THE USE OF SYSTEM DYNAMICS APPROACH TO IDENTIFY INTEGRATED COASTAL ZONE PLANNING AND MANAGEMENT INDICATORS FOR MAURITIUS: A PERFORMANCE EVALUATION MODEL

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30 October 2012
Coastal Zones

- Major focus for human society development
- Interface where land meets the sea and comprises of a range of coastal land, intertidal area, aquatic systems including the network of rivers and estuaries, islands, transitional and intertidal areas, salt marshes, wetlands and beaches (Cicin-Sain and Knecht, 1998)
Coastal Zones

Coastal zones are essential as:
- Unique geologic, ecological and biological areas of the planet
- Most productive accessible areas to man
- Unique habitats to the plant and animal kingdom
- Source of food
- Barriers to natural hazard
- Aesthetic and scenic areas

Coastal zones: fragile and vulnerable to threats
- Human pressure, Natural pressure
Coastal Zones

- Pressures due to climate change:
  - Sea Level rise
  - Coastal inundation, Storm damage, Beach erosion, Wetland loss/change, Saltwater intrusion, Displacement of existing coastal plant and animal communities inland, Loss of biodiversity, Loss of tourism activities, Loss of agricultural land, Loss of water supplies, Loss of lives

- Increase in sea surface temperature
  - Coral bleaching, Changes in quality of water – algal blooms, Decrease in sea-grass ecosystem, Reduced upwelling/resupply of nutrients impacting marine life, Increase in frequency and intensity of storms
Integrated Coastal Zone Management

The coast ‘appears’ to all purposes to be working and functioning providing us with the uses and services we want.

However, there is a need of the coastal zones to be maintained and continued for the future.

Hence, the need for a form of coastal management.

ICZM?

- Preservation of existing resources and ecosystems
- To ensure balanced management and sustainable development of these zones
- To preserve resources for future generations
ICZM Programs

- United States comprises the bulk of all initiatives established worldwide

- European Parliament and European Council
  - In 2002, adopted a Recommendation on ICZM: 20 coastal member states and 2 candidate States
  - 8 principles of sound coastal planning and management
  - Integration of existing legislations – directives, frameworks
  - In 2003, member states and candidate countries have to abide to a set of EU ICZM Recommendation: 7 goals, 27 indicators and 44 measurements

- African Continent
  - ICZM Strategies and Action Plan
  - E.g, Kenya, Tanzania, Cameroun, Ghana, South Africa
ICZM Programs

Mauritius

Development of an ICZM Framework by Landell Mills in 2010

Overall goal: promote sustainable use and development of the coastal zone in the Republic of Mauritius

Review and development of appropriate policy and regulatory framework for ICZM promotion

ICZM plan for identified pressure zones

Monitoring and Evaluation - important aspect of ICZM
Methodology

- Demo site: Flic en Flac
- Identification of Variables
- Classification of Variables according to 6 Modified and Adapted Goals of EU ICZM Recommendation
  - Data Collection
  - Causal Matrix
  - Stakeholders Views
  - Development of systemic Models
  - Model validation and scenario planning

Final Project Write up

- Ministry of Fisheries
- Mauritius Meteorological Services
- Forestry Services
- A force vive of Flic en Flac
- Fishermen association
- Mauritius Oceanography Institute
- District council of Black River
- Tourism Authority
- Ministry of Public Infrastructure
- Network operators
- Wastewater management authority
- Ministry of Local Government and Outer Islands
- Beach Authority
Results

1. Identification and classification of variables
2. Representation of data collected
3. CLD
# Flic en Flac Demo Site Goals and Variables

<table>
<thead>
<tr>
<th>Goals</th>
<th>Variables</th>
</tr>
</thead>
</table>
| 1. To control further development of the undeveloped Flic en Flac coastal zone. | 1. Hotels and bungalows development  
2. Damage by speed boats and divers  
3. Number of inhabitants in Flic en Flac |
| 2. To protect, enhance and celebrate natural and cultural diversity. | 4. Protection of plants within the coastal zone of Flic en Flac  
5. Decrease in coral cover |
| 3. To promote and support a dynamic and sustainable coastal economy. | 6. Recreational activities for tourists  
7. Construction of roads  
8. Installation of communication services  
9. Leisure/recreational activities for residents of Flic en Flac and Mauritians |
<table>
<thead>
<tr>
<th>GOALS</th>
<th>VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. <strong>Goal: To ensure that beaches of Flic en Flac are clean and that coastal waters are unpolluted.</strong></td>
<td>10. Sea water quality</td>
</tr>
<tr>
<td></td>
<td>11. Quality of sand on the beach</td>
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<td></td>
<td>12. Discharge of wastewater</td>
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<td>13. Cleaning and scavenging services on the beach of Flic en Flac</td>
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<td></td>
<td>14. Available facilities on the beach to the public</td>
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<td></td>
<td>15. Maintenance of Flic en Flac beach</td>
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<tr>
<td>5. <strong>Goal: To use natural resources wisely.</strong></td>
<td>16. Degraded marine ecosystem</td>
</tr>
<tr>
<td></td>
<td>17. Exploitation of marine resources</td>
</tr>
<tr>
<td>6. <strong>Goal: To recognize the threat to coastal zones posed by climate change and to ensure appropriate and ecologically responsible coastal protection.</strong></td>
<td>18. Widespread coastal erosion</td>
</tr>
<tr>
<td></td>
<td>19. Sea level rise</td>
</tr>
<tr>
<td></td>
<td>20. Climate change effects and extreme climatic conditions</td>
</tr>
<tr>
<td></td>
<td>21. Flooding</td>
</tr>
</tbody>
</table>
Type of building in Flic en Flac

Type of Building in Flic en Flac

%

Building Type

1 2 3 4 5 6 7 8

Hotels

2000

2011

Licences Issued in Flic en Flac

Pleasure Craft Licences

Number of Licences

- Accommodation
- Activities
- Club
- Guest House
- Restaurant
- Tourist Accommodation
Faecal and Total Coliforms Monitoring

Bacteriological Data: Total and Faecal Coliform

Year


Total and Faecal Coliform (CFU/100ml)

TC Station 1  TC Station 2  TC Station 3  FC Station 1  FC Station 2  FC Station 3

Station 1: opposite Ocean Restaurant; Station 2: Beside Pearl Beach Hotel; Station 3: Opposite old limekiln
Exploitation of Marine Resources

Estimated annual catch and effort for artisanal fishery in Flic en Flac

<table>
<thead>
<tr>
<th>Year</th>
<th>Effort</th>
<th>Catch</th>
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<tr>
<td>1993</td>
<td>1989</td>
<td>9549</td>
</tr>
<tr>
<td>1994</td>
<td>1071</td>
<td>4689</td>
</tr>
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<td>1995</td>
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<td>4392</td>
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<td>1996</td>
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<td>3168</td>
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<tr>
<td>1999</td>
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<td>2000</td>
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<td>2001</td>
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<td>2003</td>
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<td>6708</td>
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<tr>
<td>2007</td>
<td>540</td>
<td>1572</td>
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<tr>
<td>2011</td>
<td>604</td>
<td>2652</td>
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Causal Matrix - CLD

- Stakeholders views on variables: + and –
- Illustration of relationship through CLDs
- CLDs have been developed according to goals
## Causal Matrix

<table>
<thead>
<tr>
<th>PHYSICAL</th>
<th>ECOLOGICAL</th>
<th>ECONOMIC</th>
<th>SOCIAL</th>
<th>ADMINISTRATIVE</th>
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<tbody>
<tr>
<td>V1</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
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<tr>
<td>V2</td>
<td>-</td>
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<td>V3</td>
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<tr>
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<td>V21</td>
<td>-</td>
<td>+</td>
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</tbody>
</table>

**Legend:**
- : Positive relationship
- : Negative relationship
- : No relationship

**Note:** The matrix shows the relationship between different factors across various domains (PHYSICAL, ECOLOGICAL, ECONOMIC, SOCIAL, ADMINISTRATIVE) represented by rows and columns.
CLD - Goal 1

- Maintenance of beach
- Flooding
- Quality of sand on the beach
- Plant protection
- Sea water quality
- Degraded marine ecosystem
- Coral cover
- Sea level rise
- Number of inhabitants in Flic en Flac
- Number of tourists
- Recreational activities for tourists
- Coastal erosion
- Discharge of wastewater
- Construction of roads
- Installation of communication services
- Available facilities on the beach to the public
- Cleaning and scavenging services on the beach
- Exploitation of marine resources
- Leisure/recreational activities for residents of Flic en Flac and Mauritians
- Climate change effects and extreme climatic conditions
Discussion & Conclusion

- 21 variables
- EU ICZM recommendation
- Data collection from local institutions

Causal matrix

Relationship between variables: + and –

CLDs: illustration of relationship between variables:
  +: one variable causes an increase of the other variable
  -: one variable induces a decrease of the other
Thank You!