An ecosystem-based engineering framework for port design

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Port impacts on environment

Habitat loss due to dredging & civil works

Natural lagoons/wetlands cut off by infrastructure

Beach erosion
Traditional port design

2. Port site selection

3. Port layout

4. Structures & Materials

S.P. AFRICA
SUSTAINABLE PORTS IN AFRICA
Environmental impact mitigation

Avoid

Reduce

Offset
What is required?

• Overarching co-design process

• Work towards Net gain in ecosystem and bio diversity values instead of no impact

• EB port design hierarchy developed with African Partners
Ecosystem based port design hierarchy

Starting point: perceived transport capacity problem

1. Alternatives to port development
   - Port efficiency improvements
   - Other modalities
   - Improved port networks and regionalization

2. Port site selection
   - Existing (impacted) versus new port
   - Naturally favorable conditions (deep, sheltered)
   - Away from protected/unique ecosystems

3. Port layout
   - Port behind breakwaters
   - Open port concepts
   - Offshore terminals

4. Structures & Materials
   - Use of natural materials
   - Niche creation to enhance biodiversity
   - Connectivity improvements (bypasses, eco-ducts)
Ecosystem based port design

• Integrate ports with surrounding ecosystems
  ➔ avoid ecosystem impact

• Generate added value to the port and the surroundings by providing ecosystem services
  ➔ adding to welfare and prosperity
Enabler: advances in field of port and ecological engineering \(\rightarrow\) wider range of alternatives

- Port behind a breakwater
- Offshore berth
- Open port
- Port behind an (artificial) island
Tema case
Tema step 1: alternatives to a port

- Present facilities insufficient for expected container throughput
- Efficiency improvements not sufficient for ambitions
- Other modalities and international cooperation not realistic:
  - Lack of good coastal roads
  - Custom issues
  - National pride
Tema step 2: site selection

- **Existing vs new port:**
  - Already impacted environment
  - Existing network, infra and hinterland connections

- **Tema vs Takoradi:**
  - More liner vessels calls
  - Greater container berth draft
  - More modern facilities

- No realistic alternatives from ecosystem perspective
Tema step 3: layout

1. Alternatives to port development
2. Port site selection
3. Port layout
4. Structures & Materials

Environmental impacts

Offset

Avoidance

Starting point: perceived transport capacity problem

<table>
<thead>
<tr>
<th></th>
<th>Alternative - 1</th>
<th>Alternative - 2</th>
<th>Alternative - 3</th>
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<tbody>
<tr>
<td>Quality of Berths</td>
<td>***</td>
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<tr>
<td>Calmness of water</td>
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<td>Navigational safety</td>
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<td>Future Development</td>
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<td>Disturbing existing port facility</td>
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<td>Harmonization with environment</td>
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<tr>
<td>Cost Index</td>
<td>100</td>
<td>112</td>
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</tbody>
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Note: *** Good  ** Fair  * Poor
Tema step 4: structures & materials

Starting point: perceived transport capacity problem

1. Alternatives to port development
2. Port site selection
3. Port layout
4. Structures & Materials

[Diagram showing flowchart with steps and images of materials and structures]
Findings for Tema case

• Decision making primarily driven by economic and functional requirements (at all levels)
• Ecosystem based considerations hardly accounted for in alternatives and decision criteria
• Realistic alternatives possible at:
  – level 3 (port layout)
  – level 4 (structures & materials)
• Including EB alternatives no guarantee for EB implementations: tradeoffs between different criteria and stakes
Findings relevant for framework

• Realistic EB examples available at different levels of port planning & design
• The earlier ecosystems are accounted for in design process the better
• Ecosystem based alternatives/criteria are required for transparent decision making (now implicit decisions) -> stretch design space
• Our framework may be of assistance
Contributions to framework

Set-up overarching co-design process
- Value-based
- Stakeholder-inclusive
- Ecosystem-based
- Future-proof

1. Alternatives to port development
2. Port site selection
3. Port layout
4. Structures & Materials

Systemic elements of the approach
Integrated engineering design
Methods & selection criteria

contextualize
how?
Compendium of methods: Example

- Assess coastline evolution with satellite imagery (data poor environment)
- Cross-compare ports based on coastline evolution and characteristics
Results African seaports

- For all 130 ports:
  - 44.2 km$^2$ areal change
  - 23.4 km$^2$ accretion
  - 20.8 km$^2$ erosion
- Top 10% determine 65%
- Top 1 determines 13%

<table>
<thead>
<tr>
<th>Top 10 historic evolution</th>
<th>Areal change (km$^2$)</th>
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<tbody>
<tr>
<td>Nouakchott, Mauritania</td>
<td>5.9</td>
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<td>Cotonou, Benin</td>
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<td>Port Said, Egypt</td>
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<td>Damietta, Egypt</td>
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<td>Lomé, Togo</td>
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<td>Monrovia, Liberia</td>
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<td>Laayoune, Morocco</td>
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<td>Richards, Bay, South Africa</td>
<td>1.2</td>
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<td>Lagos, Nigeria</td>
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<tr>
<td>Buchanan port, Liberia</td>
<td>1.1</td>
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76,000 Landsat satellite images over past 34 years
Contact details

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http://sustainableportsafrica.com/
What about operability?

**Why?**
- Determines functioning of the port:
  - Berthing/mooring
  - Tug assistance
  - On/off-loading
- Hence determines:
  - Location suitability
  - Lay-out feasibility
- Depends on a.o.:
  - Wind
  - **Waves (LF, HF)**
  - Currents
  - Depth

**How?**
- Global wave data
- Simple models/relations

**Scale?**
- Start with Tema
- Scale-up to continent