Witteveen + Bos

Systems Approach for Port Development (SA-PoD)

Final market demand analysis report

The World Bank Group

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1

INTRODUCTION

In November 2020 the System Approach for Port Development (SA-PoD) won the third prize of the Call for Innovation organized by the WACA-program. The proposal was presented by a consortium led by Witteveen+Bos and comprising Ports Environmental Network-Africa (PENAf), CDR, Prof. Tiedo Vellinga, Boskalis and Wetlands international. The prize included a limited budget to be spent on some follow-up activities to further develop the proposed innovative approach, as per Terms of Reference (ToR) dated January 23, 2021 and signed by Witteveen+Bos. This report describes the results of the following project activities (which refer to deliverables 1-3 of the aforementioned ToR):

1 Identification and selection of potential ports to contact for discussing the Sa-PoD concept.
2 Gap analysis.
3 Recommendations.

Due to unforeseen developments after proposal submission, it has not been possible to execute the following project components:

- Consultation meetings with selected port organisations, because the alignment with the Sustainable Port Partnership (PMAWCA) was insufficient for a proper selection.
- A demand analysis. Since the interviews have not been conducted these demands could not be identified.
- Presentation at the (virtual) marketplace, as this event has not yet taken place.

Instead of these interviews, two actions were executed:

- Meetings were organised by the WACA-program with experts from the World Bank Group and Royal IHC, as well as a first meeting with all participants of the Sustainable Port Partnership (PMAWCA). In each meeting the innovative port planning approach was presented followed by a fruitful discussion. The minutes are presented in appendix III.
- A questionnaire was sent to the port authorities with assistance of PMAWCA; the response is presented in Chapter 2.2.

The key highlights of the gap analysis are that the ambitions of many ports organisations in West Africa have implement a more balanced, sustainable port development. However the port organisations are struggling in developing such plans, due to one or more of the following 'gaps': (i) Technical competences and nature based solutions; (ii) Human and institutional capacities, among others in implementing a participative planning process; (iii) Politics biased decisions; (iv) Lack of good examples and insufficient stakeholder participation. This is further elaborated on in chapter 3.

A summary of the SA-PoD approach is presented in the below section; a more detailed description is included in Appendix I. Subsequently an example is presented of the SA-PoD approach for Lekki Nigeria is presented.

Summary of the Systems Approach for Port Development (SA-PoD)

Port developments around the world, West Africa included, often impact the coastal environment, posing challenges like erosion and degradation of environment with negative socio-economic implications. To develop sustainable ports solutions which are adaptable to climate change and have net positive value a paradigm shift is required from a conventional, economic and engineering oriented approach to a stakeholder inclusive and environmental, social and economic integrated approach.

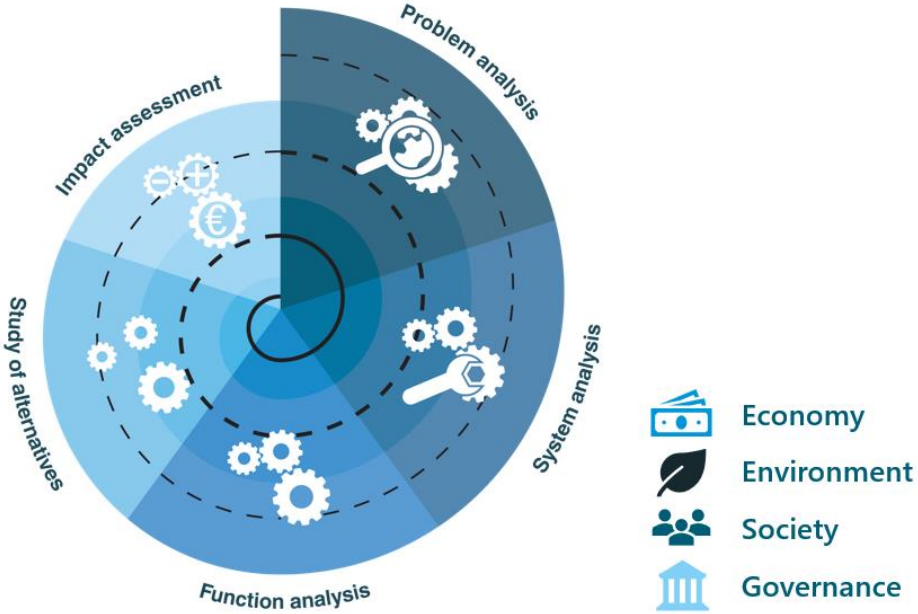
Port developments are complex and require a holistic approach based on thorough system understanding and active participation by all stakeholders. Our approach consists of a systematic five steps process that integrates the systems: **environment**, **society** and **economy**.

Each step capitalizes on the results from the previous one. They are iterative, achieving a higher degree of detail after every cycle, see Figure 1.1. The focus is different per step:

1 Problems and plans (needs and values) are identified for the port project and the larger area surrounding the port.
2 Processes in the three systems mentioned above are investigated and the root causes of the problems are determined. Focus on the specific West African context and identify opportunities.
3 Values and benefits are investigated, those that are under threat, lost and to be developed.
4 Alternatives are studied, that are on different scales and are technical as well as non-technical.
5 Assessment of the different solutions with existing methods to come to viable, bearable and equitable solutions that are widely supported.

Appendix I provides a more elaborate description of the approach.

Figure 1.1 Port system planning from general to detail in a cyclical process



In this process, relevant stakeholders are brought together to develop solutions as well as innovative finance instruments to allow for a bankable development which takes into account additional benefits for nature and society.

Example of the SA-PoD approach

The Sandbar Breakwater at Lekki, Nigeria is an example of a port development where this approach is applied, [ref. 3].

Figure 1.2 Systems Approach for Port Development - Sandbar Breakwater (Lekki, Nigeria)

The design is based on the understanding of the natural system and in particular the coastal processes along the Gulf of Guinea. Given the strong sedimentation at the western updrift side of existing port infrastructure along this coast, sand as construction material seemed very obvious. The large longshore sand transport is used beneficially and formed the basis of the breakwater. This minimised the use of rock and significantly reduced costs and transportation of rock. This resulted in less congestion, traffic accidents and nuisance. The sand nourishment that protrudes from the coast to the east of the port is an integral part of the concept as it prevents erosion and minimises the negative impacts. Through its flexible design it is easy adaptable and can anticipate climate change implications.

Applying this approach results in inclusive integrated port designs from the beginning where negative impacts are minimised and benefits are co-created. It will also lead to a reduction of the cost, hidden social costs included, during the lifetime for everybody.

More examples are presented in Appendix IV.

2

IDENTIFICATION AND SELECTION OF POTENTIAL TARGET ORGANISATIONS

The first step to bring the proposed innovative port planning approach further is to define the port organisations in West Africa and select from these the ports that seek further information, with the purpose of having further discussions on the proposed systems approach for port development.

2.1 Identification of port organisations in West-Africa

An overview is made of all 28 port organisations associated with the World Bank Sustainable Port Partnership (PMAWCA). All consortium members subsequently provided the information available to them on these ports organisations, which resulted in the compilation of a small database on these ports. This information was mostly already available to consortium members resulting from previous contacts with these ports. This included among others information on the current situation, port development challenges, port development plans, and sustainability ambitions. The combined result of this database is presented in Appendix II.

2.2 Questionnaire to port organisations

The PMAWCA send a questionnaire to its port organisation with the following questions:

1 What problems are you having in your port? Erosion, water quality and / or social impact. Please specify.
2 How can we help you in your port? For example with a 1 day workshop or a 1 week quick check-up. Please specify.

Four responses were received from Port Autonome de Douala (Cameroun), Port Autonome de Pointe Noire (Congo Brazzaville) and Port Autonome d'Abidjan (Ivory Coast).

All of three stated that there is a water quality problem, caused by port activities and refuelling of vessels. Two have problems with erosion, due to port development. One port encounters social impact due to the proximity of the port to the city. Other problems that are stated are waste management and air quality.

All three ports would like to get support varying from at least one day to one week or more.

2.3 Selection of port organisations

Based on the abovementioned overview of West African port organisations and the response to the questionnaire a selection is made of ports which appear most suitable for further contacting and eventually elaborating a systems approach for port planning. This selection is based on several criteria such as (i) existing contacts of consortium partners with port staff/management (ii) information on expansion plans (iii) the formulation of sustainable port development goals and ambitions or (iv) the current implementation of (some type of) sustainable port development policy. Preferably the approach is first implemented with two or three ports. The final selection of these ports depends on the response of the ports if they are interested.

It is noted that the systems approach for port development is in principle useful to apply for most development processes in the complex port environment. However, this approach is likely most beneficial for the development of greenfield ports[1], as well as for port expansion plans. Indeed, these strategic decisions have a lasting impact on the coastline, the port city and the entire region where the port is situated, requiring an in-depth analysis of all systems which can be identified in the port environment and the functions associated with each system, in order to identify the most sustainable port developments/designs. A lower priority to the use of the systems approach is given to improved port operation practices because their overall impact of this type of port development is easier to assess.

Greenfield and port expansion plans are however usually only (publicly) communicated by the port organizations in a stage where major decisions have already been made, port designs have been prepared and/or the tendering process or construction is ongoing. Discussions on the 'systems approach' should however be carried out in an earlier stage.

Since no consultation meetings with selected port organisations were held, the information presented mainly consists on the previous contacts of the consortium partners with these ports, as well as information presented on the port authorities' websites. All these ports formulate sustainable port development ambitions and/or implement such a policy.

The preliminary selection of ports for the further implementation of de SA-PoD approach is therefore mainly based on the availability of the early stages of port development plans, for which our approach is expected to be most beneficial. Ports with finalised port development plans, in the tendering or construction phase, have therefore not been include in the table, like the port of Ndayane port, Senegal and the Nouadhibou port in Mauritania. For the Ndayane port DP World Dakar will be responsible for the new 600 ha container port's financing, designing and building the land and marine infrastructure. The Nouadhibou port has recently deepened their access channel.

Table 2.1 presents the resulting list of ports including the assessment of the suitability for implementing the 'systems approach

Table 2.1 Selection of potential port organisations

Port	Contacts with consortium	Response to questionnaire	Planned new port or port expansion	Formulation of sustainable port development ambitions	Implementation of sustainable port development policy	Suitability for implement-ting SA-PoD[2)]
Port Autonome de Cotonou, Benin[1)]	yes		plans recently elaborated	yes		+
Port Autonome de Douala, Cameroun	yes	yes	possibly in Kribi	yes	yes	+++
Port Autonome de Pointe Noire, Congo Brazzaville	yes	yes	planned port expansion	yes		++
Ghana Ports and Harbours Authority	yes		possibly third port	yes	yes	+++
Port Autonome d'Abidjan, Ivory Coast	yes	yes	possibly third port	yes	yes	+++
Port Autonome de San Pedro, Ivory Coast	yes		apparently not	yes	yes	+

[1] Development of a completely new port on a location not developed before.

Port	Contacts with consortium	Response to question naire	Planned new port or port expansion	Formulation of sustainable port development ambitions	Implementation of sustainable port development policy	Suitability for implement-ting SA-PoD[2)]
Port Autonome de Dakar, Senegal	yes		apparently not		yes	+
Sierra Leone Ports Authority	yes		in 2016 plans for port expansion		yes	++

1 The Port de Cotonou has been elaborating quay, terminal and breakwater designs since 2018, mostly within the current port basin. These plans are currently in the tendering phase.

2 +++ Appears most suitable; ++ Possibly suitable; + Likely less suitable.

The information available to the consultants indicates that the ports of Ghana, Douala and Abidjan appear most suitable for implementing the SA-PoD approach. This however needs to be confirmed based on direct contacts with these ports. The remaining ports may also be suitable to implement the approach, but this appears at this moment in view of the available information to the consultants less likely.

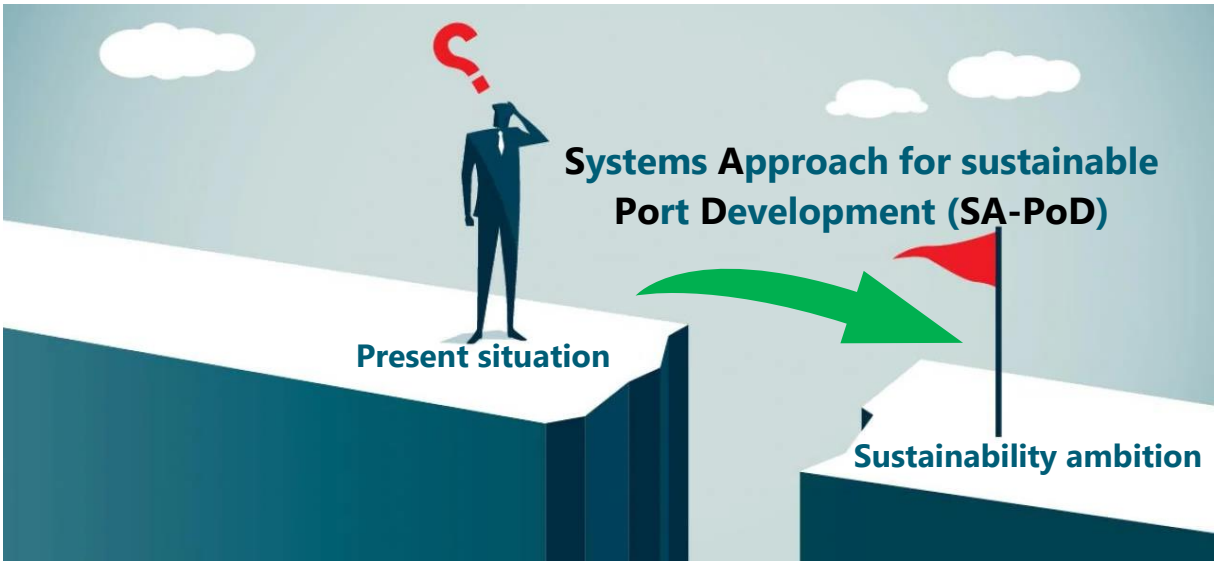
3

GAP ANALYSIS

This chapter discusses for the selected ports the gap between the current planning approach and the innovative systems approach for sustainable port development in terms of capacity, experience and expertise. The issues and challenges result from the gaps that are identified.

Since there have not been direct meetings or communication with the port organisations, the available information is rather general. As such it is not possible to make a complete gap analysis, however, an analysis is made in relation to the potential type of assistance the port organisations would need.

Figure 3.1 How to bridge the gap between the present port planning approach and the sustainability ambition of the target organisations



Typical situation at present

Typically, most ports (in the past) focused on the financial and technical aspects when preparing port development plans, aligning these plans to the principle port[1] transport functions. The awareness of the impact and importance of these plans for other stakeholders in relation to the coastal, environmental, ecological, or urban and regional impacts was typically limited. Hence the long-term sustainability of these plans was in many cases 'sub optimal', requiring later all type of measures to mitigate the negative effects.

Ambitions

In recent years the ambitions of many ports have developed towards a more balanced, sustainable port development, as illustrated in many cases by the information presented on the websites of the port organisations.

[1] Cargo (un)loading, including transshipment and terminal cargo handling and storage.

Gaps

Although it appears that most port organisations have the ambition to develop and operate their ports in a sustainable way, they appear to be struggling at the same time in developing such plans. This is among others because of the following reasons (gaps), which may or may not be relevant for an individual port:

- Technical: traditional engineering solutions in port development are usually known among the staff of port authorities. Nature based solutions are however often a novelty to these organisations. Also, a clear understanding of the overall impact of the port and of the various interactions between different port systems and functions is likely lacking.
- Human and institutional capacities:
  - In a setting where engineers and decision makers are used to be the principal actors in port planning, there is likely a lack of skills in implementing a participative planning process.
  - The traditional port stakeholders can have a 'natural bias' towards financial returns and investment costs.
  - There can be a lack of budget to hire specialists to carry out specific studies or prepare designs.
- Political economy: the scoring 'agenda' of ruling leaders may result in 'not rational' decisions. For example, port expansion plans may be developed to be opened within the term in office without a critical assessment of the efficient use of the existing port facilities.
- Lack of good examples and stakeholder participation:
  - The limited number of examples of the application of the systems approach hinders further scaling up. This relates to the dynamics in the process, and how the approach resulted in a different outcomes.
  - The broadness of the group of stakeholders that is involved appears (too) limited, it should be wide, varying from decision makers, port authorities, operators, other coastal and urban stakeholders (including NGO's) to local people.

3.1 Questions for future consultation meetings with potential organisations

In future consultation meetings with port organisations the following questions could be asked in order to establish the 'gaps' for sustainable port development more precisely, as well as the eventual support needed to assist the port organisation in implementing the SA-PoD approach. The below questions particularly relate to the planning of greenfield ports or expansion plans of existing port, especially in the early stages of plan development (see section 2.2):

Questions

- Is the port organisation currently in the early stages of a plan development process for a greenfield port, or expansion plans of an existing port (or other physical strategic port projects)?
- Is there an interest to develop these plans using a systems approach like SA-PoD?
  - If so, does your organisation experience gaps (capacity, expertise) or other constraints (time, budget, politics, legal) in the implementation of such an approach? What type of gaps?
  - What is the indicative timeline for preparing the port development plans?
- If not interested, could you elaborate briefly on the reasons?

4

RECOMMENDATIONS

This chapter gives recommendations for 2 concrete steps to be taken for SA-PoD implementation in a selected port.

4.1 Implementing the SA-PoD approach

When implementing the systems approach, different experts and specialists will be required depending on the specific location and situation. The Witteveen+Bos consortium can provide the full range of disciplines and experiences, required in many different port projects. For example, for the collaboration with port of Rotterdam, and the cooperation with the Tema port in Ghana for the implementation of the systems approach. The international experts base may be complemented with National experts from governmental institutes and/or universities.

4.2 Step 1 - initial assessment

As a first step we suggest carrying out a 1-day (online) session implementing the Systems Approach concept for an interested port organisation. This initial assessment with 2 senior consultants and 5 - 10 experts from the port organisation results in defining the problem, goals and (alternative) conceptual ideas of possible solutions.

The day starts with an introduction of the SA-PoD approach. Subsequently the facilitators will jointly elaborate on the 5 steps described in Figure 1.1 of the systems approach in groups of approximately 5 participants. At the end of the day the Port system planning cycle (see Figure 1.1) has been completed at least once. Different conceptual solutions and their impact will be presented and discussed, preferred alternatives will (possibly) be selected, and follow-up actions will be defined.

The requirements for this ‘step 1’ are an intake meeting with the contact person of the port and a stable internet connection.

4.3 Step 2 - local ‘pressure cooker’

Step 2 for implementing the SA-PoD approach could take indicatively 5 days and is preferably carried out on location, where 20 to 30 people representing all important stakeholders and national experts will be involved in different sessions.

The detailed programme will be defined together with the beneficiary/client; the following components are however envisaged:

- Introduction of the SA-PoD approach and presentation of the results of step 1 in one day.
- Field visit in two half days.
- Elaboration in small groups of the port (i) problem analysis (ii) system analysis (iii) functional analysis (iv) study of alternatives and (v) impact assessment. This will (preferably) be done in several cycles, resulting in more detail and in-depth analysis in each cycle. This step will take two and a half to three days.

- Plenary discussions aiming at overall conclusions in half a day.
- Selection of 'preferred alternative(s)' with pros and cons in half a day.

Step 2 could result in a preliminary choice of the preferred alternative for port development which has the support of the port organisation as well as the other stakeholders impacted by this development. The outcome could serve as a basis to prepare the conceptual design.

The requirements for this 'step 2' are among others the initial assessment, a diverse and complete representation of stakeholders, a venue and access to the project location(s).

Figure 4.1 Stakeholder engagement during the workshop in Tema, Ghana, February 2017 (Dano Roelvink)

4.4 Cost and general arrangements

The cost of the online session (step 1) is indicatively EUR10,000.-- with one moderator and one expert.

The cost of the local pressure cooker (step 2) indicatively EUR35,000.-- with one moderator and two experts. The costs exclude travel, DSA and allowances for the participants, the venue and the like. These costs can be reimbursed by cost incurred.

All these cost are indicative. Please contact us to customise a session that suites your needs.

Both the initial assessment and the local 'pressure cooker' will in principle take place in English. Other languages can be discussed.

5

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Appendices

APPENDIX: ELABORATION ON SYSTEM APPROACH FOR PORT DEVELOPMENT (SA-POD)

Introduction

Port developments around the world, West Africa included, often impact the coastal environment, posing challenges such as erosion, flooding and ecological degradation in ports, lagoon systems and canals.

In Western Africa these challenges are of particular interest because, the existing commercial ports were built with limited planning and considerations of potential exacerbation of coastal erosion. As a result many African seaports are erosional hotspots with significant impact on their adjacent coasts. Often there appears to be a mismatch between the positive global and regional effects of these ports, and the impacts (negative benefits) that can be experienced locally.

There is a common understanding that port development requires a paradigm shift from a conventional economic and engineering oriented approach to a stakeholder inclusive and environmental, economic and socially integrated approach to become sustainable.

Our goal is to develop sustainable port solutions that integrates and optimises the environmental economic and public benefits of the port.

In order to cater to a highly interconnected, complex, turbulent environment, our approach is more holistic, pluralistic and participatory than in the past, when profitability and economic impact have been the focus of port development. Nowadays more than ever, large infrastructure projects denote thinking in terms of uncertainty, flexibility and adaptability. Our view on sustainable port development approach goes beyond solely reducing environmental impacts, resulting in benefits for port, port-related organizations and stakeholders and the natural and coastal systems at large.

The approach elaborates on experiences several projects, among others:

- The research project 'Integrated and Sustainable Port Development in Ghana within an African Context' (2017), a pilot project for port development in the Port of Tema. The project is an example of a value based, stakeholder inclusive, eco-based and adaptive approach.
- The Sandbar Breakwater (Dangote, Lekki, Nigeria), an innovative nature based port solution.
- The five year pilot project Building with Nature Indonesia, a pilot for sustainable coastal protection along the North coast of Java where the mangrove greenbelt is restored with temporary permeable structures, and sustainable aquaculture is realised in close collaboration with the local communities.

Key features of the innovative approach

Literature related to sustainable ports (EPA 2007, PIANC 2008, Vellinga 2014) advocates the following sustainability guiding principles for an alternative approach to sustainable port development:

- A more sustainable port can be realized through embracing the *four perspectives of engineering, economy, ecosystem services and governance* in an integrated approach to port development.
- Intrinsic to this approach is Working with Nature (PIANC 2008) with a focus on achieving project objectives in an ecosystem context that not only minimize the potential long-term negative impacts of port development but seek win-win cost-effective design solutions.
- Such an approach incorporates business models which include the valuation of sustainability strategies by taking into account all external factors and system effects. Analysis is at a higher spatial scale than the port area and an integrated value assessment includes ecological, social and economic aspects.
- Early and transparent engagement of a broad range of stakeholders is required from the start to give meaning to the term 'sustainable port' in their specific context, to identify opportunities for added value and to facilitate implementation. (Traditional port development, in contrast, is associated with long lead times due to conflicting interests and lack of mutual understanding of involved stakeholders).
- Co-creation with stakeholders to identify their values, seeking opportunities to create or enhance biodiversity, and encouraging open dialogue, collaboration, and commitment of the stakeholders throughout the project, highlight the approach.

Other salient features include:

- Integration of multi-disciplinary knowledge to arrive at innovative solutions.

- Developing flexible and adaptive master plans and designs that are robust and functional in many plausible futures.
- Incorporating sustainability and uncertainty considerations in all port activities across the supply chains. This requires communicating the goals of sustainability across the entire supply chain; *allocating resources for implementation* and building upon and sharing existing sustainability best practices, keys to success, lessons learned, and approaches for implementation.

In the below section we elaborate on the overall framework of a dynamic analysis of the engineering planning and design process. This framework should be considered in parallel with the implementation of the above-mentioned features.

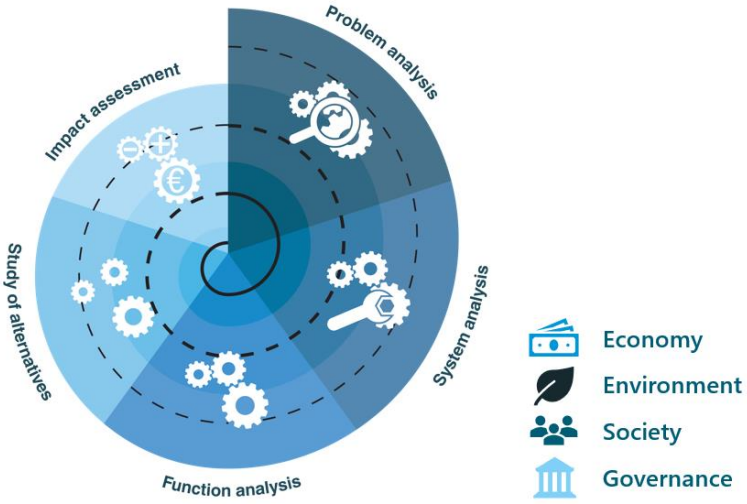
Dynamic analysis of engineering planning and design process

The overall framework of our approach is depicted in the Figure I.1and Figure I.2 below, where a dynamic analysis of engineering planning and design is carried out in relation to:

- Port planning in a cyclical process, see Figure I.1:
  - Moving from the generic towards detail.
  - Analysing problems, systems and functions, study of alternatives, and assessing impacts.
- Port planning and ecosystem impact mitigation: analysis at different spatial scales (see Figure I.2).

The context of this analysis is the development of a greenfield port masterplan, or the update of an existing masterplan. Certainly considering the dynamic situation in which the port systems operates, the update of an existing masterplan should be carried out periodically, for example every five years. This dynamic setting emerges from multiple factors, of which increased cargo volumes outgrowing the port infrastructure capacity have been eye-catching in recent decades.

Figure I.1 Port planning from general to detail in a cyclical process



The approach follows five steps, which form a cyclical process, that iterates from generic to high detail. Each cycle is carried out by the port authority in cooperation with (local) stakeholders (not in the least the local population and entrepreneurs), and experts of relevant disciplines where necessary:

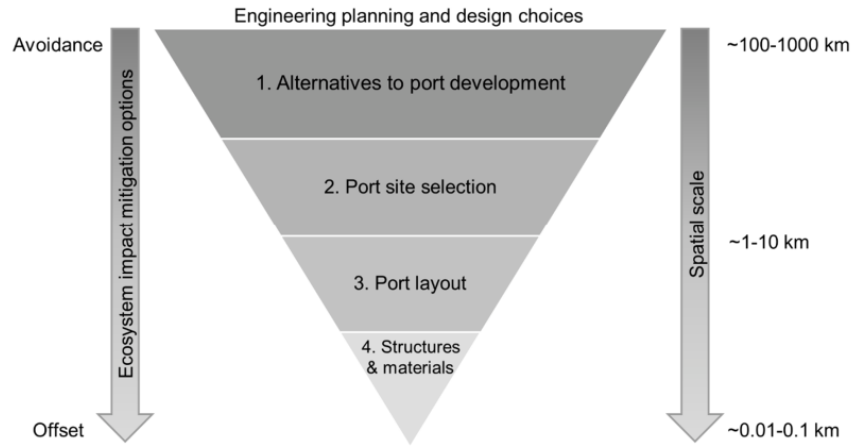
1 Problem Analysis to identify the problems and plans (needs and values) of the port project and larger area surrounding the port.
2 System Analysis to determine the root causes of the problems and identify opportunities.
3 Functional Analysis to identify values that are lost, under threat and to be developed.
4 Study of alternatives which are on different spatial and time scales and both technical as non-technical.
5 Impact assessment of alternatives to come to feasible and sustainable solutions that are widely supported. These assessments include the ESIA.

The cycles in principle refer to generic to detail, but could also relate to more information becoming available during the planning process. For example the results of the on-site investigations, hydrologic studies becoming available, or stakeholder decisions with a major impact on the port are communicated. This could interrupt and delay the execution of the planning process.

Figure I.2 illustrates that in the port planning process, the analysis looks at different spatial scales. On the highest scale we need to address the fundamental question of the necessity of port construction or expansion; subsequently for greenfield ports the port site selection is a strategic question; the next main question is the port layout, while the port structures and their materials are among the issues at the most detail.

On the next scales, the analysis zooms in from 'regional' to 'on site', and on the ecosystem scale from avoidance to mitigation. Negative impacts could be avoided on the regional scale without port construction, while eco-friendly materials can only 'mitigate' the environmental damage.

Figure I.2 Port planning and ecosystem impact mitigation: the spatial and ecological scale of analysis [ref. 0]



Typically, each spatial scale could also be analysed in one planning cycle (see Figure I.2), the planning process could in that case be completed in four cycles.

Not all stakeholders need to be involved in each planning cycle. However, the complete process should facilitate the identification of all stakeholder values and provide them opportunities for co-creation, while obtaining their commitment for the realisation phase of the port development plans.

In the next section the different elements of the port planning cyclical process will be briefly discussed. Several examples are presented for further illustration.

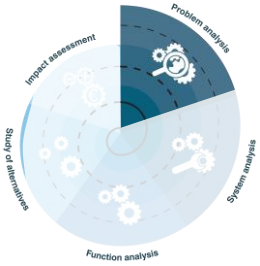
The proposed innovative approach for port development is a very attractive proposition, addressing the root causes of problems, adding value through stakeholder participation, resulting in the best value propositions. It is in principle ready for the application in every setting.

It should be noted however, that port planning is a complex process even for a well-established port authority with a capable port planning division. In addition, the proposed port planning methodology provides only a framework with a 'compendium of methods' to be implemented. A tailor-made approach is still to be elaborated on suited to the situational context and preferences of a specific port.

For less-established port authorities, planning may only be an ad hoc activity, resulting in a limited expertise on board. For this group the proposed methodology, involving even more disciplines and more stakeholders than traditional port planning, is difficult to implement.

It is therefore likely, that the less-developed port authorities require support in the implementation of the proposed approach. Fortunately expertise in this field is developing along the West African coast, for example in the 'Ports Environmental Network-Africa' (PENAf) and the Accra Ports&Harbours Authority. These institutions have gained expertise in the pilot project 'Integrated and Sustainable Port Development in Ghana within an African Context'.

Step 1: Problem analysis



Each design cycle starts with the identification of the problems and plans relevant to a specific port and associated water and coastal systems.

Problems are the unfulfilled requirements of the various stakeholders, or values that are lost or threatened, or to be developed. Traditionally port development focused on the transport economic function: the lack of port infrastructure capacity and/or inefficient port operations. Little attention was paid to other problems encountered in port development such as: coastal degradation, erosion and flooding, environmental pollution, the loss of marine ecology, urban traffic jams and air pollution, loss of livelihood of fishermen and other undesirable social developments. These issues however need to be addressed in order to arrive at long-term sustainable solutions for port development.

The identification of problems in the (vicinity) of the port, likely starts with a complete stakeholder inventory. Data acquisition and interviews can be an effective means to rapidly collect information. A workshop with the principle stakeholders could be organised to share, discuss, and rank the various problems. What is positive in the current situation, and what aspects are considered negative? To put the problems (and needs) into perspective, it could be helpful to jointly prepare a 'system story' of the port's past, present and future, and vote on 'visions' on port development from the local stakeholders perspective. What type of port developments should be aimed for in the future, and what development should be avoided?

The various stakeholders in the port impact zone have their specific interests, goals and (possibly formalised) plans. These need be considered when preparing port development plans. A proper participative approach will normally result in the identification of the existing risks, problems, opportunities and available plans.

Examples

Tema, Ghana

In the stakeholder inclusive design workshops implemented in Accra the participatory processes focus on co-learning, co-creation and co-operation and is expected to result in a more sustainable port design and operations. This enhances symbioses with the surrounding environment and gives the port a license to grow.

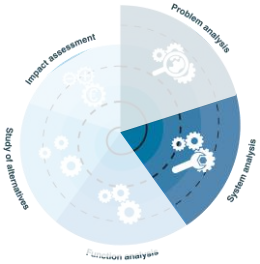
Sandbar Breakwater, Dangote, Lekki, Nigeria

One of the identified problems that has led to the concept of the Sandbar Breakwater was the strong morphological impact of port infrastructure. Strong accretion updrift leads to rapid burying of valuable armour rock of a conventional breakwater, while downdrift coastal retreat leads to loss of land and destruction. Sustainable port infrastructure with minimal environmental impact was needed.

Pilot project Building with Nature Indonesia, North Java

The understanding of the problems and the existing plans of the local communities, government agencies, experts and private companies in the project area and its surroundings was developed during multiple meetings with individual groups as well as in plenary sessions. The complexity became clear as well as the urgency of the ongoing coastal erosion.

Step 2: System analysis

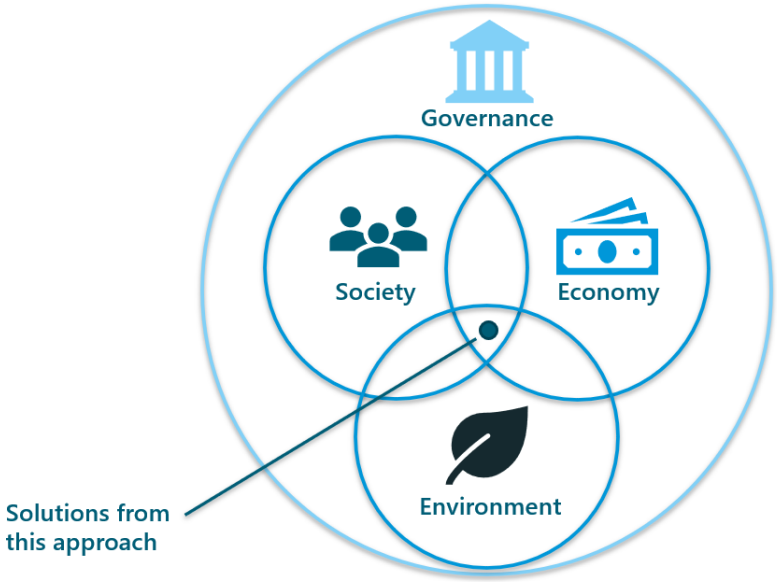


The system analysis follows the problem analysis. The understanding of the system is essential to arrive at sustainable solutions in the last step. This analysis especially requires the input of various specialists in the relevant fields.

The port operates in four subsystems and interacts with them (see Figure I.3)

- Economic
- Society
- Environment
- Governance

Figure I.3 The sub-systems the port interact with



All subsystems interact and undesired developments can also lead to dis-services, such as loss of land and property due to erosion, siltation of the port access etc.

The socio and economic subsystem interact on elements like (in)direct employment generated by the port, the fishery sector and tourism and other coastal services. The port-city relationship is usually very much under pressure due to pollution caused by port operation (emissions from vessels and cranes, dust), congestion of trucks and associated air pollution, land acquisition for port operations, dwindling incomes of fishermen due to water pollution etc. Governance and weak institutions, which is for example linked to failing enforcement of environmental regulations, should be addressed in this analysis as well.

The understanding of the economic, societal, environmental and governance systems in which the port operates is essential to carry out sustainable port planning.

In order to develop sufficient understanding of the subsystems surrounding the port, it is helpful to identify and analyse the changes taking place in these systems, as well as their causes. The port contributes to the pollution of the marine environment, but most cities also discharge raw sewerage and industrial pollution directly in the sea. The system analysis should also look at the identification of 'new' opportunities offered by the subsystems.

Subsequently it is important to quantify these physical changes and assess their monetary value (USD). This should help to underlie the port planning process, communication and decision-making.

Examples

Tema, Ghana

Through mini-symposia with researchers and local communities understanding was gained of the changes in the various systems. Presentations were held on the Tema coastal system, the coastal ecosystem response to change, and values associated with ecosystem services.

Sandbar Breakwater, Dangote, Lekki, Nigeria

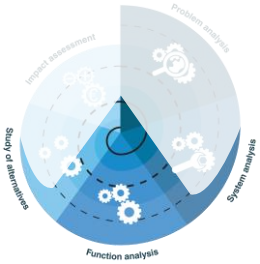
The understanding of the coastal system processes provided the basis for the concept and has led to the development of the overall conception of the Sandbar Breakwater as a sustainable nature-based port solution.

Pilot project Building with Nature Indonesia, North Java

During the multiple meetings with the local communities, government agencies, experts and private entities understanding was gained of the bio-physical system, socio-economic system and institutional system and root causes were found for the problems of coastal erosion, flooding and decreasing production.

Step 3: Functional analysis

The port is traditionally developed to facilitate the principal transport and logistic functions, based on the priorities of the port authority, the principal port operators, and the national government.
The 'sustainability' principle in recent years typically aimed at the implementation of environmental, safety and health (ESH) guidelines within the port boundaries. This results, for this restricted area, indeed in the reduction of pollution, accidents and risks of calamities.



The stakeholder engagement and the system analysis elaborated on in the previous steps, however, also generate information on opportunities for ecological, social and economic added value and corresponding functions for the current situation or after implementing solutions.

Typical functions of the port could be the:

- National strategic functions (independence, regional development).
- National security (stationing marine fleet).
- Generation of tax income for the national/regional/local government.
- Provide fishery products:
  - Export fishery products.
  - Provide more or cheaper fish products in the local market.
  - Provide artisanal fisheries.
- Provide other ecosystem services.
- Provide coastal passenger transport.
- Provide Tourism, recreation and well-being.
- Facilities cruise vessels.
- Employment generated in port operations, logistics and in other activities.

Examples

Tema, Ghana

The required functions and values are identified through stakeholder meetings and system understanding. The strongest notion after the initial stakeholder workshop was the felt need to make a paradigm shift in the approach to further expansion of the port. With the ambition is to support ecosystem values and the liveability of the region. This in contrast to the existing developments that occurred at stake of contamination, congestion and loss and deterioration of natural lagoons. Which in consequence for instance had led to welfare losses for fishermen.

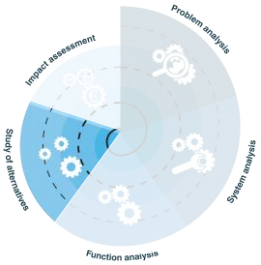
Sandbar Breakwater, Dangote, Lekki, Nigeria

The main required function of the Sandbar Breakwater is to provide a safe and calm harbour basin and approach to accommodate safe transit, berthing and continuous port operations. At the same time the

Sandbar Breakwater, including the 'Sand Engine', provides a truly sustainable solution with minimal environmental impact and mitigates coastal retreat downdrift.

Pilot project Building with Nature Indonesia, North Java
Through involvement of all stakeholders and their interaction benefits became clear varying from coastal protection to improved aquaculture. Other values that came to the table were water purification, carbon storage, more and better habitats, new livelihoods and increased health. All can be achieved sustainable.

Step 4: Study of Alternatives



Alternatives for the port development and added value functions already start to emerge in the functional analysis. They can be used as 'building blocks' for the port development. The alternatives can be elaborated qualitatively, while indicative assessments could be made in terms of pros and con (considering costs (CAPEX, OPEX), technical, and financial-economic feasibility, ecological and social impact). The clever combination of solutions has the potential to solve problems.

Solutions related to the transhipment and port logistic functions can create value added benefits when preparing conceptual port designs using among others the following sustainable design principles:

- Nature-based design, creating ecological benefits, biodiversity, cleaner water resulting in a higher fish stock.
- Multifunctional design: relatively small adjustments providing additional economic functions and social added value. For some ports this may relate to passenger transport, fisheries, wind and solar energy production.
- Futureproof design: designing robust, adaptable and resilient, while considering the physical, societal and technical developments.
- Participatory design, making use of local information and knowledge, resulting in faster project execution due to support stakeholders. The strength of stakeholder engagement and participation has already been highlighted in preceding sections.

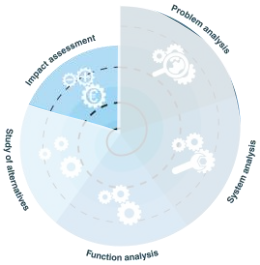
Examples

Tema, Ghana
After various meetings the following alternatives were proposed: (i) to combine the planned port expansion with a restoration of the lagoon that is physically connected to the port expansion site; (ii) to include facilities for fishing boats in the new plans and make it more a peoples port with its potential for new beaches in the lee side of the planned new breakwater and (iii) a landmark with cruise facilities as a tourist attraction also to connect to the nearby meridian crossing off-shore.

Sandbar Breakwater, Dangote, Lekki, Nigeria
Sandbar Breakwater: The alternatives that are to provide the desired function are captured within the overall concept of the Sandbar Breakwater. The use of soft material, sand, has led to minimization of the use of costly armour rock and has in turn led to minimization of construction time and environmental impact and improves resiliency for climate change, while ensuring a calm and safe harbour basin – the main function of a breakwater. The inseparable downdrift sand engine provides a soft solution for mitigating coastal retreat which is the most natural way to restore the disrupted sand balance.

Pilot project Building with Nature Indonesia, North Java
Various alternatives came to the table like: permeable structures and sediment nourishments for coastal protection and various types of aquaculture, new livelihoods, education, new regulation, advocacy and revolving funds.

Step 5: Impact assessment



The difference between the current port planning and the proposed approach is not in the evaluation methodology, but the identification of best value options. In the traditional approach this is done based on transhipment and port operational requirements. In the proposed approach, because external and system effects as well as potential co-benefits have been considered from the start of the analysis, truly integral and sustainable port options are being developed. The selected 'preferred option' likely results the best value proposition of economic benefits for society.

The innovative design approach is the best value proposition with regards to the economic benefits of society. Financial and economic project feasibility requirements, might however necessitate to adjust the port development plan aiming at lower cost with minimum loss of external and system benefits.

In the process to arrive at preferred solution, alternatives need be defined, assessed, prioritised and eventually integrated into the port design. The prioritisation, based on the pros and cons of functions and associated port alternatives, can be considered as an ongoing process. It is carried out in relation to the different levels of plan development. Table I.1 presents for these three levels of plan development the type of choices made, the type of plans elaborated, the required underlying information (studies), and finally an indication for the stakeholder engagement requirement.

Table I.1 Characteristics for three levels of port planning

Level	Choice	Type of plans	Underlying studies	Stakeholder engagement
High	Choice of functions and type of alternatives	Port strategy	Market analysis, SWOT	+++
Medium	Port layout	port masterplan	Feasibility studies , ESIA, financing plan	++
Detailed	Detailed designs	detailed designs	detailed engineering	+

Table I.1 illustrates that the stakeholder engagement is particularly critical in the port strategy phase, important in the port layout phase, and not always necessary on the level of detailed designs. The stakeholder involvement brings all the port and associated developments, risks, threats and opportunities to the table, identifies additional values for the port development, and finally assures a sufficient level of community support for the port development plan.

Examples

Tema, Ghana

The process with the pilot in Tema was running parallel with the real port expansion project. There was a lot of support from the local authorities and it changed the mindset of the parties involved.

Sandbar Breakwater, Dangote, Lekki, Nigeria

The overall concept provides integral solutions to the identified problems in the port. Since the concept is developed based on the understanding of the natural system, the concept is a perfect example of a nature-based solution.

Pilot project Building with Nature Indonesia, North Java

During the pilot many different solutions were implemented, for example permeable structures, various types of aquaculture, new livelihoods, education, new regulation, advocacy and revolving funds. Each solution was regularly monitored and evaluated. Based on the lessons learnt the designs and other project interventions were improved at later in the project when next implementation started.

APPENDIX: IDENTIFICATION OF POTENTIAL TARGET ORGANISATIONS

III

APPENDIX: MINUTES OF MEETINGS

WACA C4I
SA-PoD
Internal Expert Feedback to the Idea
April 29, 2021

Objectives of the meeting

- Present the SA-PoD winning innovation to WB experts.
- Collect technical feedback on the innovation and key issues to feature in the Road Map.

Agenda

- Introductions.
- Presentation of the SA-PoD idea.
- Expert feedback.

Overall view

- Innovative Comprehensive and holistic system.
- Think of ways we could use this activity within the Bank.
- Innovative approach also for social development activities.

Key points

- Impacts of the innovation: need to add concrete elements:
  - What has been implemented after the discussions / consultations among stakeholders? Who experienced pushback? What were the reactions? How the discussion helped to increase the understanding of the importance of maintain the coastline? How did consultations influence operators?
  - A positive point is to consult not only with decision makers but also local people. How different groups of stakeholders and local people were involved? (e.g. Women). How did stakeholders mapping take place?
    Answer: Delft University of technology, which was involved for five years, mapped stakeholders and undertook several surveys, which enabled to engage with local people, e.g. fishermen, but also to get their knowledge.
  - Build and tell a story around the approach.
- Quality of the engagement:
  - People have different interpretation of the idea of consultation. Beyond consultations, what is the level of power that people actually had? Did they only provided some initial views, or did they get integrated in the development?
  - How to balance the different level of stakeholders during the consultation process i.e. Local populations vs. Ports authorities, vs. decision makers.
  - How a common ground with authorities is achieved upstream to the consultation process?
  - Are you working with other groups promoting problem driven iterative approach (see links below on problem driven iterative approach)?
- Economic Analysis:
  - Tools used maybe not innovative itself, but the combination as part of the approach is.
  - Interesting to go beyond the classical cost/benefit analysis, integrating social benefits.
  - Have you considered for stakeholders' consultation the UNSC's SEEA ecosystem accounting approach (see link below on ecosystem accounting)?
  - How do you analyse the hypothetical benefit of jobs creation and poverty alleviation that could potentially follow port development, as part of the consultation processes on port development alternatives and site selection?
- Finance:
  - How this approach can be financed beyond a classical project window?
- Business Approach:
  - Is this always what Witteveen+Bos does for every project, and can you run this process with an open-ended engagement?
    Answer: Yes, this is our approach, as we learned the hard way that early consultations reduces the risks for complications later. Yes, we can do it in an open-ended way.

- Linkages:
  - Ecosystem service accounting: https://seea.un.org/ecosystem-accounting.
  - Problem Driven Iterative Approach: https://bsc.cid.harvard.edu/about https://usaidlearninglab.org/lab-notes/what-adaptive-management-0.
- Resources:
  - Ports Governance https://www.mdpi.com/2071-1050/13/5/2795/pdf.

Follow-up actions

- Examples:
  - Witteveen+Bos to expand on some of the questions from consultations and prepare a brief note (which would be useful in case same questions come up again during external meetings.
  - Witteveen+Bos to prepare a summary of relevant examples, presented in a story form to make it easier and more interesting to read, including the case of Tema (Ghana), the Sandbar Breakwater in Dangote (Lekki, Nigeria), and the Pilot project on Building with Nature in North Java (Indonesia), as well as other international success stories.
  - Witteveen+Bos to provide draft matrix of potential targets (as per ToR), WACA team to review and provide advice.
  - WACA team to organize remaining internal meeting (i.e., with Yin Yin Lam – Senior Transport Specialist).
  - WACA team to organize external meetings.
  - WACA team to send to Witteveen+Bos the link to eBook.

Participants

- Witteveen+Bos team:
  - Tom Wilms.
  - Bert Burgers.
- World Bank discussants:
  - Kavita Sethi – Senior Transport Economist.
  - Lili Sisombat- Senior Leadership Development Specialist.
  - Margaret Arnold – Senior Social Development Specialist.
  - Paivi Koskinen Lewis – Senior Social Development Specialist.
- C4I team:
  - Peter Kristensen – Lead Environmental Specialist.
  - Andrew Losos – Senior Transport Specialist.
  - Sergio Vallesi – Environmental Engineer.
  - Manon Cassara – Environmental Specialist.
  - Edoardo Casarotto – Transport Consultant.

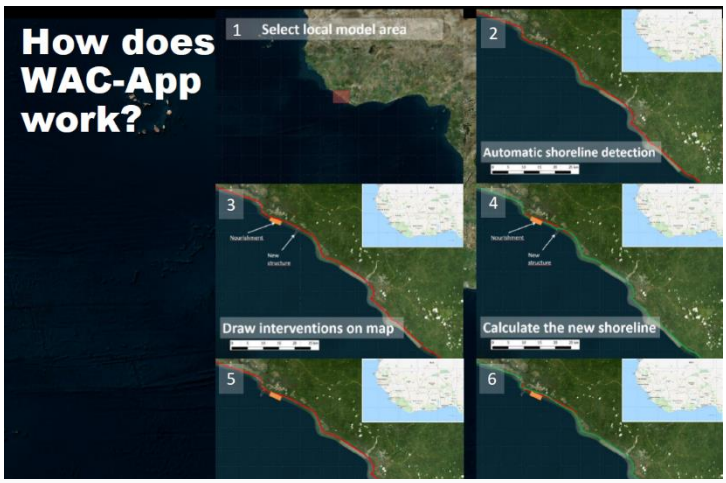
June 16, 2021

The Call for Innovation winners presented their projects to the members of the Maritime Security Environmental Protections and Operations (MSEPO) technical committee of the Ports Management Association for West and Central Africa (PMAWCA) during their annual gathering held virtually from June 14th to 16th of June 2021. The meeting tackled different challenges encountered by the Ports Members in their domains. The C4I team and winners were invited to present solutions through the WACA innovation stream in the second part of the event.

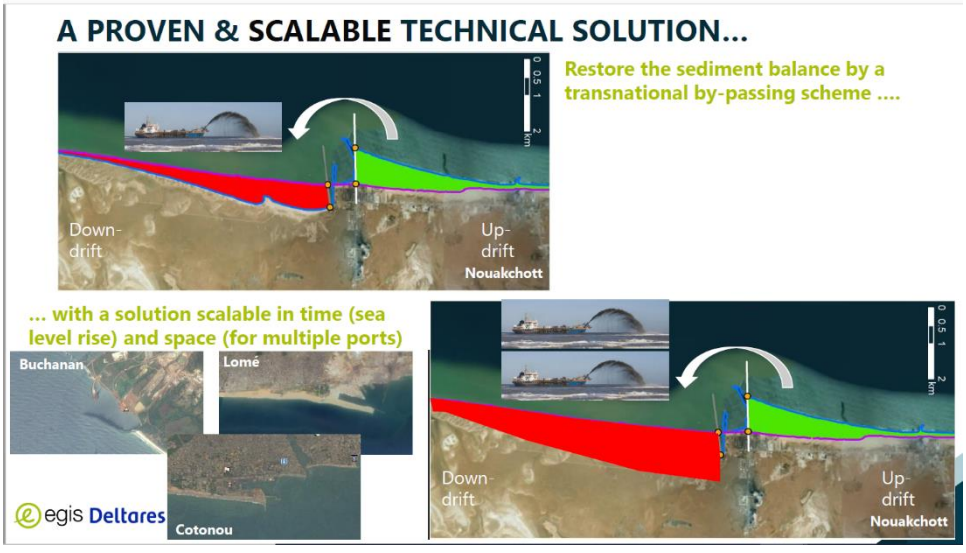
The ports have a long-standing collaboration to develop a Sustainable Ports Partnership supported by the World Bank, and the engagement with private actors to develop sustainable solutions to their social and environmental challenges is an active part of this effort. 'Africa's ports are facing many challenges and these challenges often require innovative solutions' said Andrew Losos, Senior Transport Specialist at the World Bank; the C4I was launched within that context collecting proposals from around the world.

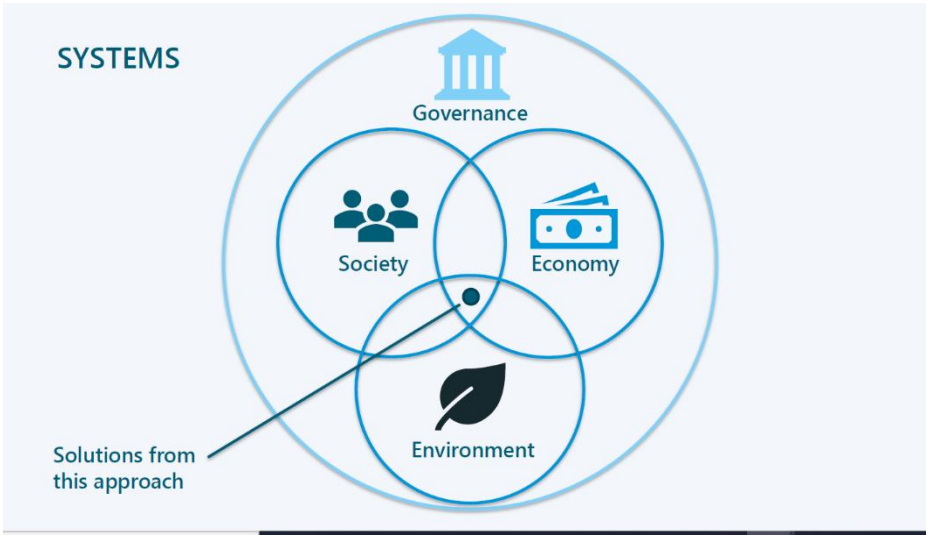
The C4I winners presented their projects to the port's members audience, initiating first discussions to advance the development of their proposals.

The WAC-APP team represented by HKV and UNESCO IHE introduced their app that bridges knowledge and communication gap between scientists, decision-makers and the public. The potential of this app lies into envisioning at very early stages of coastal projects development the impacts on the shoreline. This would allow to timely initiate adequate dialogue process with key stakeholders to optimize effects of future projects on the coastline.



The TRANS-SAND Team, represented by Egis and Deltares presented a technical, governance and financial dredging mechanism across borders. The opportunity with this innovation lies into mutualizing financial and technical resources to undertake transboundary dredging operations.





The **Systematic approach for Sustainable Ports Development (SA-PoD)** represented by Witteveen+Bos presented their holistic and inclusive mechanisms that accompany the development of a project at the stages, working with and balancing all the necessary parties.

The C4I team currently facilitates the development of Road Maps for the three winning innovations that would set realistic next steps towards the implementation of these projects as part of the WACA program. The team organized internal consultations with WB experts as well as external consultations over the past few months.

An innovation book has been developed in French and English that retrace the key moments from the C4I and provide a description and resources for innovations that were presented.

Innovation is important but continuity is critical to ensure that these solutions will come to life. Our team and C4I winners are committed to continue our engagement with WACA partners and key stakeholders in the region in that direction.

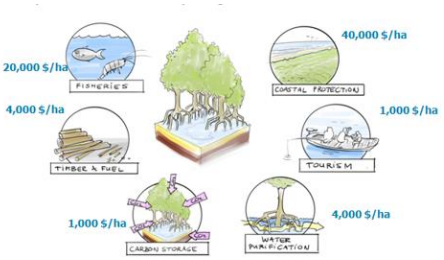
IV

APPENDIX: PREVIOUS EXPERIENCES

IV.1 Summary - Examples of good global practices in ports and lagoons management and successful case studies that could be proposed to West African countries

Port developments around the world, West Africa included, often impact the coastal environment, posing various challenges. Our goal is to develop sustainable port solutions with net positive value for society, economy, and environment. Three successful examples are shared below.

Table IV.1 Three different examples of our approach

1	Tema Port (Ghana) The project started in 2016 and has an 'action based' interdisciplinary approach with multi-stakeholder workshops combining the engineering, ecological, economic and governance aspects of port development. It resulted in an 'Africa-specific' design framework and design tools to integrate and optimise the environmental, economic and public benefits of ports.	
2	Dangote sandbar breakwater (Lekki, Nigeria) This unique and innovative design for a temporary port is based on thorough understanding of the natural sandy coastal system of Nigeria. Instead of importing expense rock armour, the port is constructed with locally available sand. The design consist of an innovative sandbar, a small groin at the tip and lee-side and basin revetments. In anticipation of future erosion of the beach to the east, a geo-tubes sleeping defence system and sand engine were built.	
3	Mangrove restoration (Demak, Indonesia) Communities in Demak are suffering from coastal erosion degrading kilometres of land as a result of unsustainable land use. The Building with Nature approach is implemented aiming to restore the mangrove coastline that reduces erosion, can adapt to sea level rise and enables inclusive economic growth through sustainable aquaculture. The goal is to trigger a paradigm shift towards infrastructure solutions that align interest of economic development with care for environment.	

These examples show that our approach fits every setting as it focuses on thorough system understanding and intense stakeholder involvement. The solution is developed from its own situational complex context, root are causes found and opportunities identified. Stakeholder involvement assures more knowledge is available, values are identified and wide support.

IV.2 Concise (1-page) - Good global practices and successful case studies

Introduction

Port developments around the world, West Africa included, often impact the coastal environment, posing challenges such as degradation and flooding. Our goal is to develop sustainable port solutions with net positive value for society, economy, and environment.

Our approach is iterative, integrating societal, environmental and economic needs in port design. This is based on intense collaboration with all stakeholders and with thorough understanding of the system.

Three different examples of our approach are: Tema Port (Ghana), Sandbar breakwater (Lekki, Nigeria) and Mangrove restoration (Demak, Indonesia).

Towards integrated and sustainable ports in Africa, the Tema Port case

Ports provide an essential link to the world market, enabling countries to trade their goods and strengthen their economies. However, the global and regional benefits of port developments do not always translate into benefits to local stakeholders. There is often a mismatch between the positive global and regional effects of port development and the impacts (dis-benefits) that are experienced locally. Port development requires a paradigm shift from a conventional economic and engineering oriented approach to a stakeholder-inclusive and environmentally, economically and socially integrated approach to become sustainable.

The research project 'Integrated and Sustainable Port Development in Ghana within an African Context' learned how to develop integrated and sustainable African ports that meet economic, social and environmental needs now and in the future. The Port of Tema, which has evolved from a small fishing village to Ghana's leading industrial centre and seaport in the last decades, formed the focal case study of the research. The research was inspired by the lessons learned from the new expansion of the Port of Rotterdam, an outspoken example of a value based, stakeholder inclusive, eco-based and adaptive approach.
The research project, funded by the Netherlands Organisation for Scientific Research, is carried out by a consortium comprising the University of Ghana, Delft University of Technology, the VU Amsterdam, Wageningen University, Deltares, UNESCOIHE-Delft and the Netherlands African Business Council and is supported by NGO's and private sector companies. The project started in 2016 and is characterized by an inter-disciplinary approach, combining the engineering, ecological, economic and governance aspects of port development.

The project results include an 'Africa-specific' design framework and design tools to integrate and optimise the environmental, economic and public benefits of ports. An 'action based' research approach has been applied and a demand driven knowledge development, meaning that users are in direct contact with the researchers. Multi-stakeholder workshops and interviews with stakeholders to hear their stories were key aspects.

Ecosystem-Based Alternatives for the Design of a Seaport's Marine Infrastructure were identified and evaluated for the case of Tema port expansion in Ghana. And to learn from past port engineering practices, a study was done to map the sandy beach evolution around seaports at the scale of the African continent. The results can be used to inform beach maintenance strategies for existing seaports and to support planners and engineers to minimize long-term coastal impacts of port expansions and new port developments in Africa in the future.

Information and links are found on the project website: www.sustainableportsafrica.com.

Sandbar Breakwater (Lekki, Nigeria)

The nature-based concept of the Sandbar Breakwater was born based on the typical natural dynamics of the West African coast (Gulf of Guinea). Learning from the development and coastal impact of the existing port infrastructure in West Africa, the application of sand as a construction material for marine infrastructure seemed very obvious. Along this coast, ports experience heavy sedimentation at the western updrift side of the breakwaters, leading to the rapid burying of valuable armour rock. The Sandbar Breakwater concept is based on this principle by using natural accretion as the basis for the port protection. Such a concept is advantageous as a large sediment drift naturally supplements the sand filling works during construction and the required rock volumes are reduced significantly, saving construction time and minimising the environmental impact. The Sandbar Breakwater in Lekki, Nigeria, had consequently significantly lower construction costs and a significant increase in its construction speed, which was vital for the feasibility of the project. This has also led to a minimisation of quarrying (i.e., blasting, sorting, etc.) and truck movements (75 % to 85 %) through the Lagos State road network, in turn minimising congestion, traffic accidents, nuisance, impact on air quality and the carbon footprint.

The key element of the Sandbar Breakwater concept is a sand body orientated close to its equilibrium and held in place by a groyne structure at the tip of the sandbar, The Sandbar Breakwater is morphologically dynamic from the start of construction, and eventually the coastline and related beach profiles reshape to a (dynamic) equilibrium. To counteract the downdrift coastal retreat, a replenishable sand engine completes the scheme. Sustainable future development is further pursued by integrated maintenance campaigns following the Building with Nature principles to guarantee the operability of the port while preserving the alongshore sediment balance and minimising the environmental impact.

As sand can be easily re-handled, this new concept is flexible and allows for a relatively easy future port expansion: the (partly) naturally accreted area in the west may accommodate the expansion of the harbour basin. Further, the soft character and the flexibility of the concept makes the Sandbar Breakwater more resilient and adaptable to climate change, compared with a conventional breakwater scheme.

By using the typical local natural dynamics as the starting point for the evolution of this concept, it follows the principles of Building with Nature and is considered a good example of a nature-based solution. The objective of the overall concept is to optimally use the natural available materials for the port and coastal protection and as such, it strives to limit its environmental and ecological impact.

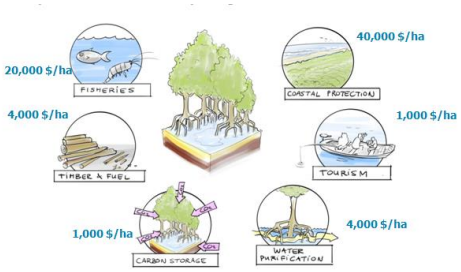
The successfully designed and implemented Sandbar Breakwater at the coast of Lekki, Nigeria, showed that this concept is a cost-effective and quickly buildable port protection. The solution includes an integrated maintenance and monitoring program to guarantee the safety of the sandbar, navigability of the access channel and to mitigate the retreat at the downdrift side of the port by means of a sand engine.

This concept may become a generic port solution in coastal environments like West Africa, with the presence of a relatively uniform wave climate, a sandy coast and a unidirectional longshore transport. The important criteria for success can already be deduced from the realisation of the Sandbar Breakwater at Lekki, Nigeria.

See also:
Van der Spek, B.J.; Bijl, E.; van de Sande, B.; Poortman, S.; Heijboer, D.; Bliek, B. Sandbar Breakwater: An Innovative Nature-Based Port Solution. *Water* **2020,** *12*, 1446. https://doi.org/10.3390/w12051446.

Sustainable restoration of mangrove coastline, case Demak (Indonesia)

Communities in Demak, at the North coast of Java (Indonesia) are suffering from coastal erosion degrading kilometres of land as a result of unsustainable land use. The integrated approach is implemented as a viable alternative to the traditional engineering approach, making the services that nature provides an integral part of the design of hydraulic infrastructure, thereby creating benefits for nature and society. It aims to restore the mangrove coastline that reduces erosion, adapts to sea level rise and enables inclusive economic growth through sustainable aquaculture. The goal is to trigger a paradigm shift towards infrastructure solutions that align interest of economic development with care for environment.



In 2015, a pilot project to restore the natural coastal mangrove forest was started. The first step was to establish a good understanding of the complex natural and local socio-economic environments. Based on this system understanding, we then chose for non-traditional solutions using temporary permeable structures made from local material to create wave-sheltered areas that stimulate the settlement of sediment and create a habitat favourable to mangrove recolonisation. Once the mangrove forest is fully-grown it will provide protection against waves. It will also provide other ecosystem services like food provisioning, tourism, nursery habitat for fishery production and CO2-storage. A long-term sustainable solution requires the integration of these technical measures into the local socio-economic and governmental context. To support a smooth transition towards sustainable practices, local communities are simultaneously trained in sustainable methods to improve the productivity of their aquaculture ponds. This is done using 'coastal field schools' as modelled from the 'farmer field school' methodology developed by the FAO in 1989 for rural development. The approach is embedded in the village regulations. Sustainability in this rural area is created by closely linking safety and livelihood.

The key lessons learnt from this project are that a combination of a thorough understanding of the bio-physical, socio-economic and governmental system and early stakeholder involvement results in higher vital benefits, reduces costs and provides the setting for sustainable design solutions. It requires a learning and adaptive planning cycle from all participants as this approach exemplifies a 'learning by doing' approach.

Information and links are found at: www.ecoshape.org/en/projects/building-with-nature-indonesia/

Wilms, Tom & van der Goot, Fokko & Debrot, Adolphe. (2017). Building with Nature-an integrated approach for coastal zone solutions using natural, socio-economic and institutional processes.

Conclusion

These examples show that our approach fits every setting as it focuses on thorough system understanding and intense stakeholder involvement. The solution is developed from its own situational complex context, root are causes found and opportunities identified. Stakeholder involvement assures more knowledge is available, values are identified and wide support.

IV.3 Elaborate (3-pages) - Examples of good global practices in ports and lagoons management and successful case studies that could be proposed to West African countries

Towards integrated and sustainable ports in Africa, the Tema Port case

Ports provide an essential link to the world market, enabling countries to trade their goods and strengthen their economies. However, the global and regional benefits of port developments do not always translate into benefits to local stakeholders. There is often a mismatch between the positive global and regional effects of port development and the impacts (dis-benefits) that can be experienced locally. Port development requires a paradigm shift from a conventional economic and engineering-oriented approach to a stakeholder-inclusive and environmentally, economically, and socially integrated approach to become sustainable.

The research project 'Integrated and Sustainable Port Development in Ghana within an African Context' learned how to develop integrated and sustainable African ports that meet economic, social, and environmental needs now and in the future. The Port of Tema, which has evolved from a small fishing village to Ghana's leading industrial centre and seaport in the last decades, formed the focal case study of the research. The research was inspired by the lessons learned from the new expansion of the Port of Rotterdam, an outspoken example of a value based, stakeholder inclusive, eco-based and adaptive approach.

Figure IV.1 Aerial picture Maasvlakte 2 and overview of all projects included in the Mainport Rotterdam Development Program (Port of Rotterdam Authority)

The research project, funded by the Netherlands Organisation for Scientific Research, is carried out by a consortium comprising the University of Ghana, Delft University of Technology (Delft UT), the VU Amsterdam, Wageningen University, Deltares, UNESCO IHE-Delft and the Netherlands African Business Council and is supported by NGO's and private sector companies. The project started in 2016 and is characterized by an inter-disciplinary approach, combining the engineering, ecological, economic and governance aspects of port development.

The project started with a field trip and wide stakeholder engagement. And to understand the Tema area - marine, coastal strip, lagoon and urban (eco)systems: critical components for the ecology

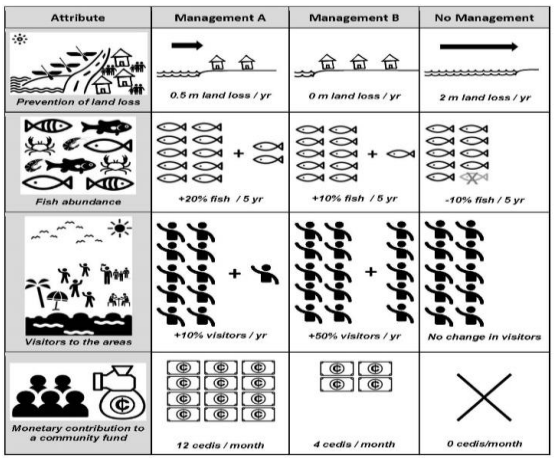
sub-project - a broad literature search was conducted in combination with satellite imagery, photos, videos, comparative studies with other areas supplemented with anecdotal knowledge of the locals as well as the Ghanaian researchers. The stakeholders, identified through a snowballing approach, were asked to share their visions of what a sustainable port means in Ghana. The information garnered from a workshop and key interviews with the Ghanaian Ports and Harbours Authority helped to understand the values of local stakeholders in relation to the port and served as input to generate conceptual port designs for further elaboration within the research project.

This was followed by personal interviews with the stakeholders. The book 'Voices on Sustainable Ports in Africa. Stories from Tema Port, Ghana' was published in 2018 to present the perspectives of a variety of stakeholders on sustainable ports based on interviews with the stakeholders in Ghana and the Netherlands, as well as the project team. The focus of the project is on developing a conceptual framework for sustainable port design. The social and ecological factors were revealed as determining the degree of sustainability of port development. They formed the criteria against which the port development plan and the design process can be evaluated. At a workshop at Delft UT the input from multiple disciplines was integrated and led to conceptual port layouts. There was a focus on value addition by considering potential eco-enhancement measures for each alternative. The workshop included not only civil engineers with knowledge of structural, hydraulic, environmental and transport engineering, but also port specialists, transport economists and ecologists. In addition to identifying sustainable design options for the port of Tema, developing and testing methods to conduct a stakeholder-inclusive design, as well as evaluating their effectiveness in a data-poor environment, was a part of the process towards creating the initial framework.

Figure IV.2 Stakeholder engagement during the workshop in Tema, Ghana, February 2017 (Dano Roelvink)

Economic valuation of ecosystem services is being used to model the effects of environmental management decisions and serve as input for the policy and decision-making regarding management practices or development plans. And a survey under local people identified how they valued quantified anticipated changes from the (eco)system.

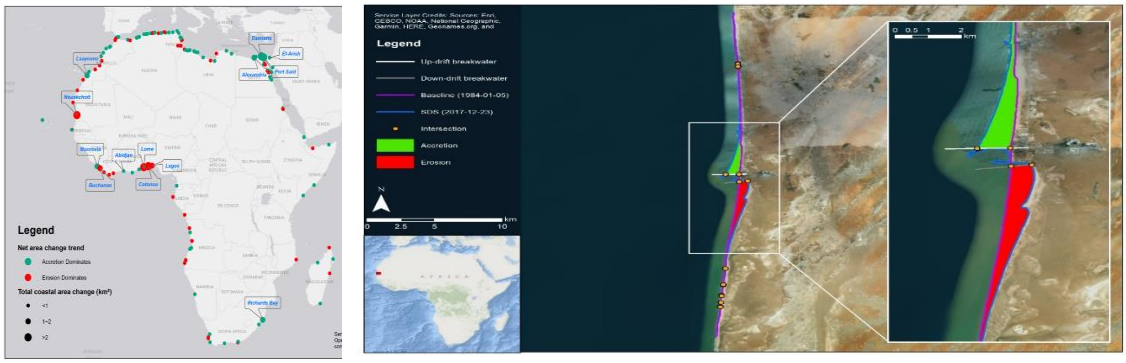
Figure IV.3 Illustration of survey form and the survey (Liselotte Hagedoorn)



The survey data allowed to obtain insights into the welfare effects of different port designs and erosion prevention measures. This is part of a PhD research at the VU Amsterdam and will be used to extend the integrated design framework, which is expected to be final towards the end of 2020.

Ecosystem-Based Alternatives for the Design of a Seaport's Marine Infrastructure were identified and evaluated for the case of Tema port expansion in Ghana. Placing the ecosystem centrally from the outset increases the opportunities to avoid and restore ecosystem impacts, and to provide ecosystem benefits to stakeholders in and around the port. The specific framework, termed the ecosystem-based port design hierarchy (EPDH), consists of four hierarchical levels of port planning and design, namely: (1) alternatives to a port development, (2) port site selection, (3) port layout design, and (4) structures and materials [ref. 1]. The EPDH framework emphasizes the importance of including ecosystem values in the higher, larger-scale levels, which are often omitted in the environmental impact assessments (EIAs) of port developments. The EPDH framework was tested by applying it retrospectively to the case study of the expansion of Tema port in Ghana. It was observed that ecosystem-based considerations played only a limited role in identifying and evaluating alternatives at all four levels of port planning and design. Ecosystem considerations were mostly not considered or were only weakly assessed. Applying the EPDH showed that a wider range of ecosystem-friendlier alternatives was possible for Tema, especially in the selection of port layout, structures, and materials. This demonstrates the need for such a structured approach and its potential added value in considering a wider range of alternatives early in the planning and design process. Placing the ecosystem centrally from the outset increases the opportunities to avoid and restore ecosystem impacts, and to provide ecosystem benefits to stakeholders in and around the port. To learn from past port engineering practices, a study was done to map the sandy beach evolution around seaports at the scale of the African continent [ref. 2].

Figure IV.4 Geographical overview of the gross coastal areal changes adjacent to 130 African seaports and the beach area change detected for the port of Nouakchott (Mauritania) between January 1984 and December 2017) [ref. 2]



The results can be used to inform beach maintenance strategies for existing seaports and to support planners and engineers to minimize long-term coastal impacts of port expansions and new port developments in Africa in the future. Both studies, on the ecosystem-based port design hierarchy and the sandy beach evolution around African seaports have been published in scientific papers. Ultimately, the aim is to implement a model which includes a coherent (integrated) framework and process design that draws together relevant stakeholders and social, economic, and ecological effects to bring about a sustainable port. It conjoins port authorities, contractors, nature conservation organizations, ecologists, engineers, and local stakeholders to co-create the port design, and to improve the fit between ports and their social-ecological landscapes.

The project results include an 'Africa-specific' design framework and design tools to integrate and optimise the environmental, economic, and public benefits of ports. An 'action based' research approach has been applied and a demand driven knowledge development, meaning that users are in direct contact with the researchers. The developed methodology is innovative and demonstrates clear value and viability in emerging countries, to solve identified challenges in an inclusive way with built-in environmental and socio-economic benefits.

Sandbar Breakwater (Dangote, Lekki, Nigeria)

For the development of the large Dangote Refinery and Fertilizing Plant Project, that is currently under construction in Lekki, Nigeria, a few quays and a jetty with a RoRo facility needed to be developed for importing the construction materials and exporting the future products. To accommodate these logistics, this new innovative concept has been developed and designed by CDR International and Svasek Hydraulics and implemented by Boskalis.

The concept of the Sandbar Breakwater was born based on the typical natural dynamics of the West African coast (Gulf of Guinea). Learning from the development and coastal impact of the existing port infrastructure in West Africa, the application of sand as a construction material for marine infrastructure seemed very obvious. Along this coast, ports experience heavy sedimentation at the western updrift side of the breakwaters, leading to the rapid burying of valuable armour rock. The Sandbar Breakwater concept is based on this principle by using natural accretion as the basis for the port protection. Such a concept is advantageous as a large sediment drift naturally supplements the sand filling works during construction and the required rock volumes are reduced significantly, saving construction time and minimising the environmental impact. To counteract the downdrift coastal retreat, a replenishable sand engine completes the scheme. Sustainable future development is further pursued by integrated maintenance campaigns following the Building with Nature principles to guarantee the operability of the port while preserving the alongshore sediment balance and minimising the environmental impact.

The concept and design of the Sandbar Breakwater is based on thorough understanding of the unique natural coastal system of Nigeria: regular swells arriving at the coast under a relatively constant angle in combination with a uniform steep and sandy coast resulting in a large and unidirectional longshore sediment transport. Following the natural characteristics of the environment, the key element of the Sandbar Breakwater concept is a sand body orientated close to its equilibrium and held in place by a groyne structure at the tip of the Sandbar.

The Sandbar Breakwater has been designed such that the initial placement of sand was minimized while the natural supply of sand, i.e. due to the alongshore sand drift around 850,000-1,000,000 m^3/year, was used to provide the long term stability of the Sandbar body. Extensive morphological numerical modelling has been conducted to optimize the design and construction phasing to ensure the stability of the Sandbar Breakwater and hence safety of the port, while minimizing the costs.

Figure IV.5 Satellite image from 24 December 2018 (Google Earth) with green line:, showing the coastline just before construction sandbar body, red line: showing the situation just after the sandbar body has been put in place according to the design and blue line:, showing the resulting reshaping after a wet season and the coastline reaching the equilibrium coastline orientation as expected

Figure IV.6 Westward looking aerial photo of the Sandbar Breakwater including the sand engine. Image courtesy of CDR International B.V.

As sand can be easily re-handled, this new concept is flexible and allows for a relatively easy future port expansion: the (partly) naturally accreted area in the west may accommodate the expansion of the harbour basin. Currently the port is already being expanded with an increased harbour basin and additional quays, as shown in Figure IV.7. The soft character and the flexibility of the concept makes the Sandbar Breakwater also more resilient and adaptable to climate change, compared with a conventional breakwater scheme.

Figure IV.7 Orthophoto of March 2020, showing the ongoing expansion of the port basin. Image courtesy of CDR International B.V.

The Sandbar Breakwater concept balances the sand and rock quantities: as sand forms the basis of the breakwater, the use of rock and concrete units is significantly reduced compared with a conventional breakwater. In general, such hard construction materials are relatively expensive and need to be quarried and transported over often large distances and narrow or congested roads. Along this coastline, sand is abundantly available, which can be safely sourced. It is an attractive construction material due to its low costs and quantities and can easily be scaled by increasing the number of hopper dredgers. The initial sand body volume is minimised to make optimal use of the ongoing import of sand, reducing the total required construction material. The Sandbar Breakwater in Lekki, Nigeria, had consequently significantly lower construction costs and a significant increase in its construction speed, which was vital for the feasibility of the project. This has also led to a minimisation of quarrying (i.e., blasting, sorting, etc.) and truck movements (75 % to 85 %) through the Lagos State road network, in turn minimising congestion, traffic accidents, nuisance, impact on air quality and the carbon footprint.

The maintenance of the access channel, Sandbar Breakwater and sand engine should be done in an integrated manner, serving the operability of the port as well as to preserve the alongshore sediment balance along the Lekki coastline as much as possible. In any case, it is envisaged to utilise the bypassed material for the replenishment of the sand engine. The amount and expected timing of the bypassing can be influenced in the design by changing the groyne length, or by increasing the groyne length at a later stage when required. The maintenance of the Sandbar Breakwater, the access channel and the sand engine should be framed following a long-term vision in which the maintenance requirements of each coastal/port element are adjusted to each other. By linking the various requirements, the alongshore sediment balance is automatically incorporated in a maintenance chain. In order to be able to specify and periodically update a maintenance plan, the regular monitoring of the coastline position, bathymetry and topography is required and is of paramount importance. In case of criticalities, maintenance can be performed relatively easily by placing or moving sand to the most critical locations either by waterborne but preferably by land equipment. The latter illustrates the flexibility in strengthening the sandbar and thereby the high resiliency or adaptability to long-term climate change-induced impacts.

The successfully designed and implemented Sandbar Breakwater at the coast of Lekki, Nigeria, showed that this concept is a cost-effective and quickly buildable port protection. The subsequent safe and continuous port operations, proves the *feasibility* of the concept. By using the typical local natural dynamics as the starting point for the evolution of this concept, it follows the principles of Building with Nature and is

considered a good example of a nature-based solution. This concept may become a generic port solution in coastal environments like West Africa, with the presence of a relatively uniform wave climate, a sandy coast and a unidirectional longshore transport. The important criteria for success can already be deduced from the realisation of the Sandbar Breakwater at Lekki, Nigeria.

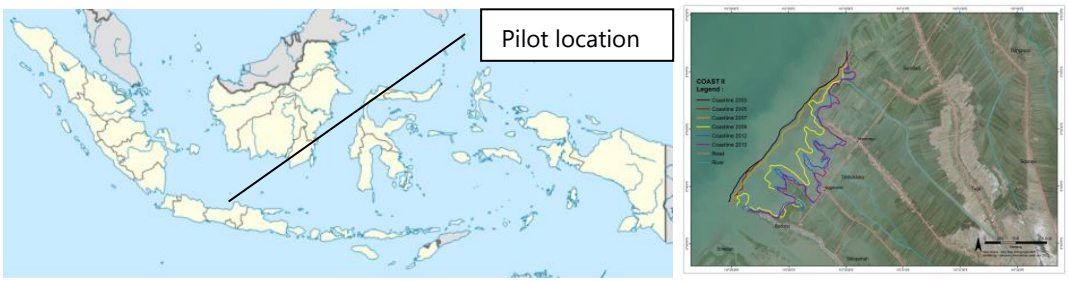
The concept of the Sandbar breakwater is new and innovative and has never been applied in the past. The constructed Sandbar Breakwater at Lekki Nigeria is worldwide the first one applied. The breakwater is successful construct and the subsequent safe operation of the port proves feasibility of the concept. It has shown that the use of soft materials, such as sand, as main construction material is safe and feasible and minimizes environmental impact. The applied Sand Engine scheme has successfully mitigated heavy coastal retreat at the east side, without any secondary effects, like relocated erosion downdrift as would be expected with hard infrastructure. The concept of the Sandbar Breakwater has been born based on the typical natural dynamics of the coast of West-Africa – Building with Nature. Hence this concept is especially applicable for WACA countries and a solution for their mutual problem with coastal dynamics in relation to ports: strong structural accretion and erosion due to blockage of longshore sediment transport. The Sandbar Breakwater and the associated Sand Engine scheme are considered complementary with regards to sustainability and are therefore considered to be inseparable within the overall concept. The overall concept minimizes environmental impact: i) it mitigates structural erosion in the most natural way by restoring the disrupted sand balance which is inherently associated with port infrastructure along this coast, ii) it uses abundant local available soft material, sand, as basis and iii) the minimization of the use of rock, led to a minimisation of quarrying (i.e., blasting, sorting, etc.) and truck movements (75 % to 85 %) through the Lagos State road network, in turn minimising congestion, traffic accidents, nuisance, impact on air quality and the carbon footprint. Besides minimizing environmental impact the concept is a quickly buildable solution, and significantly cheaper compared to conventional breakwater solutions. Further, due to its flexible character the concept relatively easy to expand, easy to maintain and therefore more resilient to climate change. The concept is ready to use and applicable for other port development along many parts of the coast of West Africa. Many research and lessons learnt of the existing port.

Sustainable restoration of mangrove coastline (Demak, Indonesia)

Introduction

Communities in Demak, at the North coast of Java (Indonesia) are suffering from coastal erosion degrading kilometres of land as a result of unsustainable land use. An integrated approach is implemented as a viable alternative to the traditional engineering approach, making the services that nature provides an integral part of the design of hydraulic infrastructure, thereby creating benefits for nature and society. It aims to restore the mangrove coastline which reduces erosion, adapts to sea level rise and enables inclusive economic growth through sustainable aquaculture. The goal is to trigger a paradigm shift towards infrastructure solutions that align economic development with the preservation or restoration of natural resources.

Figure IV.8 Left: the map of Indonesia showing the project location at the north coast of Java, in the Demak district. Figure right: map of the project area. The coastline retreated several hundreds of metres in 10 years



In 2015, a pilot project to restore the natural coastal mangrove forest was started. The first step was to establish a thorough understanding of the complex natural system and local socio-economic context. Based on this system understanding, innovative solutions were identified. Temporary permeable structures

constructed from local material creating wave-sheltered areas fostering sedimentation, creating a favourable habitat for mangrove recolonisation. Once the mangrove forest is fully-grown it will provide protection against waves. It will at the same time provide other ecosystem services like increased fish population providing livelihood for fishermen, tourism, nursery habitat and CO2-storage.

Figure IV.9 Left: permeable structures, mangrove forest, local fisheries. Figure middle and right: aquaculture yield

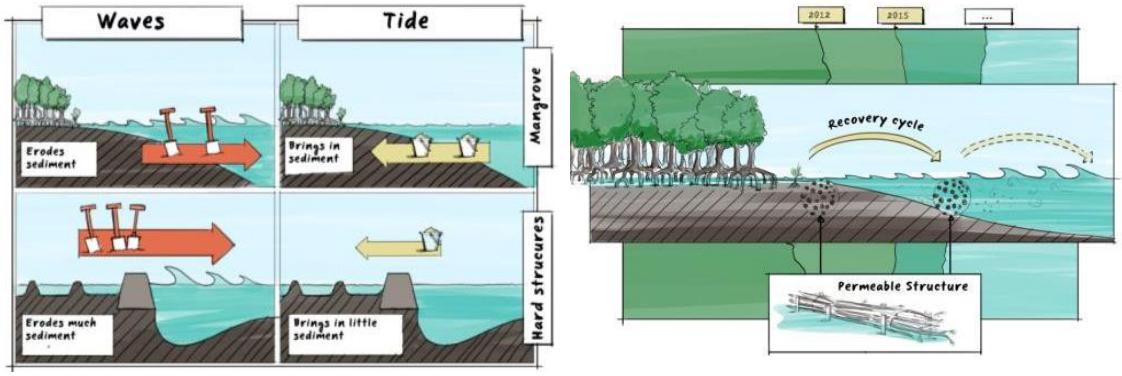
A long-term sustainable solution requires the full support of the local population and governmental institutions to sustain and expand the use of the innovative practices. To support a smooth transition towards these practices, local communities are simultaneously trained in sustainable methods to improve the productivity of their aquaculture ponds to develop a sustainable coastal zone. This is done using 'coastal field schools' as modelled from the 'farmer field school' methodology developed by the FAO in 1989 for rural development. The approach is embedded in the village regulations. Sustainability in this rural area is created by closely linking coastal safety and livelihood.

Our approach is elaborated below for the cyclical design cycle: problem analysis, system analysis, functional analysis, study of alternatives and impact assessment. The focus is on coastal mangrove restoration.

Step 1: Problem analysis

The project is located in Demak district, along the north coast of Java, northeast of the port of Semarang. The coast is a tropical muddy mangrove coast. Until the 1980s, the area mainly supported rice production. As the price of rice dropped, land-use was gradually transformed to aquaculture, producing principally shrimp and milkfish. When the aquaculture productivity declined, the remaining natural mangrove forests were cut and dredged for conversion into aquaculture ponds. With removal of the protective coastal mangroves the shores and the hinterlands became more exposed to erosion, flooding and salinisation. This resulted in degradation and loss of productive land, ponds, infrastructure and even whole villages. In the last decades the coastline has retreated hundreds of meters or even several kilometres. Other factors causing the coastline erosion were land subsidence due to groundwater extraction, canalisation rerouting sediment and disturbing the sediment influx, as well as construction of coastal structures interfering with longshore sediment transport. This analysis of the problem was achieved together with the local communities, governmental officials and project team experts.

Figure IV.10 Left: Presents the effect on the sediment balance caused by waves and tide in situations with mangroves in contrast with hard structures. With mangroves, sediments will tend to remain in balance, with hard structures however net erosion is taking place. Figure right: recovery cycle where permeable structures create shelter, sediment settles, seabed rises and mangroves recolonise and grow



Step 2: System analysis

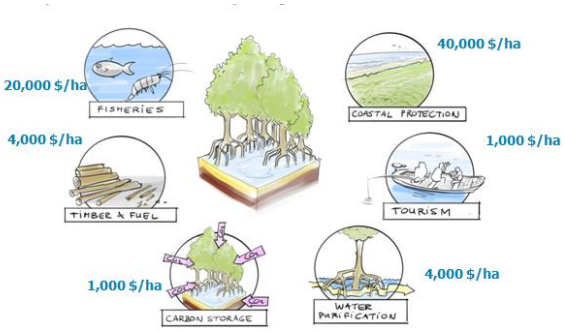
In the past this complex process was addressed by taking various measures such as construction of hard sea defences and mangrove replanting. However, these measures failed, as neither measure addressed the root causes of the problem. The hard sea defences blocked sediment transport and collapsed over years as hard structures tend to undermine themselves when built in soft sediments. When mangroves were actively planted aiming to restore the green belt, typically only a small percentage of mangroves survived after several years because planting took place in areas with unfavourable conditions for mangrove growth.

The original mangrove greenbelt provided coastal protection and additional co-benefits and was able to adapt to changes as the roots trapped sediment following the sea level rise. With this understanding of the hydraulic and morphological system the mangrove root system was mimicked with small temporary permeable structures with brushwood fill that attenuates the wave energy. These structure are permeable so the reflection is limited, which reduces scour. Due to the regular openings the tide can bring in the sediment. In the sheltered areas behind the structures the sediment transport capacity is lower, the sediments settle, gradually raising the level of the seabed. When the level is around mean sea level, the conditions are favourable for mangrove seedlings to recolonise. In our project area propagules of several species are available in the system thanks to surviving adult trees. The currents distribute these propagules widely, including to sheltered conditions where the mangroves can recolonise and grow naturally.

The system analysis took place in various cycles and increased in level of detail. The intimate knowledge of the local communities was essential together with the expertise of the various experts.

Step 3: Functional analysis

As became clear in the problem analysis, the protective function of the mangrove forest was lost and as a result the productive aquaculture ponds were flooded and eroded. Other beneficial functions for the local communities were lost too as depicted in the figure at the right. On a global scale the function of carbon storage was also lost. Restoration of the mangrove green belt would indeed bring back many values.



Step 4: Study of alternatives

To bring back the mangrove greenbelt various alternatives were developed, creating suitable conditions for mangroves to recolonise. The first alternative were permeable structures. Comparable structures have already been used for centuries in the 'Wadden Sea', Northwest Europe, as a proven method to reclaim land. The principles have been described in the 'system analysis'. A second alternative is Ecological Mangrove Restoration. With this alternative the ponds along the coast and the rivers are filled with sediment. This can be achieved by creating openings in the pond bunds to allow river water and tides to naturally bring

sediment into the former ponds as well as of mangrove propagules. A third alternative is by sediment nourishment. Fine sediment is dredged further offshore and pumped into the system where the tides can still pick it up and bring it further to the shoreline. The natural processes bring the sediment to the best location. This alternative is analogous to the 'Sand Motor' along the Dutch coast where a peninsula of 1 km by 2 km has been created in a single operation

Figure IV.11 Left: Permeable structure a few months after construction with sedimentation at the landward side (to the left). Figure right: drone photo of the project area with at the left are the aquaculture ponds and in the middle the remaining mangroves. The straight lines are the permeable structures with sedimentation landward

Step 5: Impact assessment

The alternatives were compared to each other regarding cost, durability and maintenance. Due to the cost the sediment nourishment was not selected. The permeable structures and the ecological mangrove restoration were implemented. The local communities were trained to construct and maintain these alternatives. This increased their ownership. Every year new structures were constructed and they were monitored regularly to learn how they functioned and interacted with the hydrologic and morphological system. Based on the monitoring results the new structures were adapted and improved every year.

The key lessons learnt from this project are that a combination of a thorough understanding of the bio-physical, socio-economic and governmental/regulatory system as well as early stakeholder involvement, can result in higher vital benefits, at reduced costs , providing the boundary conditions for a sustainable coastal community. It requires a learning by doing approach in an adaptive planning cycle from all participants.

Conclusion

This integral approach is a unique combination of proven methods. This approach can be adapted to every context. As the root causes are addressed it provides clearly measurable impacts for the problems at hand. Due to the integral approach and stakeholders engagement multiple co-benefits contribute to the success of the approach.