growth and entrepreneurship, and is aligned with the social responsibility envisaged for 5th generation ports (Kaliszewski, 2018; Kothuis and Slinger, 2018; Lee et al., 2018). However, the complexity of global and local forces at play in realizing societal co-benefits in ports necessitates early integration of strategic community, urban and environmental planning in port planning e.g. as early as the site selection and master planning stages. This need for early strategic negotiation for space in common natural resources, and incorporating the concept of ecosystem services, aligns with the approaches of ecosystem-based management, integrated coastal management and marine spatial planning (Douvere, 2008; García-Onetti et al., 2018; Taljaard et al., 2013). Dialectical conflicts among role players remains a challenge (García-Onetti et al., 2018) so collaboration among relevant parties including port authorities, urban planners and affected communities, and consideration of public–private partnerships, is fundamental to most successful outcomes (Oakley, 2007).

4.3 A Framework for Integrated Port Management (IPM)

To embed the natural environment in port development, we draw upon GHD (2013) and propose a port development cycle (Figure 2). This cycle conceptualises the various activities in port development, from the initial site selection through to monitoring and auditing in a logical, cyclical sequence (i.e. site selection, master planning, design, construction, operations and monitoring). It also recognizes the nested nature of the different time frames characteristic of the activities in port development, depicting a larger cycle and a smaller cycle as a nested loop. The larger cycle, involving site selection, planning, design and construction of new or expansive port infrastructure, represents stages typically occurring at 5-year (or longer) intervals (i.e. longer time scales). The smaller cycle (operations and maintenance, and monitoring and auditing) nested within the larger cycle, represents activities that occur continuously, on much shorter (i.e. day-to-day) time scales.

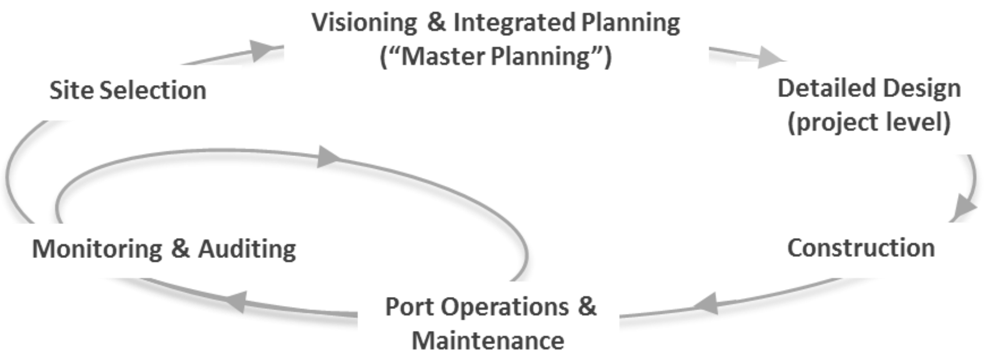

Figure 2: ***The port development cycle in which disparate environmental assessments and management systems are implemented in a fragmented fashion within each of the planning and management activities***

For sustainable port development to occur in practice, planning and actions needs to be integrated into organisational decision-making processes guided by structured frameworks (Hiranandani, 2014). This highlights the importance of proactively integrating environmental aspects into all stages of port development, from the early planning stages through design, construction and into operation.

Internationally, the value of undertaking SEAs in a more integrative manner in early port planning stages is emerging (Deloitte Inc., 2015). In the Port of Antwerp and the Port of Rotterdam severe setbacks were experienced when the planned port expansions of the Deurganckdok and the Maasvlakte 2 were initially rejected by the Councils of State in 2000 and 2005, respectively (Engelsman, 2014). In the Port of Dublin, a deliberate decision was made to undertake the SEA concurrently with the master plan development process, to assess and inform this process in terms of sustainability and the impacts on the environment (Dublin Port Company, 2012a and 2012b). Therefore, in this case the SEA process commenced at an early stage in the development of the master plan. As a result the likely significant environmental effects of various planning scenarios, and their future implementation, identified during the SEA could be integrated, which allowed mitigation to be incorporated into the official master plan to avoid, reduce or offset negative effects, and increase beneficial ones. Further mitigation measures and monitoring requirements identified as part of the SEA for the later implementation stages was also incorporated as part of the official master plan documentation. Running these processes concurrently ultimately influenced and improved the development of the master plan by bringing together and encouraging communication between teams facilitating better integration, awareness and understanding of their respective needs and aspirations, and ensuring an understanding of environmental and social assets, issues and opportunities to be incorporated into the development of options for expanding the port in order to increase efficiency and throughput capacity.

The Port of Vancouver, Canada, as part of its Port 2050 initiative (Port Master Plan), embarked on a year-long stakeholder participation to establish a shared vision for the Vancouver gateway based on a scenario testing approach, in essence aligning traditional port master planning (strong engineering focus) with approaches typically adopted in strategic environmental assessment (Deloitte Inc., 2015). In Rotterdam, following the rejection by the Council of State of the zoning plan in 2005, a new Maasvlakte 2 preparation process was initiated in 2006. The nesting of ecological impact assessment within an overarching strategic environmental assessment was critical in this process, as was broad stakeholder engagement (Engelsman, 2014). A consultative platform representing industrial, ecological and organised environmental interests was also formed. The goals for the port development were balanced. Liveability, environmental quality and port development were equally weighted. The resulting, improved strategic assessment and zonal planning received appreciation from the consultative platform and the inhabitants of the surrounding areas and in 2008 full approval for the Maasvlakte 2 expansion was granted.

Although SEA generally is not a legislated requirement for port development in Africa it is recognised in the port policies of South Africa (DoT, 2002) as an important tool to address environmental sustainability. The application of SEA for proactive integration of environmental issues at the policy and planning level is encouraged. SEAs have been undertaken for some commercial ports in South Africa (e.g. CSIR, 2003; CSIR, 2005; TNPA, 2018). For instance, in the case of the Port of Cape Town (CSIR, 2003), the SEA was not linked directly to port development processes, but was expected to exert influence on such processes in future, as well as influencing the environmental management and the implementation of future corporate social investment programmes. In other instances (e.g. Ports of Richards Bay and Saldanha), SEAs were conducted to assess strategic environmental implications and sustainability considerations, but in response to existing port development plans (CSIR, 2005; TNPA, 2018). Thus, although SEAs have been used to raise the profile of the environment in ports in parts of the African region, they have not yet been applied in an integrative manner as an essential part of early port planning stages, to simultaneously negotiate and combine environmental, social and economic considerations in master planning. Little evidence exists of recommendations from SEAs feeding back into further activities in the port planning and management cycle, nor of being incorporated into practice.

EIA has become a legal requirement in some countries (e.g. RSA, 1998), typically triggered during the port development design stage. Even so, EIA is frequently only initiated in the latter stages of design leaving little opportunity for environmental adaptation and mitigation measures to be integrated into engineering designs. As a result, recurring environmental issues are encountered, and recommended mitigation measures are untested, piecemeal and often not acceptable to environmental lobbies. There is evidence that some ports are losing their societal licence to operate. For example, in the Port of Durban, public dissatisfaction with the EIA process and recommended mitigation measures has resulted in delays and even denials of environmental approvals, and consequent delays in development with negative implications for project costs, national trading efficiencies and knock-on financial losses to the wider economy. This echoes the setbacks experienced in 2000 by the Port of Antwerp and in 2005 by the Port of Rotterdam (Engelsman, 2014), when the planned port expansions were initially rejected. We argue that the environmental issues can be addressed more effectively if the key features of the natural environment are considered early in the design process. The engineering design can then account for potential impacts. Including the natural environment in the early design stages also allows for consideration and inclusion of innovative design concepts, aligned with the principles of BwN (e.g.de Vriend et al., 2015; de Boer et al., 2019; Slinger, 2016; Vikolainen et al., 2015).

At the port operation and maintenance stages, countries usually have prescriptive legislation on measures to be taken to prevent environmental impact for an array of port activities (e.g. ESPO, 2013; Puig et al., 2015, including South Africa (Port Rules - DoT, 2009). With the need to take environmental concerns into consideration, organisations such as the European Sea Ports Organisation have introduced related codes of practice (e.g. ESPO, 2013). Useful methodologies for environmental management systems (EMS) have developed from such codes of practice (Hussain, 2018), such as those for EcoPorts (e.g. Darbra et al., 2005) and Port Performance Indicators – Selection and Measurement (PPRISM) (e.g. Puig et al., 2014; Puig et al., 2015). These include simple check lists for environmental compliance, and tools to stimulate continual improvement of sustainable environmental practices throughout the port planning and management cycle. The ISO 14001 environmental management framework is also used widely for this purpose in ports (I2S2, 2013). In the South African context, EMS is still in the initial stage of being implemented (mostly applying ISO 14001), if at all. Where progress has been made it is mostly still narrowly focused on performance compliance with little feedback into improving planning and management practices. However, eenvironmental management systems (e.g. ISO 14001) in ports are currently strongly issue-based (waste, wastewater, air pollution, dredging, etc.), primarily focussed on environmental performance across specific port activities, e.g. operational performance (monitoring environmental performance across activities), environmental condition performance (monitoring the condition of the environment), and management performance (monitoring management efforts influencing performance) (Puig et al., 2014). Although necessary, this narrow focus on environmental performance (or protection), contributes to the perception of the natural environment as a 'victim' of development that requires costly interventions to prevent or mitigate impact. If environmental management systems also embraced multi-use valuation of the natural environment (ecosystem services), the need for tracking environmental performance and protection would gain wider purpose (García-Onetti et al., 2018). Recent developments of tools for multi-use valuation (e.g. SEEA), as discussed above, hold promise in this regard.

Globally, sustainability assessments are finding their way into port management (e.g. Lu et al., 2016; Pope and Grace, 2006; Schipper et al., 2017), most recently also embracing inclusion of the SDGs of Agenda 2030 (e.g. Nitsenko et al., 2017). In South Africa, sustainability assessments are being conducted on commercial ports, albeit at a broad national scale (TNPA, 2017). Most recently Transnet conducted a national-scale sustainability assessment on the country's logistical infrastructure, including ports, in the context of Agenda 2030's SDGs (Transnet, 2018). However, the extent to which the outcomes of these national-scale assessments are feeding back into local-scale port planning and management remains unclear.

Underpinning all environmental assessments and systems is reliable long-term environmental data and information. This entails data that are collected in a scientifically sound manner, and which are managed and archived in easily accessible formats (Kusek and Rist, 2004). In South Africa, environmental data collection programmes in ports exist but they are not coordinated. Data collection is typically triggered by specific needs, for example an EIA project, or through the initiative of port environmental managers. There is an overarching long-term ecological monitoring programme in place that covers all ports, yielding potentially valuable data and environmental understanding of the systems. While such long-term monitoring programmes are critical in terms of tracking compliance and long-term environmental variability, their value remains limited because outcomes are not widely integrated back into the individual port planning and management cycles to inform improvements. Part of the problem is that scientific data are often not communicated effectively as environmental information and input to port managers. A further aggravation is the lack of a coordinated environmental data management and archiving system, often also resulting in unnecessary duplication in data collection efforts. Digital Port Environmental Information Systems are a potential solution to organise and disseminate environmental information in more accessible, user-friendly formats (e.g. Arabi et al., 2019).

Reflecting on international learning, the advantages of early consideration, alignment and integration of the environment in port development are evident. Taking environmental assessment into account appropriately at all stages in the port development cycle not only facilitates environmental protection, but can also save on infrastructure and operational costs in ports. However, it is not only important to align individual environmental assessment processes with corresponding phases in the port development cycle. The theory and practice of environmental assessment in ICM (e.g. Taljaard et al., 2011, 2012 and 2013) emphasizes the importance of the adaptive learning cycle. Accordingly, it is just as important to ensure continuity in the flow of data, information and knowledge across the various environmental stages to facilitate ongoing integration and improvement of sustainable environmental practices in ports through learning-by-doing. These insights, derived from international learning and best practices, and grounded in the experience of environmental assessment in South

Africa's ports, are synthesized into an Integrated Port Management (IPM) conceptual framework as depicted in Figure 3.

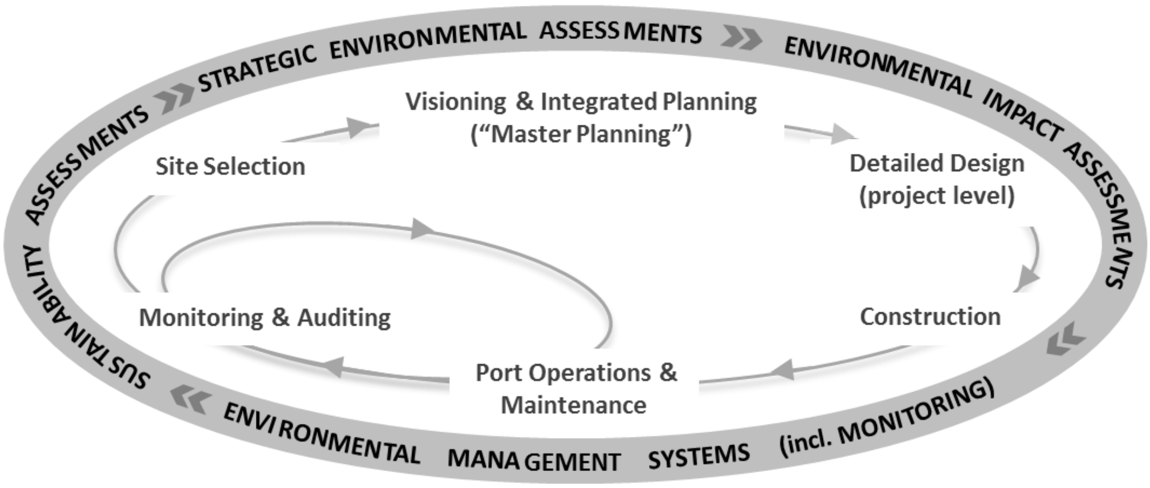

Figure 3: ***A framework for Integrated Port Management (IPM), conceptualising the alignment of environmental assessment processes with the port development phases, as well as the need for integration and continuity across the environmental processes, including monitoring and data management***

The acquisition of environmental data and information - underpinning all environmental matters in ports - is expensive. It is therefore critical that ports make the institutional investment to develop coordinated long-term monitoring strategies across the various environmental assessment procedures and management systems. This would allow monitoring to be conducted in a cost-effective manner geared for multi-purpose use. Further, the value of investing in accessible environmental data, information management and archiving systems to facilitate the multi-institutional flow of information and knowledge on port environmental matters, cannot be underestimated.

5. Conclusion

Drawing on practical scientific experience in port environmental assessment and monitoring in South Africa and the international literature, this paper proposes a change in the conceptual position of the natural environment in port development from that of a 'green handbrake' to an 'equal partner'. By merging the two concepts of natural capital (or natural infrastructure) and port infrastructure systems, the natural environment was first embedded as an integral component in a port infrastructure system. Then practical means were identified through which the profile (or value) of the natural environment can be enhanced in port development. These include applying concepts such as Building with Nature and the multi-use of natural capital.

Finally, arguing that the disconnection and fragmentation of environmental assessment processes in ports contributes to the negative connotations attached to environmental concerns, we build an Integrated Port Management (IPM) conceptual framework that contextualises the alignment of environmental processes within the traditional port development cycle, as well as the necessary continuity and coordination across environmental processes. We propose this simple, practical visualisation as a means of understanding the timing, role and value of environmental processes within the port development cycle, so as to counter the often costly perception of the environment as a ‘green handbrake’ to such development.

While specific regulations relating to environmental issues in ports may differ among countries, port development activities (as depicted in the port development cycle) and the need for environmental assessment (e.g. through SEA, EIA and EMS) are commonly acknowledged. Therefore, although the basis for the formulation of the IPM framework derives primarily from direct experience of South Africa’s port environmental processes and landlord port/public port governance model, we have supplemented this with a review of international best practices and learning. It is our view therefore that this work and the framework proposed may offer insight to, and have applicability in other ports where circumstances are similar (see Baskerville and Lee, 1999; Flyvbjerg, 2006). Such circumstances include ports where the natural environment is taken into consideration albeit in a fragmented fashion, where there is appreciation for the potential offered by innovative ecosystem-based or natural capital approaches, and where the port governance structures are such that interests wider than those of just the port itself are accorded consideration. However, critical to the effective implementation of such a framework will be its adoption in place-based organisational processes, supported by appropriate institutional arrangements.

In essence, to bridge the disconnect between environmental issues and port development in achieving long-term sustainability requires early consideration of the natural environment in port development, and an acknowledgement of the multi-use benefits from natural capital. Further, in the operations and maintenance phases, environmental management systems should not only focus on environmental performance, but also embrace multi-use valuation of the natural environment (ecosystem services) to give purpose to the need for environmental protection. Achieving this may warrant a welcome amendment to Ibrahimi’s (2017) definition of a port: ‘*A commercial port is a territorial, operational and institutional cluster of interrelated* ***[ecological]*** *– social - economic resources, activities and legitimate actors engaged in appropriate agreements...’.*

Acknowledgements

The authors wish to acknowledge the Council for Scientific and Industrial Research (South Africa), the National Research Foundation (NRF) of South Africa and the MultiActor Systems Research Programme of Delft University of Technology for their financial support to this study. Interactions with the Integrated and Sustainable Port Development in Ghana within an African context (W07.69.206) funded by the Netherlands Organisation for Scientific Research (NWO) also are acknowledged.

References

Acciaro, M., Vanelslander, T., Sys, C., Ferrari, C., Roumboutsos, A., Giuliano, Lam, J.S.L., Kapros, S., 2014. Environmental sustainability in seaports: a framework for successful innovation. Maritime Policy & Management 41(5), 480-500.

Arabi, S., Taljaard, S., Weerts S.P., 2019. An Environmental Information System for Ports: Disseminating marine science to managers. WIOMSA 11th Scientific Symposium. 1-9 July 2019, Port Louis, Mauritius.

Alshuwaikhat, H.M., 2005. Strategic environmental assessment can help solve environmental impact assessment failures in developing countries. Environmental Impact Assessment Review 25, 307–317.

Arce, R., Gullòn, N., 2000. The application of Strategic Environmental Assessment to sustainability assessment of infrastructure development. Environmental Impact Assessment Review 20, 393-402.

Audouin, M., Lochner, P., Tarr, P., 2011. SEA in Southern Africa. In: Sadler, B., Aschemann, R., Dusik, J., Fischer, T.B., Partidario, M.R., Verheem, R. (Eds.) Handbook of Strategic Environmental Assessment, Earthscan, London. pp. 151-164

Baptist, M.J., Gerkema, T., Van Prooijen, B.C., Van Maren, D.S., van Regteren, M., Schulz, K., Colosimo, I., Vroom, J., van Kessel, T., Grasmeijer, B., Willemsen, P., 2019. Beneficial use of dredged sediment to enhance salt marsh development by applying a 'Mud Motor'. Ecological engineering 127, 312-323.

Baskerville, R., Lee, A.S., 1999. Distinctions among different types of generalizing in information systems research. In: Ngwenyama, O., Introna, L.D., Myers, M.D., DeGross, J.I. (Eds.) New Information Technologies in Organizational Processes, Springer, Boston, MA. pp.49-65.

Bergen, S.D., Bolton, S.M., Fridley, J.L., 2001. Design principles for ecological engineering Ecological Engineering 18, 201-210.

Barnes-Dabban, H., Van Koppen, K., Mol, A., 2017. Environmental reform of West and Central Africa ports: the influence of colonial legacies, Maritime Policy & Management, 44(5), 565-583.

Blignaut, J., Aronson, J., de Groot, R., 2014. Restoration of natural capital: A key strategy on the path to sustainability. Ecological Engineering 65, 54-61.

Bornmann, B.T., Martin, J.R., Wagner, F.H., Wood, G., Alegria, J., Cunningham, P.G., Brookes, M.H., Friesema, P., Berg, J., Henshaw, J., 1999. In: Johnson, N.C., Malk, A.J., Sexton, W., Szaro, R. (Eds.), Adaptive management. In Ecological Stewardship: A common reference for ecosystem management, Elsevier, Amsterdam. pp.505–534.

Burt, J.A., 2014. The environmental costs of coastal urbanization in the Arabian Gulf, City, 18(6), 760-770.

Chapman, M.G., Underwood, A.J., 2011. Evaluation of ecological engineering of "armoured" shorelines to improve their value as habitat. Journal of experimental marine biology and ecology 400(1-2), 302-313.

Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S.J., et al., 2014. Changes in the global value of ecosystem services. Global Environmental Change 26, 152–158.

CSIR, 2003. Strategic Environmental Assessment: Port of Cape Town Sustainability Framework. CSIR Report No. ENV-S-C 2003-074. Stellenbosch, South Africa.

CSIR, 2005. Strategic Environmental Assessment: The Port of Richards Bay Sustainability Framework. CSIR Report No. ENV-D-C 2004-023. Durban, South Africa.

Darbra, R.M., Ronza, A., Casal, J., Stojanovic, T.A., Wooldridge, C., 2004. The Self Diagnosis Method. A new methodology to assess environmental management in sea ports. Marine Pollution Bulletin 48, 420–428.

Darbra, R.M., Ronza, A., Casal, J., Stojanovic, T.A., Wooldridge, C., Casal, J., 2005. A procedure for identifying significant environmental aspects in sea ports. Marine Pollution Bulletin 50, 866-874.

Darnall, N., Edwards, D., 2006. Predicting the cost of environmental assessment adoption: The role of capabilities, resources and ownership structure. Strategic Management Journal 27, 301–320.

de Boer, W., Mao, Y., Hagenaars, G., de Vries, S., Slinger, J., Vellinga, T., 2019. Mapping the sandy beach evolution around seaports at the scale of the African continent. Journal of Marine Science and Engineering 2019, 7, 151. https://doi.org/10.3390/jmse7050151.

de Boer, W., Slinger, J., Kangeri, A., Vreugdenhil, H., Taneja, P., Addo Appeaning, K., Vellinga, T., 2019. Identifying Ecosystem-Based Alternatives for the Design of a Seaport's Marine Infrastructure: The Case of Tema Port Expansion in Ghana. Sustainability 11: 6633-6651. doi:10.3390/su11236633.

Delmar, C., 2010. "Generalizability" as Recognition: Reflections on a Foundational Problem in Qualitative Research. Qualitative Studies, 1(2), 115-128.

Deloitte Inc., 2015. Port 2050 Scenarios Update Final Report. https://www.portvancouver.com/wp-content/uploads/2015/03/2015-04-07-Port-2050-Scenario-Refresh-Final-Report-with-appendices.pdf, Accessed on 4 March 2020.

de Vriend, H.J., Van Koningsveld, M., 2012. Building with Nature: Thinking, acting and interacting differently. EcoShape, Building with Nature, Dordrecht, the Netherlands.

de Vriend, H.J., Koningsveld, M., Aarninkhof, S.G.J., De Vries, M.B., Baptist, M.J., 2015. Sustainable hydraulic engineering through Building with Nature. Journal of Hydro-environment Research 9, 159-171.

de Vriend, H.J., Van Koningsveld, M., Aarninkhof, S.G.J., 2014. Building with Nature: the new Dutch approach to coastal and river works. Proceedings of the Institution of Civil Engineers - Civil Engineering 167(1), 18-24.

Deming, W.E., 1986. Out of the Crisis. MIT Press, Cambridge, Massachusetts, USA.

Department of Environmental Affairs and Tourism (DEAT), 2004. Strategic Environmental Assessment, Integrated Environmental Management, Information Series 10. Pretoria, South Africa.

Department of Transport (DoT), 2002. National Ports Act (12/2005): Ports Rules. South Africa Government Gazette, No. 23715, 8 August 2002.

Department of Transport (DoT), 2009. National Ports Act (12/2005): Ports Rules. South Africa Government Gazette, No. 31986, 6 March 2009.

Douvere, F., 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. Marine Policy 32, 762-771.

Dublin Port Company, 2012a. Dublin Port Masterplan Strategic Environmental Assessment Environmental Report: Non-Technical Summary. https://www.dublinport.ie/wp-content/uploads/2017/01/Dublin_Port_Masterplan_SEA_ER_NTS.pdf, Accessed on 4 March 2020.

Dublin Port Company. 2012b. Dublin Port Masterplan Strategic Environmental Assessment Environmental Report: Post Adoption Statement. http://www.dublinport.ie/wp-content/uploads/2018/04/06.-DPC_MP_SEA_-POST-ADOPTION-STATEMENT-Feb-2012.pdf, Accessed on 4 March 2020.

Elliott, M., Mander, L., Mazik, K., Simenstad, C., Valesini, F., Whitfield, A., Wolanski, E., 2016. Ecoengineering with ecohydrology: successes and failures in estuarine restoration. Estuarine, Coastal and Shelf Science 176, 12-35.

Engelsman, H., 2014. Organizational structure and culture changes in the Port of Rotterdam and Port of Antwerp after rejection of their zoning plans; What did they learn from the past for the long-term? MSc Thesis, Delft University of Technology, Delft. 184p

Bergqvist, R., Monios, J., 2019. Green ports in theory and practice. In: Bergqvist, R., Monios, J. (Eds). Green Ports; Inland and Seaside Sustainable Transportation Strategies. Elsevier: Cambridge, MA. pp.1-17.

European Sea Ports Organisation (ESPO), 2013. Top Environmental Priorities of European Ports for 2013. An analysis taking port size and geography into consideration. ESPO, Brussels.

Fischer, T.B., 2003. Strategic environmental assessment in post-modern times. Environmental Impact Assessment Review 23, 155–170.

Fisher, A.C., 1995, Environmental and Resource Economics, Selected essays, Edward Elgar, Hants, UK.

Flyvbjerg, B., 2001. Making Social Science Matter. In: Why Social Inquiry Fails and How It Can Succeed Again. Cambridge University Press, Cambridge, United Kingdom.

Flyvbjerg, B., 2006. Five misunderstandings about case-study research. Qualitative Inquiry, 12(2), 219-245.

García-Onetti, J., Scherer, E.G.M., Barragan, J.M., 2018. Integrated and ecosystemic approaches for bridging the gap between environmental management and port management. Journal of Environmental Management 206, 615-624.

GHD, 2013. Environmental best practice port development: An analysis of international approaches. Report prepared for the Department of Sustainability, Environment, Water, Population and Communities, Canberra, Australia.

Goulielmos, A.M., 2000. European policy on port environmental protection. Global Nest: the Int. J. 2 (2), 189-197.

Gray, P., 2006. Adaptive management in the 21st century. In: Lemieux, C.J., Zorn, P.A., Bellhouse, T.J., Nelson, J.G. (Eds.) Monitoring in Ontario's parks and protected Areas, 3-7. Ontario: Parks Research Forum of Ontario.

Güneralp, B., Lwasa, S., Masundire, H., Parnell, S., Seto, K.C., 2018. Urbanization in Africa: challenges and opportunities for conservation. Environ. Res. Lett. 13, 015002.

Gupta, A.K., Gupta, S.K., Patil, R.S., 2005. Environmental management plan for port and harbour projects. Clean Technologies and Environmental Policy 7, 133–141.

Haezendonck, E., Langenus, M., 2019. Integrated ports clusters and competitive advantage in an extended resource pool for the Antwerp Seaport, Maritime Policy & Management 46(1), 74-91.

Halpern, B.S., Longo, C., Hardy, D., McLeod, K.L., Samhouri, J.F., et al., 2012. An index to assess the health and benefits of the global ocean. Nature 488, 615–622.

Harvey, T., 1984. Environmental intervention: The monitoring paradigm III. Implications for management, education and training. The Environmentalist 4, 265–279.

Hein, L., Bagstad, K., Edens, B., Obst, C., De Jong, R., Lesschen, J.P., 2016. Defining Ecosystem Assets for Natural Capital Accounting. PLoS ONE 11(11), 0164460.

Hiranandani, V., 2014. Sustainable development in seaports: a multi-case study. WMU Journal of Maritime Affairs 13, 127–172.

Hossain, M.T., 2018. Assessment of sustainability initiatives in port operations: An overview of global and Canadian ports. Submitted in partial fulfilment of the requirements for the degree of Master of Environmental Studies, Dalhousie University, Halifax, Nova Scotia, Canada.

Hoyle, B., 2000. Global and local change on the port-city waterfront. The Geographical Review 90(3), 395-417.

Hoyle, B., 2001. Lamu - Waterfront Revitalization in an East African Port-City. Cities 18(5), 297-313.

Huntington, T., Nimmo, F., Macfadyen, G., 2015. Fish Landings at the World's Commercial Fishing Ports. Journal of Ocean and Coastal Economics 2(1), Article 4.

Ibrahimi, K., 2017. A theoretical framework for conceptualizing seaports as institutional and operational clusters. Transportation Research Procedia 25, 261–278.

International Finance Corporation (IFC), 2019. The Business Case for Sustainability. https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Business-Case/, Accessed on 4 March 2020.

International Institute for Sustainable Seaports (I2S2) 2013. Environmental initiatives at seaports worldwide. A snap shot of best practice. www.getf.org/wp-content/uploads/2011/06/2013-Update-Environmental-Initiatives-Worldwide-UPDATE-August-2013-Final-II.pdf, Accessed on 4 March 2020.

Iraldo, F., Testa, F., Frey, M., 2009. Is an environmental management system able to influence environmental and competitive performance? The case of the eco-management and audit scheme (EMAS) in the European Union. Journal of Cleaner Production 17, 1444–1452.

Jay, S., Jones, C., Slinn, P., Wood, C., 2007. Environmental impact assessment: Retrospect and prospect. Environmental Impact Assessment Review 27, 287–300.

Kaliszewski, A., 2018. Fifth and sixth generation ports (5GP, 6GP) – evolution of economic and social roles of ports. https://www.researchgate.net/profile/Adam_Kaliszewski2, Accessed on 4 March 2020.

Klemensits, P., 2019. Economic Development or Environmental Protection? The Dilemmas of the Developing Countries through the Case of the Philippines. European Journal of Sustainable Development 8(1), 281-289.

Kørnøv, L., Thissen, W.A.H., 2000. Rationality in Decision and Policy- Making: Implications for Strategic Environmental Assessment. Impact Assessment and Project Appraisal 18(3), 191 – 200.

Kothuis, B., Slinger, J., 2018. Voices on sustainable ports in Africa. Stories from Tema Port, Ghana. Delft University Publishers, Delft, Netherlands. ISBN 978-94-6186-945-6. 76pp.

Kusek, J. Z., and R. C. Rist. 2004. A handbook for development practitioners. Ten steps to a results-based monitoring and evaluation system. World Bank, Washington, DC.

Lam, J.S.L., Notteboom, T., 2014. The greening of ports: A comparison of port management tools used by leading ports in Asia and Europe, Transport Reviews 34(2), 169-189.

Lam, J.S.L., Van de Voorde, E., 2012. Green port strategy for sustainable growth and development. In: Transport Logistics for sustainable growth at a new level. Proceedings of the International forum on shipping, ports and airports (IFSPA). Yip, T.L., Fu, X., Ng, A.K.Y. (Eds.) Hong Kong, May 28-30, 417-427. Hong Kong: The Hong Kong Polytechnic University.

Lamprecht, J.L., 1997. ISO 14001: Issues and Implementation Guidelines for Responsible Management. Amacom, New York, USA.

Lawer, E.T., Herbeck, J., Flitner, M., 2019. Selective Adoption: How Port Authorities in Europe and West Africa Engage with the Globalizing ‘Green Port’ Idea. Sustainability 11, 5119.

Lee, P.T-W., Lam, J.S.L., Lin, C-W., Hu, K-C., Cheong, I., 2018. Developing the fifth generation port concept model: an empirical test. The International Journal of Logistics Management 29(3), 0957-4093.

Lu, C-S., Shang, K-C., Lin, C-C., 2016. Identifying crucial sustainability assessment criteria for container seaports. Maritime Business Review 1(2), 90-106.

Maritz, A., Shieh, C.J., Yeh, S.P., 2014. Ecology – Green Ports – risk assessment Innovation and success factors in the construction of Green Ports. Journal of Environmental Protection and Ecology 15(3a), 1255–1263.

Meadows, D. H. 2008. Thinking in systems: A primer. Chelsea Green Publishing. 240p.

Nicholls, R.J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., Château, J., Muir-Wood, R., 2008. Ranking port cities with high exposure and vulnerability to climate extremes. Exposure Estimates. OECD Environment Working Papers No. 1, ENV/WKP(2007)1, Organisation for Economic Co-operation and Development. Paris, France. 62p.

Nitsenko, V., Nyenno, I., Kryukova, I., Kalyna, T., Plotnikova, M., 2017. Business model for a sea commercial port as a way to reach sustainable development goals. Journal of Security and Sustainability Issues 7(1), 155-166.

Oakley. S., 2005. Working port or lifestyle port? A preliminary analysis of the Port Adelaide waterfront redevelopment. Geographical Research 43(3), 319-326.

Oakley. S., 2007. The Role of Urban Governance in Re-constructing Place, Economic Function and Social Relations in Urban Waterfront Regeneration: The Case of Port Adelaide, South Australia. Space and Polity 11(3), 279-295.

Pearce, D., Atkinson, G., 1995. Measuring Sustainable Development, The Handbook of Environmental Economics, Bromley D.W. (Ed.), Basil Blackwell, Oxford, UK.

Pintér, L., Hardi, P., Martinuzzi, A., Hall J., 2012. Bellagio STAMP: Principles for sustainability assessment and measurement. Ecological Indicators 17, 20–28.

Pope, J., Grace, W., 2006. Sustainability assessment in context: Issues of process, policy and governance. Journal of Environmental Assessment Policy and Management 8(3), 373–398.

Puig, M., Wooldridge, C., Darbra, R.M., 2014. Identification and selection of environmental performance indicators for sustainable port development. Marine Pollution Bulletin 81, 124-130.

Puig, M., Wooldridge, C., Michail, A., Darbra, R.M., 2015. Current status and trends of the environmental performance in European ports. Environmental Science & Policy 48, 57 – 66.

Reis, J., Stojanovic, T., Smith, H., 2014. Relevance of systems approaches for implementing Integrated Coastal Zone Management principles in Europe. Marine Policy 43, 3-12.

Republic of South Africa (RSA), 1998. National Environmental Management Act 107 of 1998. Government Printer, Pretoria, South Africa.

Republic of South Africa (RSA), 2005. National Ports Act 12 of 2005. Government Printer, Pretoria, South Africa.

Riekhof, M.C., Regnier, E., Quaas, M.F., 2019. Economic growth, international trade, and the depletion or conservation of renewable natural resources. Journal of Environmental Economics and Management 97, 118-133.

Roh, S., Thai, V.V., Wong, Y.D., 2016. Towards sustainable ASEAN port development: Challenges and opportunities for Vietnamese ports. The Asian Journal of Shipping and Logistics, 32(2), 107-118.

Sala, S., Ciuffo, B., Nijkamp, P., 2015. A systemic framework for sustainability assessment. Ecological Economics 119, 314–325.

Schipper, C.A., Vreugdenhil, H., De Jong, M.P.C., 2017. A sustainability assessment of ports and port-city plans: Comparing ambitions with achievements. Transportation Research Part D: Transport and Environment 57, 84-111.

Sciortino, J.A., 2010. Fishing harbour planning, construction and management. FAO Fisheries and Aquaculture Technical Paper 539. Food and Agricultural Organisation of the United National, Rome, Italy.

Slinger, J.H., 2016. Engineering: Building with Nature 101x: series of 11 videos. TU Delft. Dataset https://doi.org/10.4121/uuid:721edfdb-a984-470d-be4e-d66161c6c811, Accessed 4 March 2020.

Slinger, J., Taneja, P., Vellinga, T., van Dorsser, C., 2017. Stakeholder inclusive design for Sustainable Port Development in Africa, Singapore Maritime Technology Conference 2017, 26-28 April, 2017, Singapore.

Slinger, J., Kothuis, B., Vreugdenhil, H., van der Kraan, A., 2017. Sustainable Ports in Africa Stakeholder Workshop 9 February 2017, Tema, Ghana. Documentation and Outcomes. Delft University of Technology, Delft. 21p + appendices.

Slinger, J., 2018. Sustainable Ports in Africa. A practical stakeholder-inclusive, ecosystem-based design approach Interactive workshop session at the 34th PIANC World Congress, 7-12 May 2018, Panama. Series of 4 papers and facilitated interactive discussion.

Stive, M.J., de Schipper, M.A., Luijendijk, A.P., Aarninkhof, S.G., van Gelder-Maas, C., van Thiel de Vries, J.S., de Vries, S., Henriquez, M., Marx, S., Ranasinghe, R., 2013. A new alternative to saving our beaches from sea-level rise: The sand engine. Journal of Coastal Research 29(5), 1001-1008.

Sutton-Grier, A.E., Wowk, K., Bamford, H., 2015. Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. Environmental science and policy 51, 137-148.

Taljaard. S., Slinger, J.H., Van der Merwe, J.H., 2011. Criteria for evaluating the design of implementation models for integrated coastal management. Coastal Management 39, 628-655.

Taljaard, S., Slinger, J.H., Van der Merwe, J.H., 2013. Dual adaptive cycles in implementing integrated coastal management. Ocean and Coastal Management 84, 23-30.

Taljaard, S., Slinger, J.H., Morant, P.D., Theron, A.K., Van Niekerk, L., Van der Merwe, J.H., 2012. Implementing integrated coastal management in a sector based governance system. Ocean & Coastal Management 67, 39–53.

Taneja, P., Ligteringen, H., Walker, W.E., 2012. Flexibility in Port Planning and Design. European Journal of Transport and Infrastructure Research 12(1), 66-87.

Thissen, W.A., Herder, P.M., 2003. Critical infrastructures: Challenges for systems engineering. In: Proceedings of 2003 IEEE International Conference on Systems, Man and Cybernetics. Washington, DC, USA.

Transnet 2018. Sustainability Outcomes Report 2018. https://www.transnet.net/InvestorRelations/AR2018/Sustainability%20Outcomes%20Report.pdf, Accessed on 4 March 2020.

Transnet National Ports Authority (TNPA), 2017. National Ports Authority 2017. https://www.transnet.net/InvestorRelations/AR2017/OD%20Reports/8335_Transnet%202017_NPA%20HR.pdf, Accessed on 4 March 2020.

Transnet National Ports Authority (TNPA), 2018. Strategic Environmental Assessment (SEA) of the Port of Saldanha. South Africa.

Trujillo, L., Nombela, G., 2000. Multiservice Infrastructure. Privatizing Port Services. http://siteresources.worldbank.org/EXTFINANCIALSECTOR/Resources/282884-1303327122200/222Truji-10-24.pdf, Accessed on 4 March 2020.

United National Environmental Programme (UNEP), 2017. SEEA Experimental Ecosystem Accounting: Technical Recommendations. Final Draft V3.2. Prepared as part of the joint UNEP / UNSD / CBD project on Advancing Natural Capital Accounting funded by NORAD.

United Nations (UN), 1992. Assessment of the environmental impact of port development. A guide book for EIA of port development. Economic and Social Commission of Asia and the Pacific https://www.unescap.org/sites/default/files/pub_1234_fulltext.pdf, Accessed on 4 March 2020.

United Nations (UN) 2015. Transforming Our World: The 2030 Agenda for Sustainable Development (http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E, Accessed on 4 March 2020.

United Nations (UN), European Commission, Food and Agriculture Organization of the United Nations, Organisation for Economic Co-operation and Development, World Bank Group, 2014a. System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting. United Nations, New York City.

United Nations (UN), European Commission, Food and Agriculture Organization of the United Nations, Organisation for Economic Co-operation and Development, World Bank Group, 2014b. System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting. United Nations, New York City.

United Nations Development Group (UNDG) 2019. Sustainable Development Goals Acceleration Toolkit. https://undg.org/2030-agenda/sdg-acceleration-toolkit/, Accessed on 4 March 2020.

Van Eekelen, E., Baptist, M.J., Dankers, P., Grasmeijer, B.T., Van Kessel, T., Van Maren, D.S., 2016. Muddy waters and the Wadden Sea harbours. Proceedings WODCON XXI, Miami, Florida.

Van Ierland, E., Graveland, C., Huibert, R., 2000. An environmental economic analysis of the new rail link to European main port Rotterdam. Transportation Research Part D5,197-209.

Van Slobbe, E., de Vriend, H.J., Aarninkhof, S., Lulofs, K., de Vries, M., Dircke, P., 2013. Building with Nature: in search of resilient storm surge protection strategies. Natural hazards 66(3), 1461-1480.

Van Wee, B., 2003. Innovations in Transportation: Research and Policy Lessons of Recent Successful Cases. In: Proceedings of the ERSA Congress, Jyväskylä, August 27–30.

Vanclay, F., 2004. The triple bottom line and impact assessment: How do TBL, EIA, SIA, SEA and EMS related to each other? Journal of Environmental Assessment Policy and Management 6(3), 265-288.

Vellinga, T., 2018. The newest Port of Rotterdam expansion: Innovative and Sustainable. Presented at 39th Council & Conference of Ports Management Association West and Central Africa, July 30 – August 2 2018, Accra, Ghana.

Vikolainen, V., Bressers, H., Lulofs, K., 2014. A Shift Toward Building with Nature in the Dredging and Port Development Industries: Managerial Implications for Projects in or Near Natura 2000 Areas. Environmental Management 54, 3–13.

Villa, F., Bagstad, K.J., Voigt, B., Johnson, G.W., Portela, R., et al., 2014. A Methodology for Adaptable and Robust Ecosystem Services Assessment. PLoS ONE 9(3), 91001.

Villeneuve, C., Tremblay, D., Riffon, O., Lanmafankpotin, G.Y., Bouchard. S., 2017. A Systemic Tool and Process for Sustainability Assessment. Sustainability 9, 1909.

Waas, T., Hugé, J., Verbruggen, A., Wright, T., 2011. Sustainable Development: A Bird's Eye View. Sustainability 3, 1637-1661.

Waterman, R.E., 2007. Land in water, water in land: achieving integrated coastal zone development by Building with Nature. Terra et Aqua 107, 3.

Waterman, R.E., 2010. Integrated coastal policy via Building with Nature. Doctoral thesis, Technical University of Delft, The Netherlands.

Waterman, R.E., Misdorp, R., Mol, A., 1998. Interactions between water and land in The Netherlands. Journal of Coastal Conservation 4, 115-126.

Weinberg, G.M., 1975. An introduction to general systems thinking. Wiley, New York.

Wolanski, E., 2007. Estuarine ecohydrology. Elsevier.

Wooldridge, C.F., McMullen, C., Howe, V., 1999. Environmental management of ports and harbours - implementation of policy through scientific monitoring. Marine Policy 23(4/5), 413-425.

World Bank, 1990. Environmental Considerations for Port and Harbor Developments. World Bank Technical Paper number 126. Transport and the Environment Series. http://documents.worldbank.org/curated/en/931761468782116353/pdf/multi-page.pdf , Accessed on 4 March 2020.

World Forum on Natural Capital. 2018. What is Natural Capital? https://naturalcapitalforum.com/about/, Accessed on 4 March 2020.

Wright, C., 2002. Sea ports: Can strategic environmental assessment improve environmental assessment in the port sector? Thesis presented in part-fulfilment of the degree of Master of Science in accordance with the regulations of the University of East Anglia, United Kingdom.

Supplementary Material: Demonstration of authors' practical experience in port environmental assessment, monitoring and management in South Africa (primarily captured in grey literature)

Environmental assessment
CSIR, 2004. Strategic environmental assessment Port of Cape Town - sustainability framework. CSIR Report ENV-S-C 2003-074. Stellenbosch, South Africa.
CSIR, 2005. Strategic Environmental Assessment: Port of Richards Bay Sustainability Framework Summary Report. CSIR Report ENV-D-C 2005-014, Durban, South Africa.
CSIR, 2013 Port of Saldanha SEA CSIR Report CSIR/CAS/EMS/ER/2013/0009/B, Stellenbosch, South Africa.
Newman, B.K., Weerts, S.P., Porter, S., Mackay, F., 2008. Specialist studies for Transnet: capital expansion program Durban Bay. CSIR Report CSIR/NRE/ECO/ER/2008/0011/C, Durban, South Africa.
Van Ballegooyen, R., Bergman, S., 2012. Pier 1 in-fill development, Port of Durban: Modelling of potential environmental change in the port marine environment. CSIR Report CSIR/NRE/ECO/ER/2012/0068/B.
Newman, B., Weerts, S., Van Ballegooyen, R., 2013. Proposed development of Tug Basin, Durban Bay: Screening Level Environmental Impact Assessment. CSIR Report CSIR/NRE/ECOS/ER/2013/0048/B, Durban, South Africa.
Weerts, S.P., Van Ballegooyen, R.C., Newman, B.K., 2012. Deepening, Lengthening and Widening of Berths 203 to 205, Pier 2, Container Terminal, Port of Durban: Potential Long Term Impacts of Development Options 3C - 3H on Sandbank Habitats, Water and Sediment Quality. CSIR Report CSIR/NRE/ECOS/IR/2012/0057/C, Durban, South Africa.
Newman, B., Weerts, S., Van Ballegooyen, R., 2013. Proposed development of Tug Basin, Durban Bay: Screening Level Environmental Impact Assessment. CSIR Report CSIR/NRE/ECOS/ER/2013/0048/B, Durban, South Africa.
Van Ballegooyen, R., Theron, A., Lück-Vogel, M., Taljaard, S., 2012. Terminal de Carvão da Matola Phase 4 Expansion Project, Mozambique: Integrated Marine environmental impact assessment specialist study. CSIR Report CSIR/NRE/ECOS/ER/2012/0081/B, Stellenbosch, South Africa.
Weerts, S.P., Clark, B.M., Newman, B.K., 2014. Ecological Risk Assessment pertaining to the creation of Estuarine Habitat in Durban Bay by extension of the Central Sandbank. CSIR Report CSIR/NRE/ECOS/ER/2014/0002/C, Durban, South Africa.
Cyrus, D.P., MacKay, C.F., Weerts, S.P., Viljoen, A., 1999. A preliminary assessment of the ecological impacts of dredge spoil disposal on Richards Bay beaches. CRUZ Investigational Report No. 81: 48 pp. (consultants to Portnet Richards Bay through the Institute of Natural Resources).
Cyrus, D.P., MacKay, C.F., Weerts, S.P., Viljoen, A., 1999. Environmental Scoping Report: Options and impacts of the development of a quay for the South Dunes Coal Terminal (SDCT) in the port of Richards Bay. CRUZ Investigational Report No. 84: 28 pp. (consultants to Portnet Richards Bay through the Institute of Natural Resources).
Weerts, S.P., Viljoen, A., Cyrus, D.P., 1999. Preliminary investigation of the aquatic invertebrates, ichthyofauna and water quality of the Mvuzane River with comment on the effects of an inter-basin water transfer. CRUZ Investigational Report No. 85: 27 pp. (consultants to Mhlathuze Water through IWR Environmental).
Cyrus, D.P., MacKay, C.F., Weerts, S.P., Viljoen, A., 2000. Evaluation of the environmental impacts of full spoil disposal, with mitigating measures, onto the Central Beach, Richards Bay: Addendum to CRUZ Investigational Report No. 84. CRUZ Investigational Report No. 86: 32 pp. (consultants to Portnet Richards Bay through the Institute of Natural Resources).

Environmental monitoring and management
Cyrus, D.P., Viljoen, A., Weerts, S.P., 1998. Berth 304 dredge spoil monitoring Pre & Post survey. CRUZ Investigational Report No. 73: 26 pp.
Weerts, S., Newman, B., Arabi, S., 2011. Long-term ecological monitoring in the Port of Port Elizabeth. Final report. CSIR Report CSIR/NRE/ECOS/ER/2011/0073/C+, Durban, South Africa.
Pillay, S., Blair, A., Weerts, S., Rajkumar, A., Newman, B., 2012. Protocol and thresholds for monitoring potential ecological impacts of dredging at Maydon Wharf Berth 12, Port of Durban. CSIR Report CSIR/NRE/CO/ER/2012/0036/B, Durban, south Africa.
Newman, B., Weerts, S., Arabi, S., 2011. Long-term ecological monitoring for the Port of Cape Town: Surveys made in 2011. Final Report. CSIR Report CSIR/NRE/ECOS/IR/2011/0121/B, Durban, South Africa.
Newman, B., Weerts, S., Arabi, S., 2011. Long-Term Ecological Monitoring for the Port of Ngqura: Surveys made in 2011. Final report. CSIR Report CSIR/NRE/ECOS/IR/2011/0120/B, Durban, South Africa.
Newman, B., Weerts, S., Arabi, S., 2011. Long-term ecological monitoring for the Port of Richards Bay: Surveys made in 2011. Final report. CSIR Report CSIR/NRE/ECOS/IR/2011/0126/B, Durban, South Africa.
Newman, B., Weerts, S., Arabi, S., 2011. Long-term ecological monitoring for the Port of Mossel Bay: Surveys made in 2011. CSIR Report CSIR/NRE/ECOS/IR/2011/0124/B, Durban, South Africa.
Newman, B., Weerts, S., Arabi, S., 2011. Long-term ecological monitoring for the Port of Port Elizabeth: Surveys made in 2011. Final report. CSIR Report CSIR/NRE/ECOS/IR/2011/0125/B, Durban, South Africa.
Newman, B., Weerts, S., Arabi, S., 2011. Long-Term ecological monitoring for the Port of East London: Surveys made in 2011. Final Report. CSIR Report CSIR/NRE/ECOS/IR/2011/0123/B, Durban, South Africa.
Newman, B., Arabi, S., Weerts, S., 2012. Long-term ecological monitoring for the Port of Ngqura. Surveys made in 2012. CSIR Report CSIR/NRE/ECOS/IR/2012/0058/B, Durban, South Africa.
Arabi, S., Newman, B., 2013. Long-Term Ecological Monitoring for the Port of Cape Town. CSIR Report CSIR/NRE/ECOS/IR/2013/0052/C, Durban, South Africa.
Arabi, S., Newman, B., 2013. Long-term ecological monitoring Port of East London. CSIR Report CSIR/NRE/ECOS/IR/2013/0055/C, Durban, South Africa.
Arabi, S., Newman, B., Weerts, S., 2013. Long-term ecological monitoring in Port of Durban. CSIR Report CSIR/NRE/ECOS/IR/2013/0054/C, Durban, South Africa.
Arabi, S., Newman, B., 2013. Long-term ecological monitoring in Port of Port Elizabeth. CSIR Report CSIR/NRE/ECOS/IR/2013/0057/C, Durban, South Africa.
Newman, B., Arabi, S., Weerts, S., 2014. Long-term ecological monitoring for Richards Bay: Surveys made in 2013. CSIR Report CSIR/NRE/ECOS/IR/2014/0043/B, Durban, South Africa.
Newman, B., Arabi, S., 2013. Long-term ecological monitoring for the Port of Ngqura. Surveys made in 2013. CSIR Report CSIR/NRE/ECOS/IR/2014/0009/B, Durban, South Africa.
Newman, B., Arabi, S., Weerts, S., 2014. Long-term ecological monitoring for the Port of Mossel Bay: Surveys made in 2013. CSIR Report CSIR/NRE/ECOS/IR/2014/0010/B, Durban, South Africa.
Newman, B., Arabi, S., Weerts, S., 2014. Long-term ecological monitoring for the Port of Cape Town: Surveys made in 2013. CSIR Report CSIR/NRE/ECOS/IR/2014/0042/B, Durban, South Africa.
Newman, B., Arabi, S., Weerts, S., 2014. Long-term ecological monitoring for the Port of East London: Surveys made in 2013. CSIR Report CSIR/NRE/ECOS/IR/2014/0008/B, Durban, South Africa.
Newman, B., Arabi, S., Weerts, S., 2014. Long-term ecological monitoring Port of Port Elizabeth: Surveys made in 2013. CSIR Report CSIR/NRE/ECOS/IR/2014/0023/B, Durban, South Africa.
Newman, B., Arabi, S., Weerts, S., 2014. Long-term ecological monitoring for the Port of Durban: Surveys made in 2013. CSIR Report CSIR/NRE/ECOS/IR/2014/0011/B, Durban, South Africa.
Newman, B., Arabi, S., 2014. Long-term ecological monitoring for the Port of Ngqura. Surveys made in 2014. CSIR Report CSIR/NRE/ECOS/IR/2014/0099/C, Durban, South Africa.
Newman, B.K., Weerts, S.P., Omarjee, A., Pillay, R., 2016. Long-term ecological monitoring programme for the Port of Ngqura: surveys made in 2015/2016. CSIR Report CSIR/NRE/ECOS/IR/2016/0151/C, Durban, South Africa.
Newman, B.K., Weerts, S.P., Omarjee, A., Pillay, R., 2016. Long-term ecological monitoring programme for the Port of Mossel Bay: surveys made in 2015/2016. CSIR Report CSIR/NRE/ECOS/IR/2016/0150/C, Durban, South Africa.
Newman, B.K., Weerts, S.P., Omarjee, A., Pillay, R., 2016. Long-term ecological monitoring programme for the Port of Cape Town: surveys made in 2015/2016. CSIR Report CSIR/NRE/ECOS/IR/2016/0148/C, Durban, South Africa.
Newman, B.K., Weerts, S.P., Omarjee, A., Pillay, R., Rajkumar, A., 2016. Long-term ecological monitoring programme for the Port of East London: surveys made in 2015/2016. CSIR Report CSIR/NRE/ECOS/IR/2016/0149/C, Durban, South Africa.
Taljaard, S., Arabi, S., Weerts, S.P., van Niekerk, L., Ramjukadh, C., 2017. uMhlathuze & Richards Bay Estuarine Management Plan. CSIR Report CSIR/NRE/ECOS/IR/2018/0031/B, Durban, South Africa.