Linking the value of ocean space and marine ecosystem to coastal reclamation planning: A case study of Xiamen

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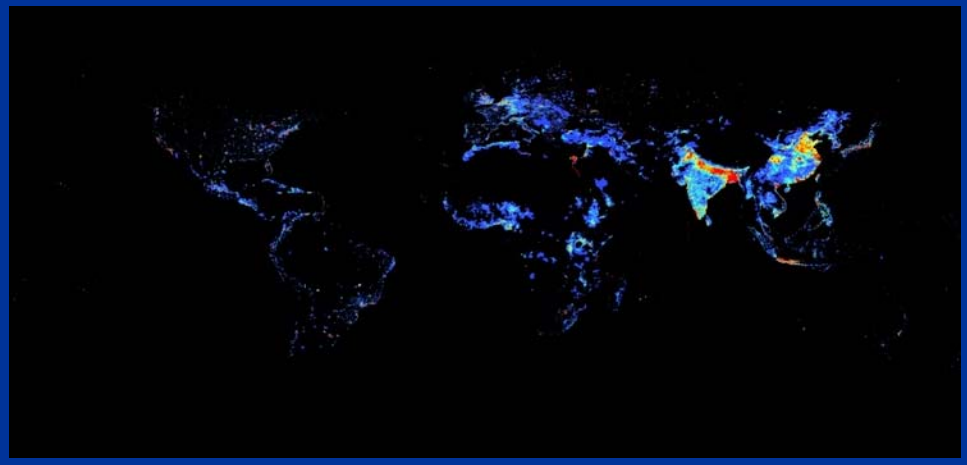
Outline

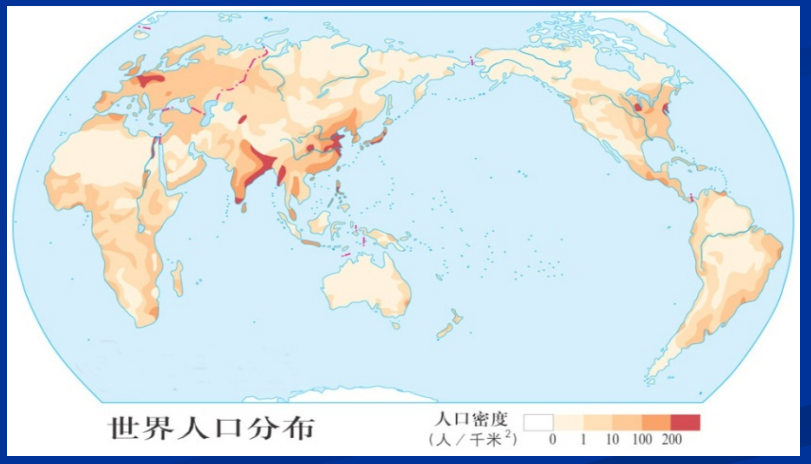
- Background
- Methodology
- Case Study of Xiamen ICM
- Conclusion and Discussion

Background

- The deficit of space: a common problem of the costal zones with high density population
  - More than half of the glob population, production and consumption is located in the coastal zones

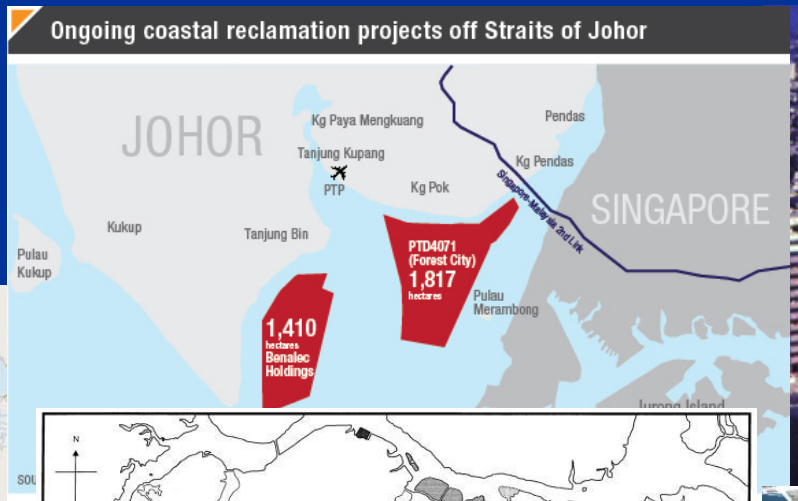


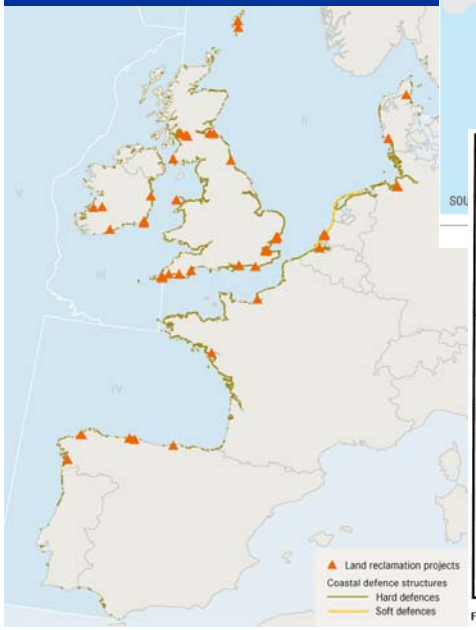
Global Night Light



Global Population Distribution

- Coastal reclamation is the solution of almost all the coastal societies to ease the pressure of lack of land
  - Japan, Singapore, China…….





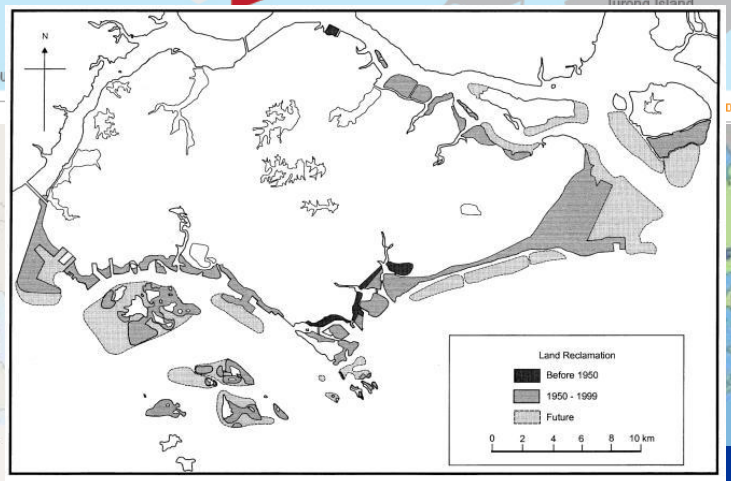
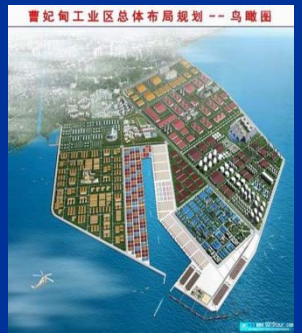
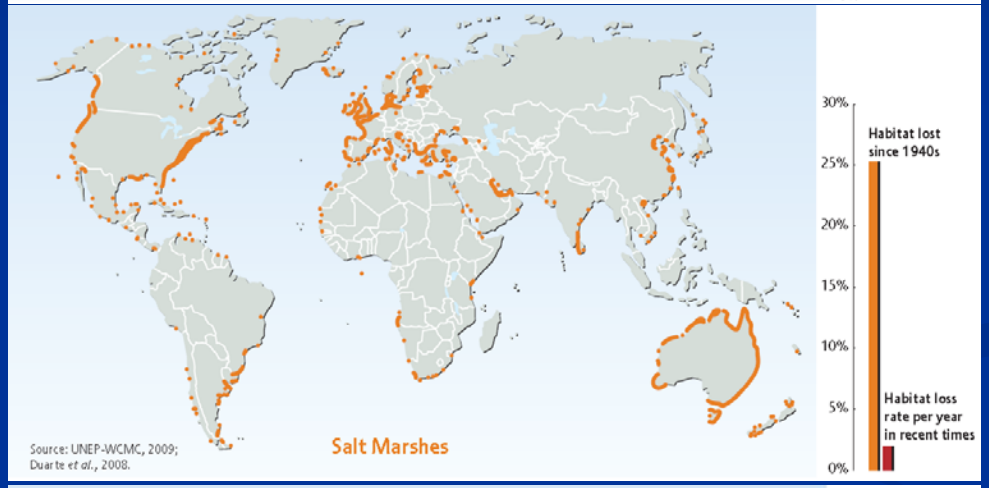


Figure R8 Reclaimed land in Singapore.

- In China, about 13.4 million ha of tidal lands have been reclaimed for agriculture, salt-making fields, mariculture, ship berths, and other uses since the middle of the 20th century.
- This led to the loss of almost half of the country's tidal lands and about 75 percent of the country's mangroves



- Issues of sea reclamation
  - Sea reclamation usually means to create more useful land area for food production, industry development zone and urban development
  - It, however, causes permanent change to the sea's natural characteristic; thereby resulting in heavy losses of ecosystems services which human-kind depends on
    - food security, poverty eradication, economic growth, and
    - global water and hydrology regulation, reducing and mitigation of climate change, erosion and storm protection and air quality maintenance, preservation of traditional culture, etc...



Lost of mangroves (>35%)

Lost of salt marshes (>25%)

Lost of seagrass (>55%)

- There is an urgent need to develop coastal reclamation planning which can balance the coastal socio-economic development and the protection of marine and coastal ecosystems.

- This research presented an analytical framework, which links the value of ocean space and marine ecosystems, to support the optimal spatial planning of coastal reclamation.

Methodology

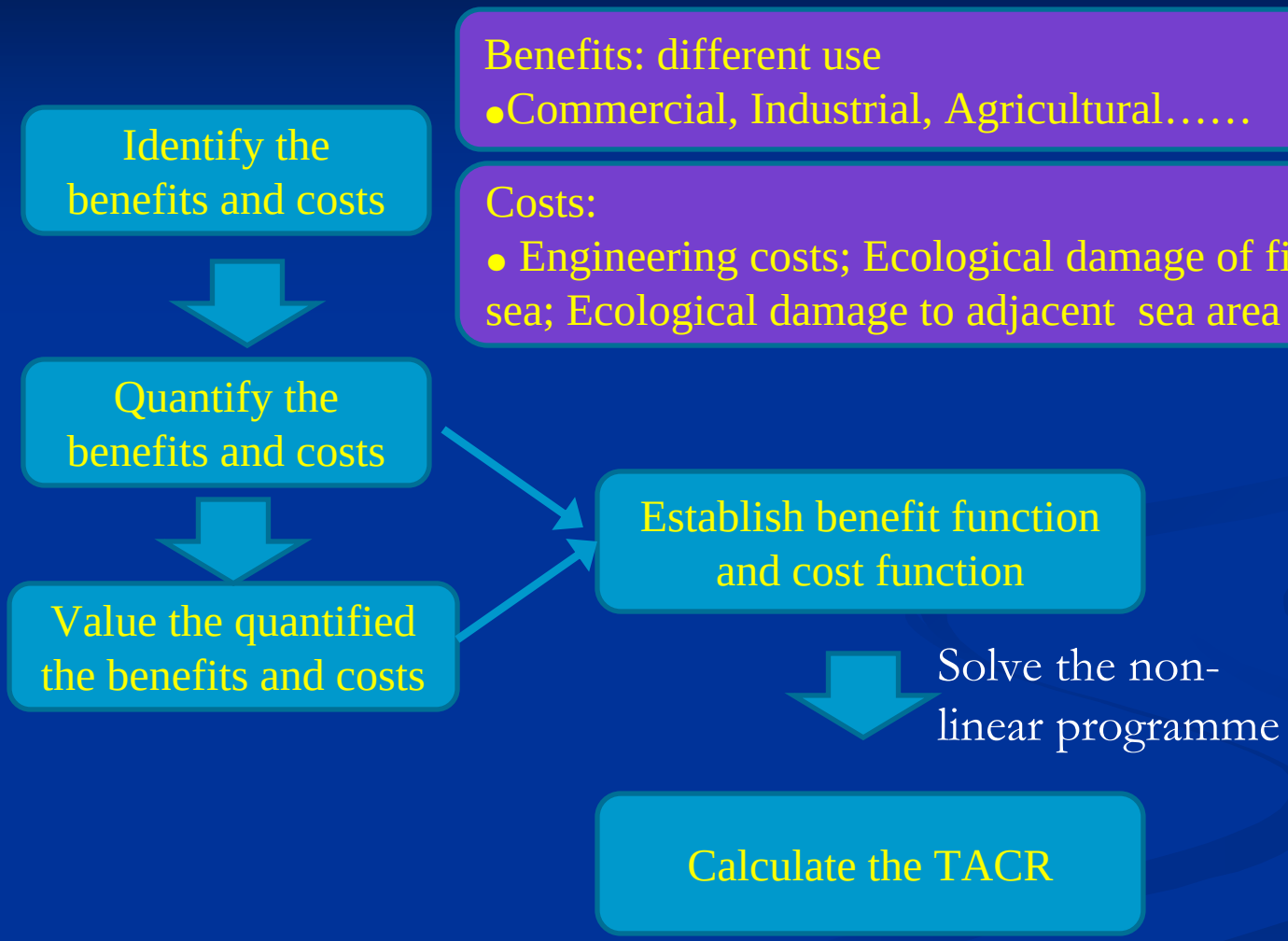
- The objective of coastal reclamation
  - Private planner: maximize the net benefit of a specific project----
  - Social planner: maximize the net benefits (or minimize the net cost) of whole society
  - Difference: the external cost, the ecological damage of sea reclamation
- The optimal reclamation planning can be thought as the following optimization problem
  - maximize the net benefits of whole society subject to a set of constraints

- Model
  - From the standpoint of the society, the objective of a social planner in charge of coastal reclamation is to maximize the net societal benefit by choosing an optimal set of location and scale for reclamation.

$$\text{Max.} \quad NB = \sum_{i=1}^{n} [p_i \times f(x_i) - c(x_i)] - \sum_{i=1}^{n} \sum_{k=1}^{m} C^k(x_i)$$

$$\text{s.t.} \quad h_i(x_i) \le h_i \max$$

Steps

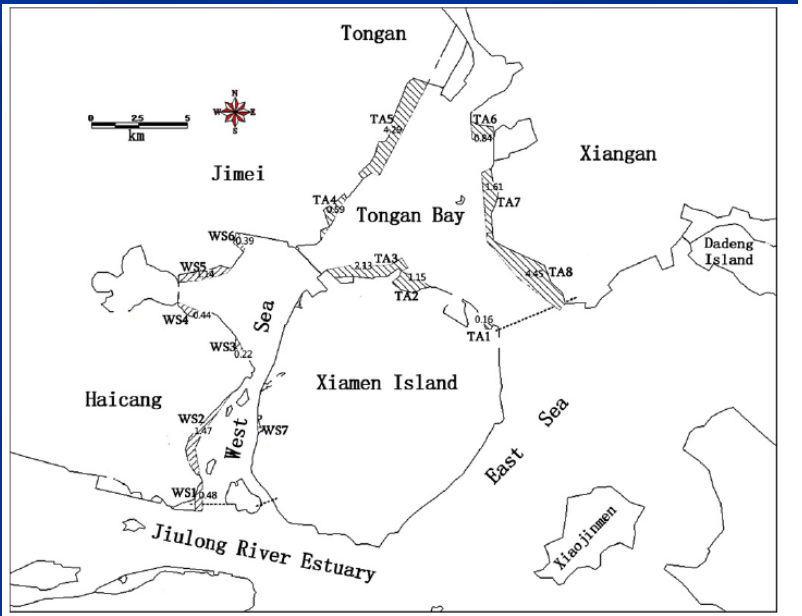

Identify the benefits and costs
Quantify the benefits and costs
Value the quantified the benefits and costs
Benefits: different use
•Commercial, Industrial, Agricultural……
Costs:
• Engineering costs; Ecological damage of filled sea; Ecological damage to adjacent sea area
Establish benefit function and cost function
Solve the non-linear programme
Calculate the TACR

Case study of Xiamen

- From 1950s, 125.74 km^2 sea area have been reclaimed. Western Sea and Tongan Bay decreased 58% and 27%

- A reclamation plan of 20 km^2 has been proposed

1930s 2000s



Benefit functions

- Weighted-average price of land for different use (commercial use and industrial use)

$$\text{Max. } NB = \sum_{i=1}^{n}[p_i \times f(x_i) - c(x_i)] - \sum_{i=1}^{n}\sum_{k=1}^{m} C^k(x_i)$$

$$h_i(x_i) \le h_i \max$$

$$B_i(x_i) = P_i x_i$$

Revenue from planned reclamation areas.

Location	Area[a] (hm^2)	Share of different uses[b]		Price of land[c] (yuan/m^2)		Weighted average price (P_i) (yuan/m^2)
		Commercial	Industrial	Commercial	Industrial	
TA1	16	0.8	0.2	3700	700	146.69
TA2	115	0.25	0.75	3700	700	70.19
TA3	213	0.25	0.75	3700	700	70.19
TA4	59	0.55	0.45	2900	250	80.92
TA5	429	0.55	0.45	2700	200	74.59
TA6	84	0.8	0.2	2500	150	95.85
TA7	161	0.75	0.25	2500	150	90.33
TA8	445	0.25	0.75	2500	150	35.17

Cost functions

- Engineering functions
- Ecological damage of filled seas
- Environmental carrying capacity
- Siltation cost

$$\text{Max.}\quad NB = \sum_{i=1}^{n}[p_i \times f(x_i) - c(x_i)] - \sum_{i=1}^{n}\sum_{k=1}^{m} C^k(x_i)$$

$$h_i(x_i) \le h_i \max$$

$$C_i^{ENGA}(x_i) = 29.7x_i$$

$$C_i^{ED}(x_i) = e_i x_i$$

$$\frac{dC^{dc}}{dx} = 0.0008x + 1.244$$

$$\frac{dC^{ecc}}{dx} = 0.306x + 5.298$$

Value of ecosystem services of planned reclamation area and engineering cost.

Location	Value of ecosystem services (e_i) (yuan/m^2)	Engineering cost (yuan/m^2)	
		Present value (C^{ENG})	Annual value (C^{ENGA})
TA1	9.13	660	29.7
TA2	9.53		
TA3	9.53		
TA4	9.16		
TA5	9.16		
TA6	9.16		
TA7	9.16		
TA8	9.16		

Dredging cost and value of carrying capacity of different reclamation scenarios.

Scenarios	Description	Area (hm^2)	Siltation (m^3)	Dredging cost (10^{4}yuan)	Tidal volume (10^{6}m^3)	Value of environmental carrying capacity (10^{4}yuan)
1	No reclamation	0	724,399	2151.47	713.20	4477.47
2	TA1	16	724,819	2152.71	711.62	4467.56
3	TA1+TA2	131	725,266	2154.04	705.48	4429.00
4	TA1+TA2+TA3	344	725,729	2155.42	693.91	4356.35
5	TA1+TA2+TA3+TA8	789	726,262	2157.00	671.19	4213.71
6	TA1+TA2+TA3+TA8+TA7	950	726,743	2158.43	662.78	4160.95
7	TA1+TA2+TA3+TA8+TA7 +TA4	1009	727,171	2159.70	658.99	4137.11
8	TA1+TA2+TA3+TA8+TA7 +TA4+TA5	1438	727,696	2161.26	637.41	4001.68
9	TA1+TA2+TA3+TA8+TA7+A4+TA5+TA6	1522	728,131	2162.55	632.18	3968.84

- Solve the non-linear programme

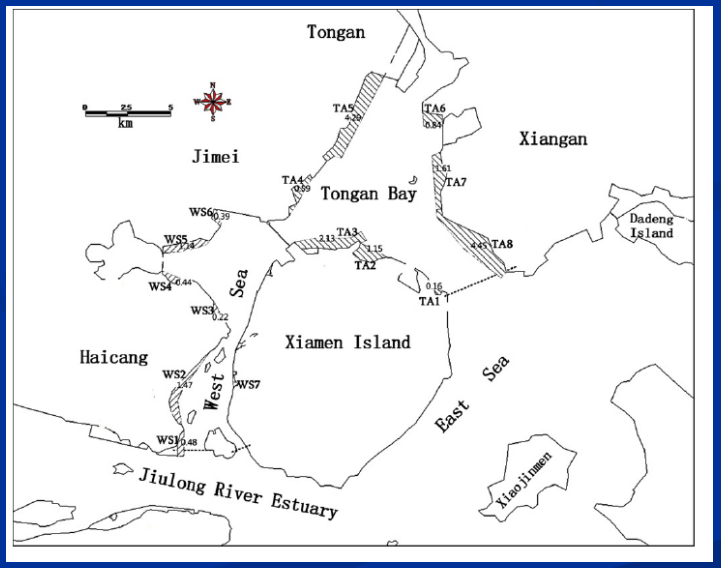
GAMS

Modeling for the Real World

- Results

Location	Planned area (hm^2)	Optimal reclamation area (hm^2) Discount rate (%)		
		4.50%	8%	2%
TA1	16	16.00	16.00	0.00
TA2	115	81.22	115.00	0.00
TA3	213	81.22	160.90	0.00
TA4	59	59.00	59.00	0.00
TA5	429	97.01	193.52	0.00
TA6	84	84.00	84.00	0.00
TA7	161	149.40	161.00	0.00
TA8	445	0.00	0.00	0.00
Total	1522	567.85	789.42	0.00

Peng B. et. al., 2013



Discussion and Conclusion

- Coastal reclamation destroyed marine ecosystem services human depend on while creating useful land for food production, industrial and urban development

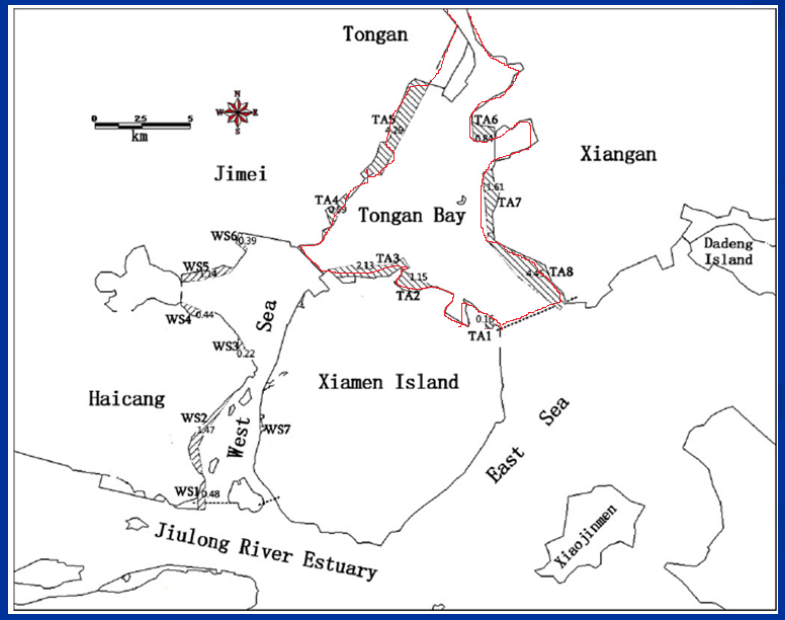
- By assessing the optimal scale and location for reclamation, we may be able to meet the current demand for land to facilitate economic development while maintaining the health and resilience of the coastal ecosystems.

- Discount rate determines the scale and location of optimal reclamation. Low discount rate means giving high weight to the long-term ecological benefit

- The result indicates that the optimal TACR Tongan Bay are 5.68(4.5%) to 7.89(8%) km2
- The area of Tongan Bay must be maintained at a minimum of 85.31 km2. (current area of Tongan Bay is 93.2 km2)
- This result can provide scientific support for the optimal spatial planning of coastal reclamation

- This result can also help us to determine the coastal reclamation red-line
  - Reclamation is prohibited within the redline

- The coastal reclamation red-line system: regime to implement the optimal reclamation planning
  - Establishment of a critical minimum sea area in each specific bay
  - the minimum area will be written into law.



Existing regulations

- Usage charge regime
  - Sea Area Use Management Law of PRC (SAUML) promulgated in 2002 provides the economic incentive to control the sea reclamation.
  - But the present usage standard for the sea reclamation is too low to restrict its function
- The Environmental Impact Assessment (EIA)
  - every ocean/coastal construction project should formulate and submit environmental impact assessment.
  - single project EIA does not consider the cumulative environmental impacts of all projects is usually easy to pass the examination because single project have relatively small impact to environment.

Thank you