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ARTICLE

Adapting environmental management systems for African ports

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Abstract
Globally sustainable environmental practices in ports have been linked to socio-economic benefits. While African ports are increasingly acknowledging environmental issues and starting to address these in environmental policy, many are still struggling with effective implementation of sound environmental management practices. Multiple factors have been identified as potentially contributing to these challenges including institutional limitations, financial constraints, and limited human and technical capacity. In this paper, we propose an EMS framework for African ports, based on international best practice, but customised to specific continental challenges, and taking guidance from integrated coastal management (ICM) best practice recognising that coastal systems are the broader domain within which ports are spatially situated. The Plan-Do-Check-Act (PDCA) model provides the adaptive management structure for the proposed EMS framework. We consider this framework as a logical and structured method to initiate the implementation of EMS in African ports more effectively, compatible with international standards such as ISO 14001. Unpacking each of the key components and elements within the PDCA model, together with motivation for their inclusion, provides greater transparency to port managers who ultimately have to understand and implement EMS processes.

Keywords Port environmental management system · Integrated coastal management · Participation · Spatial planning · Monitoring and evaluation · Communication

1 Introduction

Sea ports are significant features of coastal landscapes where a complex array of activities occur which impact the natural environment (Hiranandani 2014). These include atmospheric emissions, wastewater and ballast water discharges, production

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of solid waste, hazardous ship and port generated waste, oil spills, and dredging operations (Darbra et al. 2004; Darbra et al. 2005; Lawer 2019; Romero et al. 2014). Driven by growing environmental awareness, importance of good corporate image, pressure from legislation, and a requirement to consider third party and stakeholder needs, ports are increasingly compelled to be more cognisant of sustainability and accounting for the natural environment in their operations (Taljaard et al. 2021). This has led to the development of concepts such as green ports, sustainable ports, and eco-ports (Darbra et al. 2004; Wu et al. 2020). Towards achieving sustainability, environmental processes, such as Strategic Environmental Assessment (SEA), Integrated Environmental Management (EIA), and Environmental Management Systems (EMS), are increasingly being undertaken in ports worldwide (Taljaard et al. 2021). EMS provide a systematic means for port authorities to prepare plans that list legal requirements regulating their operations, identify environmental policy objectives, address environmental issues related to their operations, and develop and implement mitigating actions (Hossain 2018; Lawer et al. 2019). EMS facilitate the management of environmental issues in a port's day-to-day operations. EMS also contribute to social and economic benefits beyond those relating to environmental compliance, for example by improving efficiencies, reducing costs, and minimising negative impacts on human health, product/service quality, employees' motivation and performance, competitive position, market acceptance, and consumer satisfaction (Deming 1986; Darnall and Edwards Jr 2006; Iraldo et al. 2009; Martín-Peña et al. 2014).

Several generic EMS methods have been developed and are officially endorsed in many parts of the world, including the International Organisation for Standardisation (ISO) 14001 standard (ISO 2020a) and the Eco-Management and Audit Scheme (EMAS) (Petrosillo et al. 2012; Testa et al. 2014). A few have been specifically adapted for port environments, such as EcoPorts (ESPO 2020) and the World Association for Waterborne Transport Infrastructure (PIANC) Environmental Management Framework (Whitehead 2000). Internationally, there is a growing trend in the uptake of EMS in ports, although mostly in developed countries (Hossain 2018).

Africa has been identified as the world's fastest growing continent and its reliance on import and export of goods makes ports a significant role player in its future economic development (Barnes-Dabban et al. 2018). Regionally, organisations such as the Port Management Association of West and Central Africa (PMAWCA), the Regional Co-ordinating Unit (RCU) of the Abidjan Convention, and Environmental Non-Governmental Organisations (ENGOs) such as the Ports Environmental Network-Africa (PENAf) have recognised an urgent need to address environmental issues in ports (Barnes-Dabban et al. 2018). Port environmental reform is increasingly receiving attention, following institutional reform from the early 2000s as port authorities gained greater autonomy and started engaging in environmental policymaking, including the implementation of EMS (Barnes-Dabban et al. 2017; Barnes-Dabban et al. 2018). For example, in 2015, port authorities, through the Parties of the Abidjan Convention, convened to prioritise common environmental risks and to develop action plans to address risks using available EMS tools, resulting in the Ports of Abidjan and Tema achieving ISO 14001 certification (Barnes-Dabban and Karlsson-Vinkhuyzen 2018; Lawer et al. 2019). While this shows progress to

sustainable environmental reform, especially in West and Central Africa (Barnes-Dabban et al. 2018; Lawer et al. 2019), several other ports in Africa are still struggling with effective implementation of sound environmental management (Pescatori and Franceschini 2017; Taljaard et al. 2021). Multiple factors contribute to this including institutional limitations, financial constraints, and lack of human and technical capacity (Pescatori and Franceschini 2017). A critical review of these challenges is provided later in this paper.

We argue that ineffective implementation of EMS in African ports partially stems from a lack of sound science-based frameworks for implementation that acknowledge continental challenges pertaining to environmental management. This paper, therefore, aims to design a proposed EMS framework for African ports, building on international best practice but adapted to continental challenges. Acknowledging that ports are located in the broader coastal domain, guidance is also taken from best practice in Integrated Coastal Management (ICM).

2 Approach and method

In this paper, we deviate from the traditional empirical environmental science methods (experiment, survey, analyse results) and instead adopt a design science approach (Bots 2007; Taljaard et al. 2013), comprising a prototype design, which is then refined drawing on new learning gained through the research process. Following Flyvbjerg (Flyvbjerg 2001, 2006), Delmar (2010), and Taljaard et al. (2021), this research process primarily combines place-based experiential knowledge with learning gained through the interrogation of secondary data in the international literature. Place-based experiential knowledge is that situational knowledge of the authors, in this instance, garnered over more than 20 years as environmental scientists and consultants in port environmental monitoring and assessment (see Supplementary Data in Taljaard et al. 2021 for a listing of key projects to demonstrate practical experience), as well as research in ICM implementation (e.g. Taljaard et al. 2011; Taljaard et al. 2021; Taljaard et al. 2013). Through these studies, ongoing engagement with port environmental staff provided exposure to the issues typically encountered in the implementation of port environmental management processes.

The framework development process comprised four stages (Fig. 1). First, an analysis was undertaken of key international EMS methods currently applied in ports to distil and consolidate commonalities. These were structured in accordance with the Plan-Do-Check-Act (PDCA) model and comprised the prototype EMS framework. While effective EMS implementation frameworks must be adapted to organisational culture and priority issues (Balzarova et al. 2006), most apply the PDCA model (Graham et al. 2011; Rebelo et al. 2014). The PDCA model (also referred to as the Deming cycle) was originally developed by Shewhart in the 1930s (Shewhart 1939) and improved by Deming in the 1950s (Deming 1986). The ‘plan’ stage involves the development of improvement plans, the ‘do’ stage entails implementation of the identified actions, the ‘check’ stage reviews the effectiveness of planning and implementation, and finally, the ‘act’ stage addresses possible adaptations or changes to improve the effectiveness for the EMS following an adaptive

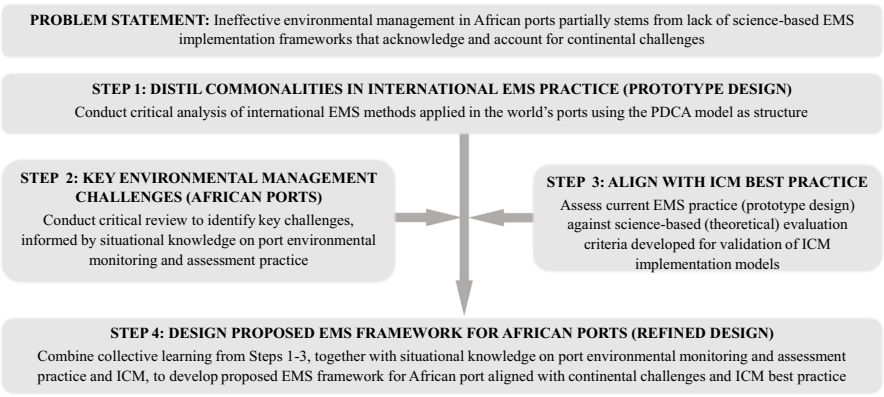

Fig. 1 Schematic overview of approach and method applied in this research

management approach (Nguyen et al. 2020). Following this, we critically reviewed available scientific literature, and reflected on our own situational knowledge, to identify key environmental management challenges typically encountered in the African context. Testing these against elements in the prototype, we were able to establish whether the prototype accounted for continental challenges, or if refinements were required. Furthermore, taking the stance that ports are spatially situated in larger coastal systems, we argued that sound environmental management in ports also can draw on learning from successful implementation of ICM, a field that has been studied much more extensively in the scientific literature. To validate the prototype against science-based (or theoretical) criteria for ICM (after Newman et al. 2002), we applied evaluation criteria developed by Taljaard et al. (2011) which have previously been used in an African context (Taljaard et al. 2013). The purpose was to establish whether science-based learning from ICM best practice could potentially be incorporated to improve the EMS prototype. Finally, this collective learning was combined to construct the proposed EMS framework for African ports (refined design), adapted to continental challenges in environmental management, and aligned with ICM best practice.

3 Analysis of current EMS practice in ports

To identify commonalities in current EMS practice, we interrogated four of the most prominent methods applied in ports worldwide, namely the International Organisation for Standardisation (ISO) 14001 standard (Brouwer and van Koppen 2008; Rebelo et al. 2014; ISO 2020a), the Eco-Management and Audit Scheme (EMAS) (Petrosillo et al. 2012; Testa et al. 2014), EcoPorts (Darbra et al. 2004; ESPO 2012a; 2020), and the World Association for Waterborne Transport Infrastructure (PIANC) Environmental Management Framework (Whitehead 2000) (Table 1). Two complimentary approaches, applicable to specific aspects within EMS, were also evaluated,

Table 1 Key elements in prominent EMS methods currently applied in ports structured within the Plan-Do-Check-Act model (● = completely addressed; ◖ = partially addressed)

COMPONENT & ELEMENT	METHOD			
	ISO 14001	Eco-Management and Audit Scheme (EMAS)	ECOPORTS (SDM & PERS)	PIANC Framework
PLAN				
Obtain commitment to EMS from organisational leadership	●		●	
Identify legislative and environmental policy requirements	●	●	●	●
Identify environmental impacts, activities, opportunities & risks (EMS scope)	◖	●	●	
Define environmental objectives and targets	●	●	●	●
Develop management action plans	●	●	●	◖
Identify team structure & responsibilities (human resource plan)	●	●	●	●
Design process for internal and external communication	●		●	●
Document EMS planning process	●			
DO				
Communicate & train port employees (competence and awareness)	●	●	●	●
Perform operational controls	●	●		●
Communicate with external stakeholders	●	●	●	●
Prepare emergency preparedness & response plans	●			
Record day-to-day performance	●	●	●	●
Conduct environmental monitoring and evaluation	●	●	●	●
CHECK				
Assess compliance (legislative, environmental objectives & targets)	●	●	●	●
Perform internal audits (e.g. annually)	●	●	●	●
Identify and record non-conformance & related corrective actions	●	●	●	●
ACT				
Implement corrective actions relating to non-conformance	●	●	●	●
Review through external auditing (e.g. 3-yearly)	●		●	●
Review by organisational leadership (to secure commitment)	●	●	●	●
Adapt and improve EMS programme (e.g. revisit 'plan', etc.)	●	●	●	●

the Port Performance Indicators (PPRISM) (ESPO 2012b) and Strategic Overview of Significant Environmental Aspects (SOSEA) (Darbra et al. 2005).

ISO 14001 was first established in 1996 (Christini et al. 2004; European Union 2016; ISO 2020a) and has since become one of the internationally recognised standards for setting criteria for effective EMS implementation (Christini et al. 2004; ESPO 2012a; ISO 2020a). Although not originally designed for ports, ISO 14001 was one of the first EMS methods that applied to port environments (Christini et al. 2004). Two major revisions to the original 1996 method have since been undertaken, one in 2004 and the other in 2015 (Ferreira et al. 2019; ISO 2020b).

As with most EMS, ISO 14001 applies the PDCA model (Graham et al. 2011; Martin 1998; ISO 2020a; Martins and Fonseca 2018; Rebelo et al. 2014; Stapleton et al. 2001). Ultimately responsibility and effective implementation of EMS requires the buy-in and support of organisational leadership and this is acknowledged as a key element within the 'plan' phase in ISO 14001 (ISO 2020a; Martins and Fonseca 2018). During this phase, the identification of environmental issues and related

activities is also stipulated, not only to address issues associated with current activities but also those that might arise in future and are a result of planned activities. Legislative and statutory requirements pertaining to environmental matters in ports also need to be identified, as well as specific environmental objectives and targets. The latter should be implementable, achievable, and measurable. Identification of resources to establish, maintain, and improve the EMS forms part of planning, together with proper documentation of the planning process and decisions, including supporting documentation.

Within the 'do' phase, ISO 14001 recognises the importance of familiarising and training the EMS implementation team to ensure awareness and competence, as well as keeping of training records (ISO 2020a; Martins and Fonseca 2018) (Table 1). The importance of communicating with external stakeholders regarding significant environmental aspects, and the implementation of operational controls and emergency response preparedness is also stipulated. It also covers environmental monitoring and evaluating, stressing the importance of properly calibrating and maintaining monitoring equipment.

In the 'check' phase, assessing compliance involves the implementation of procedures to evaluate adherence to predefined legal and environmental objectives and targets, specifically with the aim of identifying nonconformities. The latter should be holistic, recording the causes and impacts, proposed mitigation, as well as the responsible departments and/or authorities. Internal audits are also a mechanism to control quality in the implementation of the EMS process within the 'check' phase and can form part of a port's overall management review process (Martin 1998).

In ISO 14001, the 'act' phase is primarily concerned with the implementation of corrective actions pertaining to non-conformances, review, and acknowledgement of implementation programmes by the organisational leadership. External auditing by third party auditors is advisable to obtain a neutral, objective, and critical evaluation of the EMS (Martin 1998). Where required, adapting and improving the EMS process (that is revisiting the different phases from 'plan' onward) is an important final step in the 'act' phase, in accordance with the adaptive management approach (ISO 2020a).

The European Union's Eco-Management and Audit Scheme (EMAS) was developed in 1993, originally as a voluntary tool for organisations to improve environmental performance and communicate environmental matters with stakeholders and the society at large in the European Union (EU) (EC 2011; 2017). It was one of the first EMS to be applied in ports in the region and elsewhere across the world (e.g. Port of New York/New Jersey, Port of Venice, Port of Barcelona) (Testa et al. 2014). EMAS is, for the most part, well aligned with ISO 14001 (European Union 2016; Martins and Fonseca 2018; Testa et al. 2014), but it is silent on the importance of organisational leadership buy-in to the EMS process, possibly as this may not be viewed as a serious challenge within well-regulated countries such as in the EU. EMAS is also not explicit on documentation of the planning and decision-making process. However, EMAS provides clear guidance in terms of communication in that external reporting is required through a regular published environmental statement, as well as open dialogue with the public, authorities, and other interested parties (Martins and Fonseca 2018). EMAS also largely mirrors ISO 14001 in the 'do'

phase, except that it is silent on the need for emergency preparedness and response plans (Table 1). Similarly, the 'check' and 'act' phases of EMAS align well with those of ISO 14001, except in terms of requirements pertaining to external (third party) auditing (Table 1).

In 1997, the European Sea Ports Organisation (ESPO) initiated the Eco-Information Project aimed at a holistic approach to port environmental management (Wooldridge et al. 1998). In 2002, this culminated in the establishment of the Ecoports Foundation (EcoPorts 2020; ESPO 2003) which has since firmly established its reputation as the only port-specific environmental management standard worldwide (ESPO 2003). Although EMAS and ISO 14001 already existed, port authorities found these to be overwhelming and difficult to apply in complex port environments. This highlighted the need to develop a simple EMS that could be implemented by port authorities in preparation for mastering more advanced systems such as ISO 14001 and EMAS (Darbra et al. 2004). The so-called Self Diagnosis Method (SDM) was therefore developed, specifically simplified for application in European ports, but aligned with recognised international standards such as ISO 14001 and EMAS (Darbra et al. 2004; EcoPorts 2020; ESPO 2003; 2012a). The SDM simplified procedures by providing a concise port-specific checklist against which port managers can self-assess the environmental management programme of the port in relation to the performance of both sector and international standards (Darbra et al. 2004; ESPO 2012a). It comprises two sections, the first being the Port Profile to address the legal status and contextualise specific port operations and activities. The second section addresses Environmental Management and Procedures, covering aspects such as such as environmental policy, management organisation and personnel, environmental training of employees, internal and external communication, operational management, emergency and incident planning, monitoring and recording, and review and audit (Darbra et al. 2004). The Port Environmental Review System (PERS), built on the SDM, focuses on the review and reporting of significant aspects of the environmental management relevant to ports (EcoPorts 2020). The SDM, therefore, aids ports in identifying important shortfalls in environmental management, which assists with the development of environmental objectives and targets to aim for and against which to review (or evaluate) performance in PERS (Darbra et al. 2004).

Although the SDM and PERS are not explicitly organised within a PDCA model, most of the aspects addressed in these systems match elements within each of these four phases as in ISO 14001 and EMAS, but specifically customised for easier application in ports. SDM and PERS align with ISO 14001 in the 'plan' phase, apart from documenting of the EMS planning process (Table 1). In the 'do' phase, SDM and PERS lack explicit requirements pertaining to operational planning for emergency preparedness and response (EcoPorts 2020) but align well with ISO 14001 requirements within the 'check' and 'act' phases (Table 1).

ESPO also developed specific methodologies to assist with addressing specific components within the PDCA model, such as Strategic Overview of Significant Environmental Aspects (SOSEA) (Darbra et al. 2005). This tool assists ports in identifying strategic environmental aspects and evaluating their significance within the 'plan' phase (Darbra et al. 2005). The outcomes of SOSEA feed into SDM and PERS towards implementation of EMS in port-certified systems such as ISO 14001

and EMAS. Another such method is Port Performance Indicators – Selection and Measurement (PPRISM) (ESPO 2012b) which supports performance management by identifying a set of relevant and feasible performance indicators, mostly adapted to European ports. These outputs provide the port industry with a means of measuring, assessing, and communicating the interaction of ports systems with society, the environment, and the economy in a transparent manner (ESPO 2012b), spanning the 'do', 'check', and 'act' phases within the PDCA model.

In 2002, the World Association for Waterborne Transport Infrastructure (PIANC) developed its framework aimed at providing generic guidelines on the implementation of environmental management in ports (Whitehead 2000). Although not explicitly expressed as a formal EMS, this framework comprises elements which are recognisable in the PDCA model (Table 1). The framework comprises four main components, the first of which addresses policy, specifically the development of policy statements based on environmental concerns, legislation, and stakeholder inputs (PIANC 1999; Whitehead 2000). The second component deals with general management structures for assessing environmental information as well as prioritising strategies and goals. These two components align well with the 'plan' stage of the PDCA model. The third component in the PIANC framework deals with implementation and includes procedures, training, control of operations, and monitoring, aligning well with the 'do' stage in the PDCA model (PIANC 1999; Whitehead 2000). The last component addresses continual improvement and relies on audits and reviews to check the effectiveness of the system. It includes identifying corrective actions, management review, and reviewing of the goals, spanning the 'check' and 'act' phases in the PDCA model. Thus, despite the PIANC Framework using different terminologies to describe its components, it generally addresses the key elements as per international EMS standards such as ISO 14001 (Whitehead 2000) (Table 1).

Although most EMS's methods reviewed here, and which are currently applied in ports worldwide, do not explicitly acknowledge the PDCA model as a framework, it is possible to recognise and organise corresponding elements of this framework within these EMS methods and draw comparisons amongst them (Table 1). There are strong commonalities in elements addressed across the different EMS, perhaps not surprisingly so given that most of them are modelled on the international certified ISO 14001 standard. These commonalities provide a sound foundation (prototype design) upon which to develop a proposed EMS framework for African ports (refined design).

4 Key challenges facing environmental management in African ports

To facilitate effective environmental reform, EMS frameworks must be adapted to place-based issues (Balzarova et al. 2006). Indeed, a study on West African ports found that context-specific factors strongly influence the type of green port measures adopted in the transition towards sustainability (Lawer et al. 2019). Ports here were found to focus on immediate priority issues such as waste management, rather than future priorities such as climate change mitigation because of limited financial

capacity and relatively little public pressure to deal with climate change (Lawer et al. 2019). On the other hand, local challenges can hamper transition to sustainability, even in addressing immediate priorities, if not acknowledged and accounted for in tools such as EMS frameworks. In this section, we interrogate the international literature and reflect on our own situated knowledge in port environmental management, to identify key challenges encountered in African ports. Testing these against elements in the prototype (Table 1), we make an assessment of whether these challenges are accounted for in current EMS practice, or whether refinements are potentially required to optimise systems for the African context.

Dedicated institutional arrangements for dealing with environmental issues are a key requirement for sustainable port development, or green ports (Di Vaio and Varriale 2018; Lawer et al. 2019). In Africa, ports are predominantly state-owned and are often hindered by operational inefficiencies which result in environmental impacts and other problems. Following institutional reform from the early 2000s to promote competitiveness, port authorities gained greater autonomy and began to engage in environmental policymaking (Barnes-Dabban et al. 2017; Barnes-Dabban et al. 2018). Environmental reform followed, especially in Central and West African ports, including institutionalising environmental interest in dedicated departments (Barnes-Dabbana et al. 2017). This demonstrated the value of adopting flexible and adaptable approaches and developing a communicative and consultative culture in port organisational systems (Barnes-Dabbana et al. 2017) and resulted in the Ports of Abidjan and Tema achieving ISO 14001 certification (Barnes-Dabban and Karlsson-Vinkhuyzen 2018; Lawer et al. 2019). However, the lack of institutionalisation of, and managerial accountability for, environmental issues remains a challenge for sound environmental management in many other African ports (Pescatori and Franceschini 2017; Taljaard et al. 2021). Institutional frameworks are often poorly set up and this is further complicated by complex stakeholder dynamics (Pescatori and Franceschini 2017). In the case of South Africa, legislation does (RSA 2005) promote sustainable environmental development, but the implementation of environmental assessment and monitoring programmes is mostly still executed in a fragmented manner with only limited feed-back to improve port operations (Taljaard et al. 2021). While dedicated institutional arrangements to address environmental matters (e.g. appointment of port environmental managers and officers) have been realised, the official implementation of EMS is still, at best, in the initial stage. Where progress has been made, it is mostly still narrowly focused on compliance with little feedback to improving management practices. The EMS prototype (Table 1) does account for challenges pertaining to *legislation and environmental policies* and *managerial commitment* in the 'plan' component but is not explicit on the importance of *environmental institutionalisation*, for example through the establishment of dedicated environmental departments preferably captured as specific requirements in port legislation and policies.

Together with the lack of managerial accountability, especially in state-owned enterprises, is a lack of financial commitment to address or mitigate environmental impacts in ports (Pescatori and Franceschini 2017; Barnes-Dabban and Karlsson-Vinkhuyzen 2018; Barnes-Dabban et al. 2018). Financial constraints often determine the extent to which environmental matters are addressed in ports. Often the

focus is on short-term priority issues, rather than dealing with environmental risks in a more holistic manner (Lawer et al. 2019). Financial challenges are a reality in most developing countries, even though financial sustainability remains a key pillar of effective implementation of environmental management in port, requiring a proactive coordination already in the planning phases (Di Vaio and Varriale 2018). Financial planning and securing of financial resources is probably viewed as an implicit requirement for EMS and, therefore, not explicitly addressed in existing EMS methods (Table 1). However, in the context of African ports, it may be crucial to explicitly identify this as an element in the 'plan' component, emphasising the critical importance of timeous execution of *financial planning and securing of financial resources* to ensure sustainability in the long term.

A major challenge facing sustainable environmental management in ports is the lack of human and technical capacity and support (Di Vaio and Varriale 2018; Lawer et al. 2019). In African ports, technical capacity and even appropriate equipment for environmental monitoring are often limited, with available areas of competence dictating environmental effort (Lawer et al. 2019). For example, access to affordable energy remains poor and irregular in many African countries (UNECA 2015), challenging initiatives to achieve emission reduction (e.g. through cold ironing which requires reliable electrical supply) (Lawer et al. 2019). The lack of human and technical capacity and support is best addressed in the planning stages. While *human resource planning* is captured in the 'plan' component of the prototype (Table 1), the requirement to also plan for *technical capacity requirements* is not explicit.

Another challenge encountered in African ports, and which hampers environmental reform, is the lack of education and awareness, and engagement with key stakeholders such as transport and terminal operators (Lawer et al. 2019; Mbalisi and Offor 2012). For example, studies have shown a positive correlation between education and awareness raising programmes and reduced coastal litter (Jambeck et al. 2018). It is not only important to raise awareness of employees at all organisational levels in ports and with stakeholders (Di Vaio and Varriale 2018), but also in local communities and other port users that potentially contribute to environmental impacts (Mbalisi and Offor 2012). This challenge is best addressed through dedicated training programmes in effective and efficient environmental management practice, not only for port employees but also for key stakeholders (Di Vaio and Varriale 2018), as well as engaging in public education and awareness initiatives (Mbalisi and Offor 2012). The EMS prototype (Table 1) acknowledges *training for port employees* in the 'do' component, but the need for *general (public) education and awareness* is not apparent, an element which may well contribute to improved environmental sustainability in the Africa context and which could be facilitated through the dedicated environmental departments.

Competition for coastal space has contributed to increased conflict between ports and adjacent communities along the so-called port-city interface, as has been observed in east and southern African ports (Humphreys et al. 2019). Such conflict also arises from environmental problems in ports, such as air and water pollution (Humphreys et al. 2019). For example, divergent environmental priorities have emerged in the decision-making about proposed port infrastructural development in Durban (South Africa) between ports and urban communities, resulting in projects

either not being approved or being delayed (Taljaard et al. 2021). In the Africa context, especially, coastal spaces in and around ports have social significance to local communities often providing livelihood support (Lawer 2019). Poor engagement with local communities on potential environmental risks to livelihoods linked to a project in the Port of Tema (Ghana) resulted in major conflict and bad publicity for the port (Lawer 2019). Conflict around environmental matters therefore poses challenges to port environmental management, often manifesting in costly delays of projects, bad publicity, and time-consuming arbitration (Humphreys et al. 2019; Lawer 2019). Such conflict may well be mitigated if the *reliance that local communities have on healthy coastal environments in and around ports* is timeously acknowledged and addressed in the planning phase of environmental management processes (Taljaard et al. 2021). In setting environmental objectives for ports, it is important to engage with affected communities to assess their use and reliance on common coastal systems and identify and mitigate potential environmental impacts of port operations and activities. Simply giving communities access to port spaces may not suffice (Lawer 2019) as the environmental quality of such spaces is critical in the delivery of ecosystems services to communities, for example cultural and recreational use, and artisanal fisheries. Consideration of the *reliance and use of local communities on coastal environments in and around ports* is not apparent in current EMS methods (Table 1), but timeous consideration thereof in the 'plan' component hold benefits to port sustainability.

In summary, reflecting on key challenges facing African ports suggests that the EMS prototype accounts for the importance of *legislation and environmental policies*, *managerial commitment*, and *human resource planning and training*, but is not explicit on *environmental institutionalisation*, *financial planning*, *technical capacity planning*, *general (public) education*, *and awareness* nor the need to acknowledge and consider *reliance of local communities on coastal environments in and around ports*.

5 Learning for ICM best practice

Because seaports are spatially located within the larger coastal landscape, we argue that effective port environmental management should draw on ICM best practice, a field that has been studied much more extensively in the scientific literature. Taljaard et al. (2011) developed evaluation criteria to be used as a theoretical framework for the validation of ICM implementation models and applied these in an African context (Taljaard et al. 2013). In Table 2, we apply these criteria to the EMS prototype (Table 1).

The EMS prototype met six of the fourteen criteria for successful implementation of ICM (Table 2). The prototype was found to partially address five of the criteria, namely *requires cooperative institutional structures across tiers of government and sectors, with clearly defined roles and responsibilities* (criterion 4), *requires establishment of overarching [common] objectives, and associated indicators and targets related to the coastal system against which to measure compliance* (criterion 5), *ecosystem based approach, rather focusing on specific issues, problems or sectors*

Table 2 Evaluation of current EMS practice in ports (prototype) against criteria for ICM implementation

ICM Criterion		Evaluation
1	Acknowledges participatory, actor involvement	*Does not meet criterion.* Not explicit on participatory, actor involvement
2	Acknowledges valid and relevant scientific information and knowledge (scientific support) as an integral element	*Meets criterion. Identifying environmental impacts, activities, opportunities, & risks* is included in the 'plan' component
3	Requires clear process management to be adhered to so as to achieve a desired outcome	*Meets criterion.* The PDCA model forms a structured management process
4	Requires cooperative institutional structures across tiers of government and sectors, with clearly defined roles and responsibilities	*Partially meets criterion. Obtaining commitment to EMS from organisational leadership* is included in the 'plan' component, but not explicit on dedicated environmental institutional structures
5	Requires establishment of overarching (common) objectives, and associated indicators and targets related to the coastal system against which to measure compliance	*Partially meets criterion. Set environmental targets and objectives* is included in the 'plan' component, but not explicit on negotiating these with external stakeholders (e.g. local communities)
6	Requires monitoring and evaluation programmes to be established	*Meets criterion. Environmental monitoring & evaluation programmes* are included in the 'check' component
7	Considers coastal system in its entirety (i.e. as a social-ecological system) with the coastal ecosystem as central focus (rather than specific issues, problems, or sectors)	*Partially meets criterion. Set environmental targets & objectives* are included in the 'plan' component, but not explicit on social objectives & targets (e.g. explicitly addressing local community dependencies and needs)
8	Requires delineation of coastal management units and geographical zoning of different use areas within (i.e. marine spatial planning)	*Partially meets criterion – Identify environmental impacts, activities, opportunities & risks (EMS scope) and define environmental objectives and targets* are included in the 'plan' component, but not explicit on the delineation of EMS boundaries and basing objectives and targets on sound spatial plans
9	Presents ICM as iterative, adaptive process	*Meets criterion.* The PDCA model depicts a cyclic adaptive management process
10	Acknowledges concept of ecosystem limitation	*Does not meet criterion.* Not explicit on the concept of ecosystem limitation
11	Requires an enabling legal framework	*Meets criterion. Identify legislative & environmental policy requirements* are included in the 'plan' component
12	Acknowledges continuous development of education and awareness as an integral element	*Partially meets criterion. Communicate & training of employees* are included in the 'do' component, but not explicit on wider public awareness raising as an integral element
13	Acknowledges continuous capacity-building programmes as an integral element	*Meets criterion. Identify team structure & responsibilities* are included in 'plan' component, *as well as Communicate & train employees* in the 'do' component
14	Acknowledges sound funding structures (financial support) as an integral element	*Does not meet criterion.* Not explicit on acknowledging sound funding structures (financial support) as an integral element

only (criterion 7), *delineate management units and marine spatial planning)* (criterion 8), and *continuous development of education and awareness* (criterion 12). The three criteria that were not explicitly met by current EMS practice including *participatory, actor involvement* (criterion 1), *acknowledge limitations of ecosystems* (criterion 10), and *establishment of sound funding structures* (criterion 14).

6 Proposed EMS framework for African ports

Reflecting on challenges facing African ports, the prototype (Table 1) can be improved by explicitly acknowledging and addressing *environmental institutionalisation*, *financial matters*, *technical capacity*, *general (public) education and awareness*, and *reliance of local communities on coastal environments in and around ports*. Learning from ICM best practice, the prototype can also be improved through explicitly addressing *participatory, actor involvement*, the *acknowledgment of the limitations of ecosystem*, and the *establishment of sound funding structures* (Table 2). Building on the EMS prototype, using the adaptive (PDCA) model, Fig. 2 depicts a proposed EMS framework for African ports (refined design) that accommodates additional elements in support of key continental challenges and lessons learnt from ICM best practice.

Within the PDCA model, the 'plan' component deals with planning, addressing elements such as situational analyses, objective setting, identification of management actions, and allocating employee roles and responsibilities. Managerial commitment and institutionalisation of environmental matters (e.g. through establishment of dedicated, resourced departments) are key elements to be secured early on in the planning stages of EMS (Barnes-Dabban et al. 2017). Furthermore, the interrogation of spatial plans establishing uses and activities in and around ports is important in order to identify potential conflicts (e.g. Trozzi and Vaccaro 2000) and to establish environmental footprints, as has been demonstrated in successful ICM implementation (Taljaard et al. 2011). Such footprints typically dictate the geographical boundaries of the EMS. A participatory process, involving key external stakeholders and local communities potentially affected by port operations, should be followed in the negotiation of socio-ecological objectives and targets. In the African context, environmental footprints of ports often extend into areas supporting community livelihoods, necessitating a participatory approach and ongoing communication to address and mitigate potential conflict.

Design of environmental monitoring programmes, to evaluate environmental issues specific to the port, also falls within the 'plan' phase. These programmes can be expensive and therefore need to be properly planned and coordinated. Realistic financial planning is an important element in the planning phase of environmental management programmes, as the execution of management actions relies on not only human resource capacity, but also financial resources. It may be necessary to prioritise management interventions to align with budget availability. Pro-active, emergency response planning is required to prevent detrimental impacts in the case of oils spills for example. Finally, the documentation of EMS planning processes and outcomes and the communication thereof is important.

The 'do' components within the PDCA model entail the execution and control of planned management actions (Fig. 2). Communication and training of identified employee teams is an integral element, creating the level of competence required to execute specific actions. Environmental monitoring comprises a key component within this component of EMS, as the acquisition of environmental data and information underpins an ability to evaluate the environmental performance in a port. The high reliance of communities on coastal resources and associated inter-relationships with port operations, especially within the African context, warrants broader education and awareness programmes (Mbalisi and Offor 2012; Taljaard et al. 2011). Such programmes can take on different forms from formal to informal initiatives, for example through meetings, workshops, print, electronic, and audio-visual media. The use of environmental education materials like posters, leaflets, and billboards has been shown to be effective in schools and public places to keep the citizens constantly informed (Mbalisi and Offor 2012). Finally, to enable sound evaluation in the latter stages of the 'do' phase of an EMS, it is also important that a system is in place to control performance and to accurately record the day-to-day operations and outcomes.

The 'check' and 'act' phases of the current port EMS systems are, by comparison, well structured to deal with the African context. The 'check' component in the framework focuses primarily on evaluation of operational outcomes and monitoring outputs, and to assess these for compliance with legislative and policy requirements, as well as socio-ecological objectives with the aim of identifying potential non-conformances and related corrective actions. Annual internal audits also form part of this evaluation phase.

The 'act' component deals with management responses to outcomes of the 'check' phase. Corrective actions need to be implemented, and outcomes of the EMS process need to be communicated and reviewed, by the organisational leadership to sustain buy-in and commitment. True to the cyclic, adaptive management approach, management responses also need to ensure that protocols are in place to

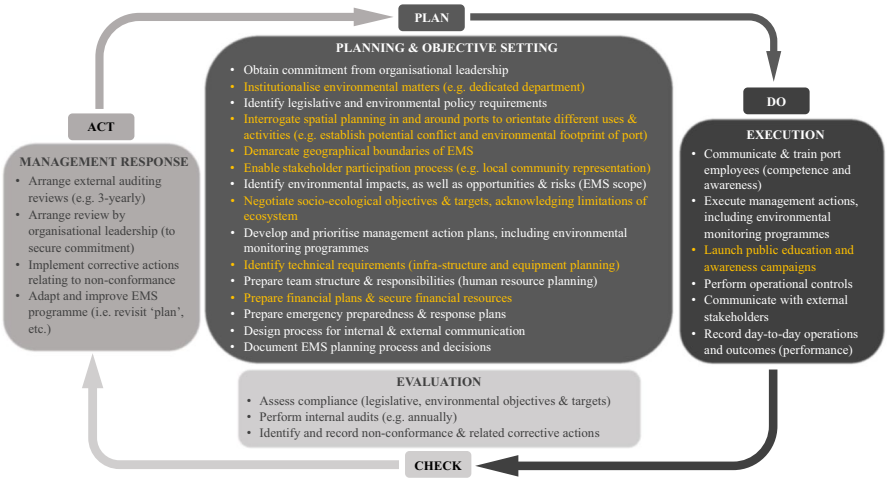

Fig. 2 Proposed EMS Framework for African ports, refined to address key continental challenges and incorporating ICM best practice (as highlighted)

revisit the entire EMS process from planning rippling through the other components within the PDCA model.

7 Concluding remarks

Globally sustainable environmental practices have been linked to socio-economic benefits and it has become imperative for African ports to adopt such practices to remain competitive in the market. The design and implementation of effective EMS is fundamental to this. Despite some progress, many African ports are still struggling to implement sound environmental management practices. This stems, at least partially, from a lack of transparent and systematic frameworks to guide implementation and motivates the need for an EMS framework for African ports, building on international best practice but adapted to key continental challenges. Incorporating elements shown to be effective in successful implementation of ICM takes advantage of opportunity of recent advances in that field and recognises the broader environmental coastal domain within which ports are spatially situated. A design science approach and the PDCA model provided an adaptive management structure for developing an EMS framework appropriate for application in African ports. We consider this proposed EMS framework as a logical and structured method to initiate the implementation of EMS in African ports more effectively, compatible with international standards such as ISO 14001. Unpacking each of the key components and elements within the PDCA model, together with motivation for their inclusion, the framework provides greater transparency to port managers who ultimately must understand and implement EMS processes. The next step comprises the empirical validation and refinement of the proposed EMS framework through studying site-specific applications in African port case studies. The framework may also have applicability in other developing economies facing similar challenges, but this will also have to be tested through empirical validation in those regions.

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Declarations

The authors declare no competing interests.

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