Building with Nature

To balance the urban growth of coastal Kochi with its ecological structure

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1. Introduction

The World Bank in a 2010 report notes that ‘Thirteen of the world’s 20 largest cities are located on the coast, and more than a third of the world’s people live within 100 miles of a shoreline. Low-lying coastal areas represent 2 percent of the world’s land area, but contain 13 percent of the urban population (McGranahan et al. 2007). This clearly indicates how attractive coastal areas are for human settlements and urban growth. But on the flipside, in the light of climate change and natural disasters, these regions stand more to lose than any other. Of these, more than developed countries, the regions in the developing countries seem to be in more danger. A recent study of 136 port cities showed that much of the increase in exposure of population and assets to coastal flooding is likely to be in cities in developing countries, especially in East and South Asia (Nicholls et al. 2008).

Due to its high economic value on the national and local scale, coastal areas are developed and inhabited inspite of impending sea-level rise and coastal flooding. Thus in these areas, it becomes impertinent that water safety be an important criteria in planning and designing.
1.1 Estuaries and Barrier Islands

Prichard (1967) presents one of the more commonly cited definitions of an estuary: a “semi-enclosed coastal body of water which has a free connection with the sea and within which sea water is measurably diluted with freshwater derived from land drainage. [4] These aqua systems exhibit a wide variety of life forms which depend on saline conditions including salt marshes, mangroves and a huge variety of fish and shellfish. Because of their sensitivity and complexity, estuaries are highly susceptible to human influence.[4]

Barrier islands are formed of loosely consolidated materials, primarily sand, and generally include a sandy beach, frontal and secondary dunes, interior wetlands and maritime forest, a backshore zone, and the lagoon or sound that separates the island from the mainland. [4]. These structures are so vulnerable to the forces of wind, waves, storms, hurricanes and sediment transportation that their size, shape and location keep changing.

1.2 Urban growth

The urban growth of coastal areas are dependent on coastal and waterfront activities. Sea-based industrial activities can trigger the urban growth of coastal areas. These result in a change in the socio-economic conditions. Port and industries are added to socio-economic factors that predominantly consisted of traditional fishing and agriculture.

It is interesting to note that the processes that maintain the socio-economic conditions in the national scale are not always the same as that in the local scale. At the national scale, coastal areas are important due to the presence of one or more of these - a harbour, a port, marine export industries, other coastal industries, sand mining etc. While at the local scale, coastal areas are important because of these - immediate environment, traditional fishing industry, agriculture etc. But the parameters at the local scale ensures a self-sustained coastal population which put little stress on the national scale.

1.3 Ecological structure

As should be clear, the socio-economic conditions at both scales are dependent on the ecological structure of the coastal area. The ecological structure here implies a healthy coastline where there is little beach erosion so that locals gain from the presence of the beach for fishing and recreation, it implies optimum conditions for breeding fish so that local as well as national fish industries can grow. It implies regulated saltwater intrusion so that agriculture can continue. It also implies ample coastal green so that tourism and the afore mentioned activities can thrive. Thus we see a dependency of socio-economic growth on the ecological structure.

The graduation project ‘Building with Nature: To balance the urban growth of coastal Kochi with its ecological structure’ charts out development strategies for the predicted urban growth of the coastal village of Blankunapuzha such that they are flood resilient. The rapidly industrialising village is located on one of the barrier islands of Kochi in south-west India.

keywords: estuaries, barrier islands, Kochi, India, socio-economic, ecological, coastal flooding, sea-level rise
View of Kochi city from the islands
2. Defining the Problem Statement

Kochi, nicknamed the Queen of Arabian Sea, a coastal port city on the south-west coast of India in the state of Kerala was chosen as the project location. The city's barrier islands and its interaction with the sea were studied to understand the dynamics and the problems of the region.

2.1 Project Location - Kochi, India

“A city born in storm, nurtured in rivalry and established as battling ground for European empires.”

The Kochi harbour was born in 1341 AD after a massive flood in the Periyar River silted the historic international port of Kodungallor. Ever since then, Kochi has been a centre of international trade.

2.1.1 History

The princely state of Kochi was formed in 1102 AD after the breakup of the Kulasekhara Empire to which it belonged. The kingdom was ruled from elsewhere north of Kochi at that time. It was after the 1341 floods when the natural harbour was formed in Kochi that the Royal Kingdom shifted its base to Kochi. Later in the 1500s, Vasco da Gama arrived in Kochi and subsequently established the Portuguese rule. Kochi was the capital of Portuguese India until 1530 while they ruled Kochi until 1663 through the Kochi Raja. The Portuguese rule in Kochi was followed by the Dutch from 1663-1773 and the British from 1814-1947 when India became independent. Under all the colonial kingdoms, Kochi flourished and grew as a port city.
2.1.2 Geography
Kochi’s islands on its west constitute the intervention area of this project. The islands on the west between the Periyar River on North and the Andhakaranazhi inlet on the South are taken for the regional study while the Vypin Island with the Periyar River on the North, Arabian Sea on the West, Cochin Estuary on the East and the Cochin barmouth on the south is considered for interventions.

These lie between the coordinates N10°11’4” E76°09’55” and N9°45’9” E76°16’50”.

2.1.3 Demographics
Kochi city on the mainland has a population of 601,574 according to the 2011 Census of India with a density of 6340/ sq.km while the population of the metropolitan area is considered to be at 2,117,990. The islands on the west have a density of approximately 2000/sq.km.

2.1.4 City Structure
The mainland is urban in character and comprises of residential buildings, banks, commercial areas, areas for recreation, educational institutions, administrative institutions and also the High Court of Kerala.

The islands on the west, south of the barmouth are fully utilized for port activities and heritage and tourism. Further south occupation changes to fishing and agriculture. The islands north of the barmouth were predominantly used for fishing and agriculture. Of late it has been used for tourism and recreation and very recently, port activities have expanded onto these islands.
2.1.5 Morphological Evolution

The Kochi estuary as we know today took several millions of years to form though the main estuarine region is not geomorphologically considered old.

It is interesting to note that many historic ports are in inland areas now. The sea receded to form barrier islands later on. In 1341 AD, the Periyar River north of Kochi flooded silting the Kodungalor Port on the north and in the process carving out a natural harbour in Kochi. This catapulted Kochi’s economic growth. Later during the British rule, an island was constructed in the harbour and the barmouth was widened by the British to expand the port. Over the years many land reclamation projects were carried out in the name of agriculture. This has resulted in a weak coastal system thus making it susceptible to beach erosion. The last major hazard the coast had to endure was the Indian Ocean Tsunami in 2004. The last map shows how the beach has changed its form and shape due to erosion and accretion.

Thus when dealing with a sensitive area such as this, one should be careful of the measures since any small intervention can result in drastic changes in the long term.

2.1.6 Importance of the City

The Kochi port is well situated in the international shipping route from Europe to the Far East. Cochin Shipyard is the largest ship-building and maintenance facility in the country while the International Container Terminal is the biggest in the country. The rapid expansion of port and on-shore facilities still continues with the latest addition being an LNG Terminal on one of the barrier islands. According to OECD reports, in 2070, Kochi will have an asset of 50.4 billion USD exposed to risks of climate change.
2.2 At the Local Scale

In the development plans for Kochi, it is proposed to develop the city ‘as a mutli nuclei city and recognising the fact that commercial hubs have a great influence in deciding the travel patterns, especially intra city travel patterns’. (Kochi Vision 2031 Draft)

These commercial hubs, called as sub-centres, ‘would accommodate higher order commercial and related uses so that most of the requirements of the people (residential and business communities) may be served by the sub-centres in that sub-region’. (Kochi Vision 2031 Draft) The Kochi Vision 2031 Draft accepts that these sub-centres may not provide answer to specialised shopping for which one might have to go to the main city but creation of these centres will definitely reduce the intra-city shopping trips.

One such sub-centre will be created in the village of Elankunnapuzha on the southern edge of Vypin Island in West Kochi. The projected population of the area in 2031 is 98119 with a density of 6780 per sq.km (Kochi Vision 2031 Draft). This is double the amount as per the 2001 census. The new population will not only consist of the natives but will also consist of immigrants who will come in search of new jobs that sprout with new developments.

2.2.1 Elankunnapuzha: Past, Present and Future

Elankunnapuzha Panchayat (village equivalent of Municipality) has seen a substantial change in its character and image over the years. It has transformed from a predominantly fishing settlement to a partly industrial area and sees its future as a sub-centre of the big city in the mainland.

Formed in 1341 AD in the floods, the area had an important trading port called the Malipuram Port. This port doesn’t exist now. Salt from Mumbai was transferred to Kochi via ship at the Malipuram Port which was distributed by the Kochi Maharajah, thus becoming an important source of income for him. Because of the port and being a coastal land, the village was often visited by the colonial powers - the Portuguese, the Dutch and the British who have established forts and churches in the area.

During India’s freedom struggle, sons of the region played an
important role and made their mark. After India’s freedom from the British in 1947, the Panchayat as its own administrative unit was formed in 1953. The inhabitants mainly consisted of salt workers and fishermen then.

The image of the area is fast changing with new industrial developments like the LNG Petronet Ltd. It is only in a matter of years that this will influence the socio-economic conditions of the area. The added sub-centre proposal will change the face of this coastal village.

2.2.2. Elankunnapuzha as a Sub-Centre

Elankunnapuzha is one of the six sub centres proposed in the city. These sub-centres are to be promoted by the Government and the Local Government by giving incentives to the private sector and through public-private partnerships. They are to have higher order commercial facilities like:

a) Wholesale trade centres
b) Shopping Malls/ Department Stores/ Supermarkets etc
c) Food Plazas
d) Restaurants and Hotels
e) Commercial Offices
f) Banks and other Financial Institutions
g) Retail shops
h) Movie houses/ auditoria/ convention facilities/ community halls
i) Public amenities/police station/post office
j) Public parking facilities
k) Pedestrian facilities
l) Recreational spaces

The new sub-centre and the new population require new facilities. The project will make a statement as to how these new developments should take place keeping in mind existing settlement patterns and the natural landscape. The project will integrate and strengthen the roles of the coastal and the natural landscape into the changing urban fabric.
Clockwise (from top): View of west coast from Lighthouse, Pedestrian Causeway to the beach, Carnival at the beach, Sea-wall
Clockwise (from top): Chinese fishing net in the mangrove forests, Pokkali fields, Lighthouse, Fish farms, Fishing boats docked at wetlands.
2.3 Problem Definition

The project takes root in the annual monsoon floods that the coast of Kochi is subjected to. The barrier islands subjected to these floods mainly consist of coastal villages whose means of defending their coasts are limited. The waterfront areas of the northern islands are under the Port Trust of India which makes the islands an inevitable area for development. These port related developments consist of a marina, an international containership terminal and storage facilities for petroleum. These developments are changing the image of these islands from coastal villages to industrial areas.

Background:
As mentioned before, the project location is Elankunnapuzha Panchayat, a village in the hinterland of the city of Kochi. The area was studied in the background of the new developments mentioned before and the problem of coastal flooding. The study on these factors gave rise to an issue that is a consequence of new developments - that of ecological nature. New developments were almost always done at the cost of ecology. These are the main issues at a larger scale but are not the issues per se, for the project. They provide the project with anchor points. These broad issues are:

i) New developments - Industries and sub-centre
ii) Coastal issues - Annual coastal flooding, unstable coast
iii) Ecological problems
iv) Climate Change

Urban Analysis:
Having these issues as the background, an urban analysis was done on the area to understand the existing urban fabric and how the different layers that interact with each other. Broadly, it consists of a study on

i) The settlement patterns, landscape, infrastructure and coastal flooding in layers.
ii) Relationship with the sea
iii) Implications of the realization of the sub-centre
2.3.1 Background

2.3.1.1 New Developments

Realizing the potential of the city as a coastal city as well as a port city, Kochi is growing at an alarming rate towards the west. While the IT sector and the international airport on the east pulls the city’s growth to the east, the major economic sector of the city i.e. the port still pulls the city to the west. Though until now, development was focussed towards the south of the barmouth, stress now is on development of the islands north of the barmouth viz. Vypin, Vallarpadam and Bolghatty Island. The port facing fronts of the northern islands are developed as an LnG Terminal and an International Container Transhipment Terminal. These new ventures have already hiked up land value which will ultimately lead to a massive real estate development.

Industrial Development:

The coastal front of Elankunnappuzha is fast being developed as an oil hub. Two oil companies have already set up their storage terminals on the coast - LNG Petronet Ltd’s LNG Storage Terminal and Indian Oil Corporation’s LPG Storage Terminal. One more such terminal is to come up along the coast.

Kochi Vision 2031:

As per Kochi 2031 Vision (Draft), the projected population for these islands are approx 700,000 of which around 200,000 will be in the northern islands. As mentioned earlier, in order to minimize transportation for the people, the 2031 Vision identifies Sub-Centres throughout the Kochi City Region to decentralize the city. Elakunnapuzha in Vypin Island is identified as one such Sub-Centre.

There are also plans to strengthen the transport network in these regions. All these plans will convert these village hamlets into modern settlements. But none of these plans take coastal defence or water safety into consideration.

The new LnG Terminal at Vypin Island
**Stakeholders**

The estuarine region has a wide variety of stakeholders like the Cochin Port Trust, Inland Water Authority of India, LnG Petronet Ltd, the real estate sector, mechanized ferry, MATSYAFED - the modern aquaculture sector and of course the Tourism Industry. The effects of some of these stakeholders on the environment is shown below in the flowchart. Any sort of development on these islands have an effect on the outer delta, the beach erosion and the overall health of the system.

**Consequences of Rapid Development**

As the island is being rapidly development, it was necessary to study what sort of impact it had on people and the surroundings. The following flowchart explains the consequences. The consequences were mostly of ecological and societal nature.

**Conclusion**

As a conclusion for further design, the industrial developments and the creation of the sub-centre will be regarded as anchor points. From the flowchart, it was concluded that there will be no more land reclamation as these have irreparable consequences on nature. The others could be managed at a policy level.
2.3.1.2 Coastal issues

Coastal issues in Kochi’s islands are mainly restricted to coastal flooding and beach erosion/accretion. These issues don’t restrict itself to one area as water has a far reaching influence. Therefore regional studies have been done on this. The geographical area between two inlets have been taken as the regional area.

Coastal flooding:
Over the years many instances of flooding and damages to houses have been reported along the coast. In one such flood in the 2004 monsoons, 2000 houses in the project area were flooded. Though there have been repair and rehabilitation works especially after the 2004 Tsunami, the area is still susceptible to these issues. The latest of such problems were reported in September 2012 when the monsoon retreat caused storm surge and coastal flooding in these areas.
Erosion and Accretion:
The Shoreline Assessment Map of Kerala show clearly how unstable the coast is. Erosion is a regular and widespread affair on the coast. In one place near Cochin, about two km width of land has been eroded since 1850 (Korakandy, R, 2005). Erosion is very severe during the monsoon months of June - September. The 2004 Indian Ocean Tsunami, left in its wake a new beach at Puthuvype in one of the islands.

Though no direct correlation between erosion and fisheries is on record, the socio-economic impact of this environmental phenomenon on the fishermen community through considerable reduction in the traditional shore landing facilities is quite alarming (Expert Committee, 1985, pp 351-352) (Korakandy, R, 2005).
Conclusion

Plotting out the coast over centuries make it clear that the coast has a very unstable character. A straight coast has changed to an estuary after the floods of 1341. In geological terms, the estuary is still in its infancy and is continuing to evolve. Hard structures like sea-walls will restrict this evolution.

What needs to be in place is a soft coastal defense system that will not inhibit the estuary’s evolution and any urban development or interventions should respect the evolutionary process of this estuary.
Timeline of Coastal Defence employed in the state of Kerala
Source: compiled by author from different sources
2.3.1.3 Ecological Issues

The traditional livelihood and the overall health of the estuarine system owes a lot to the ecological structure of the estuary. The most interesting areas are mangrove forests and saltwater intrusion and how the local communities have adapted their livelihood accordingly.

**Mangrove Forests:** The Kochi estuary has a thick vegetation of mangrove forests. They are salt resistant and is a rich breeding ground for fishes, shrimps, clams, mussels etc. These forests are known to be a haven for migratory birds. The Mangalavanam Mangrove Forest in Kochi is one such sanctuary.

They are known to act as barriers against erosions, storm surges and tsunamis. Mangroves play a significant role in coastal stabilisation and promoting land accretion and fixation of mud banks. It also helps in dissipating winds, tidal and wave energy. Mangroves, which absorb carbon dioxide, had to a large extent helped in checking pollution in the district.

Developments in the islands of Kochi have resulted in the reclamation of these lands for other uses such as agriculture, aquaculture and other developments discussed in the previous section.
**Salinity and Occupation**

The map on the page before shows how the salinity level of the water around Elankunnapuzha is more saline than other regions. But this doesn’t show in the number of species of fishes like in the northern inlet. This might be because the area is close to the port. But as can be seen, the traditional occupation of the project area is predominantly fishing. Cultivation is not the most prominent traditional occupation though it is present.

**Saltwater Intrusion**

The coastal community has devised an interesting way of farming to deal with saltwater intrusion which is called aquaculture. This type of farming makes use of a rice variety called Pokkali which is very salt-resistant. During the months of monsoons, when the salinity of the water is very low, rice is cultivated and during the other part of the year when the salinity is high, these fields are used for shrimp cultivation when the shrimps can feed on the agricultural wastes.

But nowadays, these privately owned aquaculture fields are sold as land values are high and rice cultivation is not lucrative. But few organisations like MATSYAFED have been successful in turning fish farms into tourism.

**Conclusion**

The ecologically rich areas are mostly held by the poor farmers who will sell the land if they get a good price. This has to be prevented by government actions. Even if sold by the farmer, these lands should be developed as natural recreational areas or as profit-making economical
2.3.1.4 Climate Change

The impacts of climate change on Kochi were derived from a joint study done by Oak Ridge National University in USA and Cochin University of Science and Technology called the Possible Vulnerabilities of Cochin, India, to Climate Change Impacts and Response Strategies to Increase Resilience.

The study concludes that of the four impacts climate change can have on a city including gradual increase in global temperature, increase in storm intensities, changes in precipitation patterns and rise in sea level, it is the latter two that will affect Kochi the most. The impacts have been explained in the flowchart.

Changes in Precipitation Pattern

For Kochi, the changes in precipitation pattern is found to be in the form of an increase in intensification of precipitation. The study shows this will result in storm surges and an increase in groundwater table which if not well drained can cause water logging. Since the canals are mostly silted up or act as garbage dumping yards, water logging becomes a serious problem. These two issues are seen as a result of sea-level rise also.

Sea-Level Rise

The other two issues that crop out of sea-level rise is saltwater intrusion and highertide levels - both of which make living and farming conditions poor. The low lying islands will thus become uninhabitable and the population will be forced to leave the islands and move to the mainland thus creating major congestion. Since majority of this population is poor, it will create slums in the mainland.

This becomes a serious issue in the city and has to be looked into with great concern. This gives rise to the objective of making the islands safe in light of climate change.
**Inundation**

The inundation map on the right indicates those areas that will be inundated with a sea-level rise of 1m. According to the map, the harbour areas and other areas demarcated for development will be inundated.

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**Conclusion**

The area has to be equipped to deal with climate change. More efficient coastal defence systems and better drainage facilities are recommended. Some areas are prone to inundation. Development on these areas should be temporary and shouldn't cause too much investment.
**Typical Year in the Island**

**Conclusion**

The activities shown in a typical year should be able to continue without any hindrance at the specified time.
2.3.2 Urban Analysis

The starting point of the urban analysis of the area was the layer analysis. The layer analysis clearly showed how the different layers affected each other. The conclusion of the layer analysis was the starting point of the next section of the analysis - analysing the settlement pattern. This analysis concluded that the study area had two main settlement areas, on the east and the west, and this formed the base for further analysis of the eastern and western settlements.
2.3.2.1 Understanding the Layers

The area was studied with the following layers - geography of surrounding area, the ground, landscape, infrastructure, settlement pattern, floodable areas and the existing coastal defence system.

The geography of the surrounding area consists of the surrounding water - the sea to the west and the backwaters to the east. The next layer, the ground, sets the base for the next layers. It's the layer which contains soil. On top of this is the landscape layer, which consists of wetlands, mangrove forests and paddy fields. Next to this is the infrastructure layer which consists of canals and roads. On this is the layer called settlements. The last two layers study the possibility of flood and the existing coastal defence.

The layers of landscape, infrastructure and settlements have to be studied together as they are closely linked to each other. The settlement pattern clearly shows the divided settlement and the void between these settlements. The influence of the sea, the landscape and the infrastructure is quite evident in the settlement patterns of the area.

The layer of coastal flooding and coastal defence shows the extent to which the settlements are vulnerable. Most of the coast still remains exposed to flood.

Conclusion

Settlements are dependent on favourable conditions. They follow the direction of the infrastructure. New infrastructure eventually implies new settlements along it. The settlement here is divided by the green in between. It should be noted that the local people respect their landscape - they settle around it but not on it.
2.3.2.2 Settlement Pattern

As concluded from the layer analysis, the settlements are divided into two – one along the west and the other along the sea. The reasons for this could be that the settlements along the west are dependent on the sea and hence settle as close to it as possible. The settlements on the east, sea the highway as a reason for setting. This side of the island is also close to the mainland. This could be another reason for the affinity towards the east of the island.

Between the settlements

There are very few East-West connections between the two settlements. The existing connections are very weak and unattractive. The connections consist of narrow roads and bridges which don’t do much to the image of the area.

During floods, these weak links make it difficult for people to run away to safer inland areas.

Green Barrier

The settlements are separated by a ‘green barrier’. This barrier consists of mangrove forests, wetlands and fish farms. Though ecologically valuable, this area is underused in terms of being a hotspot of activities and people movement.

Conclusion

The east and the west need better and stronger connections to act as a wholistic unit. This should also prove helpful as efficient evacuation routes. The green that acts as a barrier should act as a seam and bring people from both the areas together.
**Between the settlements**

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During floods, these weak links make it difficult for people to run away to safer inland areas.

Coastal communities separated by landscape are poorly connected to the main road.

The area is divided into two parts: along the sea and along the highway. These parts are connected by weak connections.
**Green Barrier**

The settlements are separated by a ‘green barrier’. This barrier consists of mangrove forests, wetlands and fish farms. Though ecologically valuable, this area is underused in terms of being a hotspot of activities and people movement.

**Conclusion**

The east and the west need better and stronger connections to act as a wholistic unit. This should also prove helpful as efficient evacuation routes. The green that acts as a barrier should act as a seam and bring people from both the areas together.
2.3.2.3 Analysing the West

The western part of the area lies along the sea and largely consists of population that is dependent on the sea. The relation of this area with the sea was analysed along the length of the coast. The coast is protected by sea-walls in the north. Sea-walls, coastal vegetation, houses, industries and wetlands play an important role in this relationship which will be explained in the next section. The value of the beach as a recreational space is also analysed.

It is interesting to note that the southern part of these settlements seem to be away from the coast than the northern part. The regular accretion at the southern edge might be an explanation for this.
Land and Sea

The analysis of the relationship of the land on the west and the sea is done by taking sections along the coast. The easiest way for man to reach the sea (or the beach) is through roads. Therefore the sections have been analysed with respect to a road. The road here signifies man's relationship with the coast. But of course, for communities who live directly along the coast will have a direct implicit relationship with the sea, though restricted at times with a sea wall or coastal vegetation.

Section 1-1', Section 2-2', Section 3-3' investigate the seafront with sea walls. Section 4-4' and Section 5-5' investigate the changing relationship with the sea due to settlements and vegetation. Section 6-6', Section 7-7' and Section 8-8' investigate the relationship of the industrial area with the sea.
Seawall

The sea-wall can be seen as a hard edge - one that separates the sea from the settlements. It is a visual barrier that visually disconnects the sea from anyone on the street.

The street here has a changing relationship with the sea. Though visually disconnected, the sounds and smell of the sea can be felt on the road. As the coast progresses south, this relationship fades with increasing distance of the road from the sea. The distance is then filled by houses. The house itself is visually separated from the sea by the sea wall.

Along this stretch, there is one point where there is a break in the sea-wall. This might be for easy access for the fishermen. But this break in the sea wall becomes a social space in the evening after the day’s catch. The break might be more preferred than other locations along the beach because it is not secluded and has an open relationship with the sea as well as their houses on the other side.

Seawall as a visual barrier

Coastal communities behind the wall

Break in the seawall act as social spaces
Coastal Vegetation and Industries

Further south, the relationship changes and doesn't depend on the sea-wall. It is still not visually accessible because of coastal vegetation and houses along the coast.

The houses give way to industrial developments and they form a rather hard border. Though there are access points through the industrial area, these form a mental hard edge and people become less willing to penetrate them. Section 7-7' shows a pedestrian cause-way made on wetlands which are used quite frequently to the access the beach.

Conclusion

The existing Beach Road is not an effective road to be in touch with the sea. A parallel road along the beach will improve the relationship with the sea and will bring more people to the beach. Taking into consideration the frequent flooding and the 2004 Indian Ocean Tsunami that struck the area, it is inevitable that the new Beach Road should be resilient and should be well connected to the main road on the east for faster evacuation.
Beaches

Not all the beaches along the coast are used. But from the analysis, a relation was found between the used beaches and the unused beaches. The used beaches were always next to a local attraction which would attract people.

Beaches close to the aquaculture ponds are used by visitors to the area. But predominantly by fishermen. Light House Beach was used more by the public. Festivals are held here. The beach is also visited by people from the city on the mainland owing to proximity to the mainland. But of the three main beaches on the whole Vypin island, the Lighthouse Beach, though closest to the city, is least used because it is least people friendly and poorly accessible.

However, if a beach is well accessible and well maintained, it will be well used.
Access to the Beach

There are only four access points to the beach in the 6900m long coastal stretch - with an average of 2km between the access points. These access points are not people-friendly. They are accessed from vehicular routes:

1. Southern Edge of Njarakal Beach: near the Njarakkal Matsyafed Aquatourism pond
2. at Chaapa Beach: entrance is a break in the sea wall, rural setting. One wouldn’t notice it when you drive by. Visitors are mostly those that visit the Malipuram Aquatourism ponds nearby. Doesn’t attract visitors.
3. at Lighthouse Beach: Lighthouse attracts visitors who go on to the beach. Most urban of all the locations. Accessed by a pedestrian causeway with random parking facilities.
4. near LnP Petronet Terminal: not used extensively as it is close to an industrial area. The area is still being constructed, so most areas are restricted. Deters visitors.

These access points are far away from each other and makes each beach isolated from each other. The vehicular route is away from the beach and separated from the beach by houses and coastal vegetation.

If the access points are connected by a road on the beachfront, the beach will be more alive. Other beaches will be visited more often if connected to Lighthouse Beach since it is the most visited beach in the area. The beaches are also used by the fishermen. Both recreation and fishing should be allowed to exist in harmony.
Used beaches

Attractions close to these beaches

Missing links in the beaches

Used beaches
Conclusion

The beaches are poorly accessed and there is a lack of connectivity along the beach. The beaches are not people-friendly. Therefore, more access points to make it a beachside town not just geographically. There should be a North-South connection along the beach which connects the different access points already existing and the ones proposed. The proposed connection will pass through areas that are different in character (as shown in the sections) due to the differing land uses. The connection will have the backside of houses facing it at certain points. These areas have to be specially looked into.
2.3.2.4 Analysing the East

The analysis of the eastern part is restricted to the main road that connects the southern and northern tips of the larger Vypin Island. This road is a state highway (SH) and hereafter will be mentioned as SH 63. Almost all the commercial, administrative and public activities in the panchayat are concentrated on this highway. For this very reason, all the smaller settlements away from this highway are very much dependent on it. The highway is analysed for its uses and its potential in the future during Elankunnapuzha’s new role as a sub-centre.

The outer communities are dependent on the SH 63 for all non-residential needs. It is also the easiest way to go to the mainland.
As can be seen from the map, SH 63 is the most intensely used road in the area. As it is still a rural area, the usage of the road is not as intense as one expects. Nevertheless, the road provides the inhabitants with facilities such as shops, markets, banks, churches, temples, schools, health centres and other public amenities like post office, village office and the panchayat office.
The future for SH 63

The highway is the main connection in the area and it is not fully utilized. Areas west of the highway are considered to be ecologically valuable as well as sensitive to flood. Therefore these areas are best not used for any development. Thus when the panchayat is developed as a sub-centre of the main city, the highway should be the hotspot of all activities.

Considering the present uses of the land adjoining the highway, recommendations for commercial and office areas have been made. These hubs will merely be an extension of the present activities in those areas. Areas which are currently used for fish markets, vegetable markets and other commercial shops can be developed as a commercial centre, thus not changing the image of the area. The area near banks and administrative offices like Panchayat office and Village Office can be developed as Business/Office centres.

Of the facilities a sub-centre must have according to Kochi 2031 Vision, the least optimum on the highway are recreation facilities. Indeed, the highway can have a few parks, but taking into consideration the varied landscape the area has, it is only but natural to have recreational facilities integrating those landscapes. This is will be explained in the next section.
Conclusion: an East-West Connection

The east is proposed to be developed as a sub centre with facilities and the beachfront is developed on the west. If they are not properly and efficiently connected, the two parts will remain to be divided. Stronger connections are required between the two. The existing connections are narrow and unattractive.

The connections from the proposed commercial centre should be given highest priority for strengthening.
Existing connections
2.3.2.5 Spaces for Recreation

Gifted with a long coast and a varied landscape, the people of Elankunnnapuzha don’t have to go very far for recreation. Being in a wetland, most of the households own a boat which is used to get across canals or even for an outing in the evening. But this is the privilege of the locals, the new population won’t have this privilege.

Existing Recreational Spaces

The wetlands in the north are developed for recreation. Some of them are used as fish farms by MATSYAFED (an organisation for fishermen) for tourism. This is called aquatourism. Facilities for fishing and boating can be used for a fee. Similar wetlands which are not owned by MATSYAFED are used by locals for economical and recreational purposes such as boating and fishing.
Existing organised spaces for recreation: Matsya fed Aquatourism

Fishing ponds, Boating areas and mangrove forests
Unused Green Spaces: Barrier to Seam

The wetlands and mangroves on the south are not used properly. Either left as backyards of the houses or given up for development, they do little for the urban growth.

The wetlands and mangroves which now separate the two parts of the island should be used as a meeting point for the two sides. It should act as a seam and join both the sides. Considering the success of aquatourism, even for people from the main city, these green areas can well be used for recreation. From the previous analysis, mangroves were found to be useful as buffers for flood and were good sedimentation agents.

Conclusion
The many advantages of landscaped areas can be integrated to form a green core for the future urban growth of the area. This green core will convert the green barrier to a green seam by having organised spaces for recreation which will bring people to the centre. Coastal vegetation with its properties of acting as coastal buffers, supporting aquatic life and reducing the intensity of flood will be integrated to this. Plans for a new highway over these areas will also be integrated into this.

Green barrier can be converted to green seam with organised spaces for recreation

The vast green space that acts as a barrier
Unused mangrove forests, wetlands and canals make up the green barrier.
2.3.3 Summary of Conclusions

- The industrial developments and the creation of the sub-centre will be regarded as anchor points. Land won't be re-claimed for any developments because of its consequences on tidal action, erosion and ecology.

- The coast has a very unstable character. The estuary is still in its infancy and is continuing to evolve. Hard structures like sea-walls will restrict this evolution. What needs to be in place is a soft coastal defense system that will not inhibit the estuary's evolution and any urban development or interventions should respect the evolutionary process of this estuary.

- Ecologically rich areas have to be developed as natural recreational areas or as areas like fish farms which will contribute economically.

- To deal with climate change, more efficient coastal defence systems and better drainage facilities are recommended. Some areas are prone to inundation. Development on these areas should be temporary and shouldn't cause too much investment.

- The activities shown in a typical year should be able to continue without any hindrance at the specified time.

- Settlements are dependent on favourable conditions. They follow the direction of the infrastructure. New infrastructure eventually implies new settlements along it.

- SH 63 will be developed as site for facilities for sub-centre. This will intensify the highway.

- The east and the west need better and stronger connections to act as a wholistic unit. This should also prove helpful as efficient evacuation routes. These routes should make the beach accessible as well. The connections from the proposed commercial centre along SH 63 should be given highest priority for strengthening

- The green that acts as a barrier should act as a seam and bring people from both the areas together through recreation. Coastal vegetation with its properties of acting as coastal buffers, supporting aquatic life and reducing the intensity of flood will be integrated to this. Plans for a new highway over these areas will also be integrated into this. These areas will have leisure facilities for the sub-centre

- The existing North-South Beach Road is not an effective road to be in touch with the sea. A parallel road along the beach will improve the relationship with the sea and will bring more people to the beach. Taking into consideration the frequent flooding and the 2004 Indian Ocean Tsunami that struck the area, it is inevitable that the new Beach Road should be resilient and should be well connected to the main road on the east for faster evacuation.
2.4 Problem Statement

Huge developments on the islands are going to change the land-use, the socio-economic and the ecological structure of these islands drastically. The change can lead to unecological growth and can alter the vitality of the region. At the same time, the coast is subject to erosion and flooding every monsoon season. There is still no effective measure to tackle this.

The village of Elankunnapuzha is seeing huge growth in its future, though the present is shaky. Growth is inevitable, the population and assets on these islands will increase thereby increasing the human footprint. This will consequently lead to this village being subjected to all of the urban problems like urban heat island, pollution, unclean environment, drainage problems etc.

To prevent such a hazardous and unplanned growth, the main aim of the project is to ‘Guide the urban development of Elankunnapuzha Panchayat as a coastal wetland town and equip it for coastal flooding and climate change’. As studied in the previous sections and as will be explained in the next sections, the project’s main aim will be to reinforce and restore the village’s image of a coastal wetland and make it capable of carrying this image forward in its future developments.
3. Research Questions

The main research questions and sub-research questions that are asked here will focus the project in the right direction.

3.1 Main-Research Question

The main research question that guides the whole project is “How spatial and physical interventions can help balance the urban development of the Kochi estuary with its ecological structure in the light of climate change”

3.2 Secondary Research Questions

In order to answer the main question, it is important to have information regarding the salient variables of the main question. These are answered with secondary research questions.

- What kind of impact will the proposed development plans have on the area?
- How will the proposed development plans affect the ecological structure? How does the ecological structure fit into the plans?
- What role will natural landscape and topography have in the future development?
- How can future development be guided so that the natural landscape and topography be conserved and protected?
- How can the future development as well as the green areas be protected from coastal flooding and climate change?

The panchayat of Elankunnappuzha is taken as the case study to investigate these questions.
4. Urban Assignment

The end goal of the project is to ‘Guide the urban development of Elankunnapuzha Panchayat as a coastal wetland town and equip it for coastal flooding and climate change’. With the graduation project, the natural landscape and regional attributes will be integrated into the urban fabric by making it part of the development plans.

As these areas are under the threat of flood, the development of these areas should be flood resilient.

Breaking down the assignment further,
1. On the west, a beachfront design with a new N-S Beach Road with strong connections to the east.
2. Design of the connections itself to make it more attractive and efficient as evacuation routes.
3. Design of the green in between zone as a recreation zone unique to the area.
4. These areas are prone to flooding. Hence design of the above elements should be flood resilient.
First design scheme to be worked on
5. Theoretical Framework

The theoretical framework of the project consists of separate frameworks for the design, civil, legal and management parts of the project.

5.1 Building with Nature (BwN)

The BwN philosophy is that of taking a stand along with nature to face disasters rather than take an defensive stand like in the past. The methods employed will be soft measures rather than hard ones which cut off the water from the people living along it. As Dr. Ronald Waterman puts it, it is the ‘flexible integration of land-in-sea and of water-in-the-new-land, making use of Materials, Forces & Interactions present in nature, taking into account existing and potential nature values, and the Bio-geomorphology & Geo-hydrology of the coast and seabed’. Though Waterman uses the philosophy for huge land reclamation, I propose to use the philosophy to strengthen the coastline as well as the backwaterfront.

The Vypin Island of Kochi has severe beach erosion due to which recreation and livelihoods have taken a backseat. Though there has been measures to prevent coastal flooding, there have been no measures to prevent beach erosion. It will be an integral part of my project to tackle coastal defence and beach erosion through Building with Nature. On a philosophical note, this principle can be used while making spatial interventions also.

5.2 New Urbanism + Delta Urbanism

The New Urbanism is an international movement which was started in the 1980s to tackle urban sprawl and car dependency by coming back to the basics like pedestrian streets and compact neighbourhoods. Delta Urbanism aims at ‘Urban development with integrated infrastructures for flood-protection and water-management’. Moreover it considers these regions as special regions with special urban design tasks.

Scholars have argued that New Urbanism offers a model urban design framework for creating resilient communities, in part because New Urbanist design affords opportunities to maximize open space within a development site without necessarily reducing the number of dwelling units that can be built (Berke and Campanella, 2006). Increasing development densities on certain portions of development sites while setting aside other portions as open space can enable project designers to steer construction away from the most hazardous areas while simultaneously protecting environmentally sensitive features (e.g. wetlands, sand dunes, and riverine floodplains) that provide flood hazard mitigation services. (Stevens et al, 2009) Being a developing country, issues of urban sprawl are hard to tackle and is bound to happen in India.

A combination of New Urbanism and Delta Urbanism will provide a design framework for the project so that there is a water related urban design with a emphasis on compact settlements with options for community resilience and environment protection.

### 5.3 Landscape Architecture

Since the project deals with natural landscape and about integrating green zones into the urban fabric by developing them, principles of Landscape Architecture will also be used for the design project.

### 5.4 Coastal Zone Management and Integrated Coastal Zone Management

The United States was one of the first to initiate a Coastal Management Zone Act in 1972. Although the U.S concept of coastal zone management (CZM) purportsto be integrated, in fact most of the state programs that have emerged focus primarily on the management ofshore land use and, so far at least, less so on coastal water-related issues. [11]

During the 1980s, a more complex and multi-faceted CZM approach called the Integrated Coastal Zone Management (ICM) was formulated at the United Nations Conference on Environment and Development. This took into consideration a lot more issues rather than just the shore land-use. One of the key issues was climate change.

In September 2012, the Government of India had agreed to include Kerala in the second phase of Integrated Coastal Zone Management in India. Thus ICM fundamentals and concepts will provide the conceptual management framework.
6. Methodology

The methods adopted to study the regions and answer the research questions are diverse and varied. The main methods used are literature review, site study, workshops and lectures, modelling, consultation with experts etc.

6.1 Literature Review

Literature will be the primary database of this project. These will include books and reports written on coastal management, ecological management, landscape architecture, earth sciences, urban planning and design.

Studies and reports done by scientific institutes like Centre for Earth Science Studies, India (CESS) and National Institute of Oceanography (NIO) on coastal erosion and flooding, by Centre for Marine Fisheries in India (CMFRI) on socio-economic and ecological structure of the islands, by the Town Planning Department of Kerala, India and Cochin Port Trust of India on future development of the region and NATO reports on Estuary Management will also be used in a large way to form the base for the project. The studies done by the local authorities and researchers will give an in-depth analysis of the issues present in the region.

6.2 Site Study

It is important to visit the site and understand the site and its issues firsthand. The site study will include direct interaction with the inhabitants and a photographic documentation of the region. But within the limited time available, the distance of the project location and limited manpower, it would be impossible to get an overall thorough understanding of the region with site review. Reports and publications done by researchers will help in this regard since they are a result of more collaboration and resources.

6.3 Workshops and Lectures

Workshops and lectures on related topics will be very helpful to understand how these issues can be tackled. The workshops and lectures organised by the Delta Interventions Studio and other lectures inside and outside the Faculty of Architecture will be useful for the project.

6.4 Modelling

The graduation project titled “Cochin Estuary Morphological Modelling and Coastal Zone Management” by Marten Strikwerda in the Civil Engineering Department will be used to see how urban interventions can affect the estuary. I believe this can contribute greatly to the outcome of the project.
6.5 Consultation with Experts

Experts from CESS, CMFRI, Town Planning Department, GIDA, Tourism Department, Elankunnapuzha Panchayat, the locals and students and urbanists who have worked on these areas before will be consulted.

Experts in similar fields in TU Delft, Deltares, Wageningen University and students and urbanists who have worked in similar areas will also be consulted for advice.
7. Societal and Scientific Relevance

7.1 What is New?

7.1.1 Integrating different variables

Though the issues discussed have been published in scientific reports and presented at conferences, they have never been integrated and understood at the level of urbanism. With my project, I will take it from the dusty reports to a plan that can be realized.

7.1.2 Geographical Boundaries v/s Political Boundaries

Such issues and interventions are mostly studied and executed within political boundaries. But in this project, the issues are studied within geographical boundaries uniting the affected areas as a geographical unit and breaking the political boundaries between them. This hasn’t been done before at a regional scale though at a local scale, the Goshree Island Development Authority (GIDA) ensures the same.

7.2 Societal Relevance

The area has a high density of urban poor as well as fishermen who help maintain one of the primary industries of Kochi. If the project can repair and help prevent damages such as those caused by the 2004 Indian Ocean Tsunami and safeguard these inhabitants and in the future, a higher population and assets worth billions, then it would have a societal relevance beyond measure.

7.3 Scientific Relevance

Most important cities around the world are situated along a delta or an estuary. With climate change, increasing storms and hurricanes, most of these cities are under threat. Studying such issues and understanding the various factors involved in it will help improve the knowledge base required to deal such situations.

8. Involved Disciplines

This section explains the disciplines other than urban planning and design involved in the project.

As the project mainly deals with coastal defence and related urban design, Hydraulic Engineering is a very important part of the project. For this I will be working with Del-tares and using the Morphological Modelling of the Cochin Estuary Thesis done in the CITG faculty. The other disciplines included are Fisheries, Agriculture and Landscape Architecture as they have an inseparable connection to the socio-economic and ecological structure of the area.
9. Time Schedule

The graduation project is planned from the month of January 2013 to June 2013 and is shown below.
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Appendix

Literature Review Paper

Building with Nature
Balancing Coastal Safety Measures with their Ecological Structures

Course AR3U022 Theory of Urbanism,
M.Sc Urbanism, Delft University of Technology

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11th Graduation Lab Urbanism Conference

Abstract: Measures to ensure a safe coast have evolved over time. Conventional measures involved hard engineering solutions like retaining walls, massive concrete channels, dams, levees, sea walls etc. Though efficient in preventing flooding, these hard structures have grave consequences on the ecological structure of the region. A good example for this is the Delta Works in South-West Netherlands. After the devastating 1953 floods that killed around 2000 people and destroyed about 200,000 hectares of land, a series of dams called the Delta Works were constructed to ensure a safe south-west delta. But these dams prevented the mixing of salt and freshwater resulting in irreparable damage to the ecological system. Such consequences in all parts of the world have made professionals step back and take stock. The situation is more serious in developing countries when money invested for such huge infrastructure ends up not fully serving the purpose. This has resulted in a changing philosophy which looks for softer approaches that work with nature and efficient spatial planning. Comprehending that the richness of deltas and estuaries lies in its natural resources and realizing the need to protect them is the first step in this regard. The concept of “Building with Nature” stresses on using natural processes to design water management infrastructure. Land zoning regulations (eg. floodplains) and landscaping are also effective tools for mitigating floods. This literature review paper studies how the concept of “Building with Nature” and spatial and landscape planning tools can be used to balance coastal defence and the ecological structure of tropical estuaries with a focus on developing countries. The paper concludes by making a summary of the concepts and gives broad guidelines that can be used for coastal defence of estuaries in developing countries.

Keywords: estuary, coastal defence, ecological structure, Building with Nature, planned retreat, accommodation, coastal vegetation

1. Introduction

Deltas and estuaries are valuable resources for the countries they are located in. They are valuable natural resources and at the same time provide excellent facilities for port and shipping. Thus they play a big role in the economy of their countries. With climate change and consequent rise in sea-level, most of the coastal areas worldwide are subjected to increasing chances of flooding and erosion. This calls for an effective coastal defence strategy.

Conventional coastal defence measures include hard structures like dams, levees, retaining walls, groynes and sea walls. But most of these measures are expensive and in certain cases don’t serve the purpose as expected. Huge structures like dams cut off one region from the other interfering in the sedimentation and water circulation processes. This prevents the natural processes from occurring in the ecosystem and consequently results in the deterioration of the ecosystem. This is exemplified in the Delta Works Program in the Netherlands. After the floods of 1953, which cost 2000 lives and destruction of 150,000 hectares of land, a series of dams were built on the country’s south-west region cutting off the sea from inland waters. Though the country lost a substantial amount of its coastline, this ensured that the region was safe from future coastal floods. But cutting off the sea meant cutting off the supply of saltwater which destroyed the aquatic ecosystem that thrived on the intermixing of saltwater and freshwater. This had unforeseen consequences in the local ecological structure.

The paper investigates ecological concepts which can be employed for coastal protection ranging from physical protection to spatial planning and landscape techniques. The concepts are elaborated in the following sections with application. In the conclusion, these techniques are then evaluated in the context of
developing economies and with respect to the graduation project.

1.1 Ecological Concepts for Coastal Defence

Such incidences have led to a change in the thinking of coastal defence measures and have led to a transition from hard structures to soft structures with lesser impact on the ecological footprint. The concept of ‘Building with Nature’ aims to do the same. As the measures employed by this concept are not always economically viable, cost-effective measures like efficient spatial planning and landscape techniques which were known to mitigate flooding were reviewed. The three broad concepts reviewed across structural, spatial planning and landscape architecture respectively, are -

1.1.1 Building with Nature: This concept works along with nature to face disasters. It is proactive and utilizes natural processes and provides opportunities for nature in the infrastructure development. As Dr. Ronald Waterman, a specialist in chemical, environmental and civil engineering, puts it, it is the ‘flexible integration of land-in-sea and of water-in-the-new-land, making use of materials, forces & interactions present in nature, taking into account existing and potential nature values, and the biogeomorphology & geo-hydrology of the coast and seabed’.

1.1.2 Spatial Planning: Having a flood-responsive spatial plan can minimise engineering solutions required to ensure a safe coast. Its advantages are equivalent to that of passive design strategies over active design strategies. Efficient spatial planning like zoning regulations to define floodplains, positioning new development on highland, digging up retention ponds and accepting unpredictable behaviour from the sea in long term plans go a long way in minimising the need for active solutions.

1.1.3 Vegetation and Landscape: In recent years, consideration for the use of less expensive ecological engineering alternative to reduce the threats from many natural hazards is on the increase. It is a ‘soft’ engineering approach, where natural ecosystems or enriched planted degraded wetlands are used as buffers against many flood related natural hazards. (Adejumo, 2012)

2. Building with Nature

The concepts reviewed in this section are the results of researches done by the Ecoshape consortium in Netherlands.

2.1. Concept

Traditional approaches involved designing water management infrastructure which served only one purpose. But it is crucial that these should serve more than one purpose and that it is aligned with natural processes rather than working against them, and that is adaptable to cope with changing conditions such as sea-level rise and climate change. Traditional approaches focus on minimizing the negative impacts of infrastructure projects (building in nature) and compensating for any residual negative effects (building of nature) while ‘Building with Nature aims to be proactive, utilizing natural processes and providing opportunities for nature as part of the infrastructure development process.’ (De Vries, H.J. and Van Koningsveld, M, 2012) These solutions are also adaptable as they allow society and environment to respond slowly to climate change and sea-level rise.

2.2. Applications

Applications which are useful in tropical estuaries have been reviewed here. These include beach nourishment and preventing erosion of tidal flats which were done in the Netherlands and strategies for tropical coastal areas which were studied in Singapore.

DeFland Sand Engine: This method involves a process of concentrated beach nourishment. The idea is to deposit significant amount of land in one location which will be gradually redistributed along the shore by the wind and the waves. Since it’s a natural process, it will be gradual and will limit the disturbance made to the ecosystem and at the same time provide new areas for nature and recreation. With concentrated depositions, either the footprint is smaller or the frequency of distribution is smaller or both.

The project envisaged a hook-shaped peninsula which would provide resting areas for seals at the end of the spit with a shallow lagoon that would offer habitats for flatfish. Some of the sand will be transported to onshore and promote development of dunes. In the first monitoring of the project, the development seems to be going as expected with sediment being deposited along the coast and seals visiting the area.

Oyster reefs in Eastern Scheldt Estuary: The tidal flats of the Eastern Scheldt Estuary in South-West Netherlands have been eroding at 2-3 cm per year. Rather than raising the dike levels to prevent erosion, ecological solutions to create a reef out of dead oyster shells held together by steel wires and oyster larvae which will attach to these shells were used to expand
the reef. Once the oysters establish themselves, the steel wire will corrode and the reef will survive on its own. This has already started to reduce the erosion in the area.

_Tropical Coastal Systems:_ Singapore where around 20% of the land is reclaimed by destroying mangroves, reefs and seagrass meadows was the location for research on Building with Nature on tropical coastal systems. The envisaged design solution should alleviate the coastal erosion, enhance the potential for recreation and strengthen biodiversity, while also taking into account the proximity of busy shipping lanes and housing developments. (De Vriend, H.J. and Van Koningsveld, M., 2012) According to Tjeerd Bouma, a senior scientist at the Netherlands Institute for Sea Research, ‘rehabilitating an ecosystem may take a long time, even in the tropics’. Therefore it will take time to start seeing the effects of these solutions. But due to limited space, these design solutions cannot be implemented everywhere. To create new ecosystems, the program also made ‘habitat-promoting tiles’ which can be fixed to already existing sea walls to make them conductive for new microhabitats.

3. Spatial Planning

In this section, concepts in design of cities and planning instruments like policies and regulations have been reviewed.

![Figure 1: Conventional protection measures in an open coast and estuary](image)


3.1 Concepts

**High land:** Living on higher elevation is an obvious solution to the problem of sea-level rise. Many ancient Chinese cities in the Yellow River Plain were built on relatively higher places. In few cities, during flooding, the ground level of the cities became relatively lower because of the silt deposited outside the city. This silt was legally allowed to elevate the subsided land. As a consequence, retention ponds were also formed, which means that when the ground of the city was elevated, water from the waterlogged areas could also be drained to the ponds. (Yu.K., Li, D., and Lei, Z., 2008)

**Water catchment areas:** Earth based retention ponds are known to manage storm water. These help substitute the natural absorption of forests or other natural processes that are lost during development. This is recommended in highly urban areas where surface run-off is very high.

The efficiency of these retention pond systems is demonstrated in the neighbourhood of Bukit Jelutong housing estate in Malaysia which has helped it to overcome its excess storm water and avoid serious flooding in low lying areas. (Dulk, R.M and Shariff, M.K.B.M., 2008) The polders in the Netherlands are also an example of water catchments which store storm water and prevent soil subsidence. They also prevent saltwater seepage during summer droughts.

**Planned retreat:** Planned retreat means progressively giving up threatened or vulnerable land by moving away from the coastal frontline, or by preventing future developments along the coast that may be affected by sea-level rise. The alternative of defending hundreds of kilometres of shoreline with stopbanks and sea walls would require enormous capital and maintenance costs. (National Institute of Water & Atmospheric Research Ltd. 2001) Hard protection can also cause imbalance in the ecosystem. But allowing beaches, estuaries and marshes to retreat naturally with rising sea level will maintain the integrity of these areas as ecosystems.

**Accommodation:** At accommodation, the difference is that human impacts are minimised by adjusting human use of the coastal zone (Nicholls 2003). This strategy thus uses an altered use of land, including adaptive responses such as elevation of buildings, roads, railways and, modification of drainage systems and land-use change. For natural coastal and estuarine systems, it also includes enhancing the existing natural protection of dunes by vegetation and fencing, or creating and planting upper intertidal areas and salt marshes. The accommodation or planned retreat concept accepts and integrates natural coastline evolution into conservation plans. Also accelerated sea level rise is tolerated here. (Schleupner, C.) Such concepts are useful while planning for unpredictable conditions and futures.
Figure 2: Planned Retreat and Adaptation measures in an open coast and estuary

Zoning Regulations: CPSL II (2005) recommended the establishment of coastal regional plans with defined buffer zones and flood hazard zones. Coastal buffer zone, defined by setback lines, ensures protected zones between the sea and the hinterland, where human land-use and development are tightly restricted. Several categories of buffer zones may be defined, e.g., from zones where all human activities are prohibited to zones where certain time-limited activities are allowed. But buffer zones are long-term planning measures and have to be considered decades before they might actually fulfill their function. Coastal flood hazard zones are areas potentially endangered by storm surges and can be defined in several categories, e.g., low, middle, and high probability of flooding or low to high vulnerability. Some areas have to be demarcated for future coastal defence purposes.

3.2 Applications

Accommodation Strategies: In Martinique in the Caribbean Sea, about 18% of the total coastline needs to be protected by hard measures, while 67% of the coastline might serve well with accommodation even if scattered houses or small settlements are found along the coast and within the impacted area. The measure will differ with the vulnerability of the area. Concerning the vulnerable infrastructure along this coastal strip the optimal adaptation measure would now partly be hard protection as shown in Figure 3.

Figure 3: Potential adaptation measures with respect to vulnerable population to sea level rise impacts Source: Schleupner, C. Regional spatial planning assessments for adaptation to accelerated sea level rise - an application to Martinique's coastal zone, Hamburg

4. Landscape and Vegetation

The concepts reviewed are concepts involving purely vegetation but they are almost always used in combination with spatial planning and coastal defence techniques.

4.1 Concepts

Coastal vegetation as buffer systems: Protected vegetation, apart from preserving bio diverse species, "emphasize ecosystems as buffers to mitigate flood related impacts" (Ademoto, 2012). Buffers lessen or moderate the impact of floods and storm surges. A buffering coastal forest allows a portion of a wave to pass through the vegetation with its force gradually attenuated, while a solid wall may be broken apart, lifted up, or overtopped. (ProAct, 2008) The ProAct Report of 2008 explains that after a storm surge, partially destroyed mangrove forests will regenerate naturally while the costs for repairing a concrete sea wall is high.

After the 2004 tsunami, many studies indicated that mangrove forests played a crucial role in saving human lives and property. Greenbelts of other trees, vegetated coastal dunes, seagrass beds, and intact coral reefs all performed a similar protective function in some areas. Where mangroves and other coastal habitats had been destroyed, often illegally, the waves were able to penetrate far inland, destroying homes, inundating farmland and washing away people and livelihoods. (Environmental Justice Foundation, 2006) ProAct (2008) study shows that a 50 meter band of Avicennia species reduced a one
meter high wave to just 0.3 meter while a 100 meter buffer of Sonneratia forest reduced wave energy by up to 50 percent. Protected ecosystem constitute coastal and flood plain defence lines safe guarding lives, properties and grey infrastructures. (Adejumo, 2012) Coastal vegetation should be seen as buffers in coastal areas.

4.2 Application

Mangrove forests: The coastal defence strategy for Martinique island included both accommodation and landscape strategies. 15 % or about 78 km of the coastline of Martinique that shows vulnerability might adapt to rising sea levels by mangrove forest conservation and regeneration. The measures differ with the vulnerability of the area. The optimal adaptation measure of vulnerable population in the Fort-de-France Bay might be the protection of mangrove forests while for the vulnerable infrastructure along this coastal strip, the optimal adaptation measure would now partly be hard protection.

5. Conclusions

The paper takes root in the grave ecological imbalance created by traditional hard engineering solutions for coastal defence and reviews structural, spatial and landscape concepts which are more ecological.

Building with Nature: The concept of Building with Nature which uses natural processes for coastal defence is very valuable. Methods like the Delfland Sand Engine are effective and allow nature to adapt to the changing conditions during the course of the time. On the monetary front, they are less expensive than traditional beach nourishment but it could still be expensive for developing economies. Oyster reefs in the Eastern Scheldt were successful in controlling tidal flats erosion. But the effects of a re-created tropical ecosystem are still hazy. As this paper deals with tropical estuaries, it might be useful to combine the above solutions discreetly.

Spatial Planning Tools: Some of the concepts, like siting major buildings on higher level and designing polder-like water catchments, are more appropriate before a city is constructed. Such cities are better prepared for floods. Other measures like elevating the ground and constructing retention ponds can be done in an existing city and is most often done when there is new found awareness of sea-level rise and flood hazards. Planned retreat and accommodation are those measures that are taken on a planning level for future sea-level rise and inundation scenarios. These concepts ensure that the coastal ecosystem is maintained even with a changing coastline. It thus differs from zoning regulations which aims to preserve ecosystems but aren’t flexible with the changing coastline.

Landscape Tools: The landscaping tools which are explained, if employed without any planning will not be fruitful and won’t bear any result. They have to be used in combination with the spatial planning tools. As seen in Building with Nature, landscape strategies are often used for repairing the coastal structurally and as seen in the case of Martinique, it is appropriate to use it in combination with other spatial planning tools and hard engineering solutions. In Martinique, the coast is protected using a mix of hard engineering solutions, accommodation and landscaping.

Developing Economies: In developing economies, the money that is available to be spent on coastal defence is scarce. Therefore, the best response to sea-level rise and climate change in the coastal zone is therefore an appropriate mixture of mitigation and adaptation. (Nicholls 2003) The paper explains less expensive spatial planning and landscape tools to ensure a safe coast. Some of them can be realized on a local scale while the others need planning into the future. An appropriate mixture of all the techniques explained with respect to the vulnerability of the areas in the estuary will help planners in achieving a feasible solution for coastal defence.

5.1. Guidelines

These broad guidelines were drawn based on the different concepts that were reviewed.

1. Building with Nature - a tailor-made solution is not available for tropical estuaries. Therefore a mixture of measures for coastal, estuaries and tropical conditions has to be used.
2. Spatial Planning – Planned retreat and accommodation can be used in the spatial plans while a scientific network of retention ponds can be executed at the local level by the inhabitants.
3. Landscaping Tools – Planting mangroves will trap sediment and can thus be a useful element in protecting tropical estuaries from floods.
4. A judicious mix of these three elements can be used with respect to the vulnerability of the area.
5.2. Relevance to graduation project
The aim of the graduation project is to design a regional coastal defence strategy and an adaptive strategy at the local level for a rapidly changing coastal neighbourhood. Planned retreat and accommodation stand a better chance than zonng regulations since they are more flexible and is fitting to the location of the project. Other strategies which involve landscape techniques can also be used. Given the limited source of finance in developing countries, the strategies explained in this paper can be used to create a city that is safe from coastal floods and sea-level rise. There are more methods which need to be studied. This paper only gives a broad idea of the literature reviewed.

References

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