Seawards!
New sea defense for the Randstad as a Coastal Metropolis - designing for Katwijk aan Zee

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The place where sea and land meet have always attracted people. To me, the coast is a magical place. For the past 10 years I worked on the beach in Katwijk aan Zee and I watched flocks of people swim, play, lay, walk, talk and eat at the beach every day. That is why the newspaper articles about climate change, sea level rise and the lack of proper coastal defense alarmed me so much. What will my beach be like in 50 years?

To answer this question I chose to work on the coast of the Randstad and Katwijk in particular for my graduation. This report is the result of this graduation project and shows what steps I took to get to the end result of this work: my breakwater barrier. This design couldn’t have been developed without sufficient knowledge of hydraulic engineering. Therefore I would like to stress the benefit of working on a university where different technical disciplines come together. I am very grateful to have had the opportunity to be assisted by several experts from the faculty of Civil Engineering, my mentor Henk-Jan Verhagen in particular.

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SUMMARY

According to the latest predictions, the average sea level will rise with about 1.2 meters in the coming century. The 60 kilometers of sandy coast along the Dutch city agglomeration Randstad is not prepared for such a threat. The coast needs to be enforced. In the meantime, the coastal zone, with all its charming seaside resorts, is one of the strengths of the Randstad area. Therefore the goal of this graduation project is to design a new coastal defense that enhances the strength of the Randstad Coastline.

Firstly, a new Structure Plan for the coastal zone is made. In this plan, the Randstad is envisioned as a Coastal Metropolis, with the coast as a major strength. The plan proposes to intensify the built area along the coast and create better east-west connections towards the coast.

For the coastal defense itself, the plan opposes to the current and future policy, which is fortifying the coast by the suppletion of extra sand. Apart from this conventional method, there are numerous other techniques for coastal defense. The ‘soft’ techniques are most optimal for the Randstad Coast because they are flexible and respect the natural coastal morphology.

The new proposed technique is a Breakwater Barrier. This strip of new land made of sand, protecting the existing coastline. It is 8 km long and is located 800 seawards from the coast.

The barrier-concept is designed in more detail for the seaside resort of Katwijk aan Zee. The traditional seaside resort of Katwijk aan Zee experiences a lot of pressure from the continuously expanding hinterland. Also, its low geographic position causes pressure from the sea.

The barrier will discharge the town of Katwijk of this pressure. New connections towards the beach barrier will redirect the traffic flows in the area. The village will be protected from storm surge waves and the relation of the charming seafront with the sea will be enhanced. The new boulevard will be improved and in the meantime new ‘coast capacity’ is created on the reef. The barrier will have a marina, vacation homes and a hotel/conference center.

By assigning different safety levels to the barrier, the most efficient dimension for the reef is chosen. This way the required amount of sand for the construction is comparable to the amount of sand needed for plans for coastal defense made by the authorities.

Although the costs for the construction of this reef are higher than the costs of conventional methods of coastal defense, the reef offers many benefits: the reef can be exploited to gain income, the character of the current coastline won’t be affected, the intervention is flexible and subtle. And most importantly, the beach barrier will create a new exiting coastal landscape that is unique in the world.
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1.1 Problem field

Holland has always been struggling with water. The Dutch city agglomeration of the Randstad, with about 7 million inhabitants, lies under sea level for a large part, making the area extremely vulnerable for dangers that come with the rising sea level. This chapter will elaborate this issue, which forms the basis of this graduation project.

Coastal protection

Climate change and the rising of the sea level are nowadays generally considered a fact. In its worst case scenario, The Royal Dutch Meteorological Institute (KNMI) predicts a temperature rise of 4 °C up to the year 2100. The Intergovernmental Panel on Climate Change (IPCC) even predicts a rise of 6 °C until the end of this century. This can cause a sea level rise of 0,55 to 1,20 meters. (Deltacommissie, 2008)

The Dutch government has asked the Delta Committee to give advice about the protection of the Netherlands against these effects of climate change. The main issue for this advice was to make the Netherlands climate-proof on the long term, safe against floodings and an attractive environment to live, work, invest and recreate. As a result of the new climate-predictions and calculations, the bar for standards of flood protection has been raised. (Deltacommissie, 2008)

However, in the Delta report the Committee states that these standards are not met everywhere and that arrangements have to be made to protect the Netherlands from flooding. Among various recommendations, the Committee advises to strengthen the existing sandy coastal defense. Furthermore, the committee states that the coast should be broadened about 1 kilometer in the next hundred years.

The Dutch sandy coast stretches out for about 60 kilometres in front of the Randstad. It protects the dense urban area of the Randstad against the North Sea. Since large parts of this area lies under sea level, a failure of the sandy coastal protection would cause a large flood with catastrophic consequences.

But apart from the advised sand nourishment, there are many more ways to improve the coastal protection. These can be divided into ‘hard solutions’ (protection by dikes or hard constructions that retain the sand) and soft solutions’ (natural or artificial nourishment of sand) (Pilarczyk, 1990). All these measure have different spatial effects when implemented along the Randstad coast.

Randstad Agenda

The Randstad is an urban agglomeration that contains about 7 million inhabitants with an average density of about 1000 inhabitants/km². The area counts for almost half of the Gross National Product. (Regio Randstad, 2007) Besides that, it contains the largest sea- and internet hub of Europe, one of the four largest airports and horticultural areas of international importance. With its high population density, the Randstad region is confronted with a lack of space for dwelling, economic activities, recreation and infrastructure. In the mean time there is a need for protecting and expanding the natural and environmental values. (Waterman, 2008)

In the Randstad Strategic Agenda 2040, the government aims on developing the Randstad into a sustainable and economical competitive top region. One of the goals of the Agenda is to develop about half a million new dwellings up to the year 2040. Another goal is to enhance the strengths of the Randstad. Among those strengths is the Randstad coastline. It gives the Randstad a strong identity, providing unique recreational, ecological, economical and residential qualities (Zuid Holland, 2008). However, only when the flood protection system lives up to the current standards, the government will keep investing in the urban agglomeration of the Randstad, building new dwellings and enhancing strengths. This means that possibilities and restrictions that come with the issue of flood protection have a large influence on the plans and decisions made for the Randstad area, (VROM, 2008)
Though, reasoning the other way around would mean that designing and building new coastal protection should go hand in hand with designing the future of the Randstad. For the issue of coastal protection, plans and goals for the Randstad can be taken into account. A vision of the future position of the coast in the Randstad can be a guideline in thinking about coastal broadening.

**Katwijk aan Zee**

Building new sea defense has obvious consequences on a local scale. Therefore it is important to regard the development of the Randstad coastal zone on the scale of an individual seaside village.

The traditional seaside village of Katwijk aan Zee is located centrally in the Randstad coastline. It has the middle wing of the Randstad as its direct hinterland, with a large cluster of towns and villages around the city of Leiden. According to the municipality, the need for dwellings in this region is high. With the large new building-site of Valkenburg, the pressure from the land-side on the seafront of Katwijk increases. In the meantime, the pressure from the sea is rising, according to the predicted climate changes. Moreover, the town wants to keep its genuine character and protect the nature reserves in the surrounding coastal zones.

The future development of the coastal zone of Katwijk will involve many aspects like residence, recreation, infrastructure and nature. Therefore, Katwijk is a challenging location for making a design for the renewal of coastal protection on a local scale.
Issues combined
The previous issues can be summarized as:
THE COAST AS WEAKNESS vs. THE COAST AS STRENGTH

- The Randstad area is not properly protected from flooding due to sea level rise. The coastal protection can be improved by various techniques.
- To become a top region, the Randstad will grow and enhance its strengths, among which the coastal quality. But this has to happen within the limitations and with the possibilities of the flood protection system.
- The pressure from land and sea have consequences on a local scale.

Looking at the issues of the renewal of coastal protection and the development of the Randstad, it can be reasoned that designing and building new coastal protection should go hand in hand with designing the future of the Randstad. So instead of fortifying the area against the water, the issue of coastal protection is a challenge to improve the coastal zone of the Randstad.

1.2 The assignment

The main aim of this project is to combine the issues of coastal protection and the development of the Randstad and Katwijk, and design a new sea defense that goes hand in hand with the Randstad as a future top region. This general aim can be specified in three different goals:

- Firstly, to design a renewal for coastal protection, it is crucial to make a statement about the relation between the Randstad and the coastal zone itself. A strategy will be made to structure future metropolitan urbanization towards the coast.
- Secondly, for integrating a sea defense system in a design for the future of the Randstad coastline, it is necessary to study these different solutions and their spatial effect on the coastline.
- Thirdly, the concept of Randstad going seawards will be translated to a local scale. Designing on a local scale will help to make sure that the coastal renewal fits the existing situation and that it enhances the existing qualities.
CHAPTER 2. COAST AS STRENGTH
2.1 Analysis seaside villages

According to the Randstad Agenda 2040, the coastline is one of the important qualities for the Randstad as a metropolitan area. But what exactly does the coastal region of the Randstad contain? What are its qualities and weaknesses and how can they be strengthened or improved within a strategy for urbanization and coastal defense? To answer these questions it is useful to analyze the current situation of the various seaside villages along the coast.

The Randstad coast hosts many different functions and can be characterized by a broad range of different intensities: from quiet nature reserves like Meijendell and traditional seaside villages like Katwijk aan Zee to vibrant beach resorts like Scheveningen. But for the entire range goes that recreation is the main use of the coastal zone. (RIKZ, 2002.) Not only do the beaches and dunes have a recreational value for the Dutch inhabitants but also for the inhabitants of the densely populated Ruhr-area in Germany. For them, the Dutch coast is the nearest coastal recreation area (Pilarczyk, 1990).

For this analysis a coastline was defined that reaches from the IJ-channel to the Nieuwe Waterweg and contains the following seaside resorts:
- IJmuiden
- Bloemendaal aan Zee
- Zandvoort
- Noordwijk aan Zee
- Katwijk aan Zee
- Wassenaarse slag
- Scheveningen
- Kijkduin
- Ter Heijde
- Hoek van Holland

In the analysis the seaside resorts are elaborated and compared according to the following topics:
- number of inhabitants, number of visitors, amount of sleeping accommodation, amount of hotels, restaurants and bars, length of the beach, accessibility, amount of parking space, morphology and specialties or character.

The results of this analysis are shown in the scheme in Appendix I.
IJmuiden has a quiet and spacious beach with a few beach pavilions that are opened all seasons. IJmuiden is located next to the estuary of the IJ-kanaal, in the shadow of the Corus Steel Factory. The coastline of IJmuiden has undergone a large transformation in the past 10 years. Since the southern pier of the IJ estuary was extended, the beach has gradually broadened. A marina was build, accompanied by several hotels, office buildings and a Yacht Club.

Bloemendaal aan Zee is part of the municipality of Bloemendaal, separated by the national dune reserve of Kennemerland. Despite its remote location, Bloemendaal receives many beach recreationists. It is a popular destination for young people especially, thanks to the trendy beach pavilions. Bloemendaal aan Zee is only accessible by one bus service and the road N200, that connects Zandvoort and Bloemendaal to Amsterdam.

Zandvoort aan Zee is originally a fishers village, that grew into a town of more than 16,000 inhabitants nowadays. Zandvoort used to be a seaside resort that attracted workers from Amsterdam. Nowadays, Zandvoort attracts visitors from all over the country and foreign tourist. The racing circuit and the casino are the main attractions. Zandvoort is directly accessible by train. But apart from that the town is quite car-oriented: Zandvoort has an enormous amount of parking spaces.

Noordwijk aan Zee has developed from a fishers village into a large seaside resort. Noordwijk has the image of a luxurious beach destination due to the numerous high-end hotels and restaurants. The large hotels and congress facilities make Noordwijk popular for business events. Noordwijk is surrounded by dune reserves and flower fields. This location makes Noordwijk a precious residential site; some of the house prices are the countries highest.

Katwijk aan Zee was founded as a fishers village south of the estuary of the Old Rhine. Today it still has the atmosphere of a traditional village, although it is completely enclosed in the urban area of Leiden. With many pensions and several small and mid-size hotels, Katwijk has the image of a quiet family seaside resort.

Apart from the actual seaside villages, there are numerous accesses to the beach
that cross the natural dune areas. At a few locations this type of access, which is called a ‘slag’, is provided with amenities like parking lots and snack carts, for example the Langevelderslag, Duindamseslag and the slag of Kennemerland. In this analysis the Wassenaarseslag represents this type of destination for beach recreationists.

Scheveningen is the largest and most vibrant seaside resort of the Randstad coastline. It is part of the city of The Hague. Attractions like the Kurhaus, the pier, Casino and Circus Theater attract visitors from all over the country and from across Europe. Next to the popular attractions and boulevard, the old village and the harbour can be found. A design for renewal of the coastline, that is about to be executed, will enhance the connection between these parts of Scheveningen.

Kijkduin was founded as The Hague’s other seaside resort and started with a few hotels and villa’s. It hasn’t experienced the growth that Scheveningen has. With a small boulevard, several shops, restaurants and beach bungalows, Kijkduin is a middle-size seaside resort.

Ter Heijde is a tiny seaside village with only 600 inhabitants. The coastline of Ter Heijde forms the weakest spot in the Randstad coastline. Only a single dune ridge protects the village from the sea. Ter Heijde is enclosed by the urban area of Monster, part of the Westland. The large majority of the beach recreationists are one-day visitors from the Westland area. This can be linked to the small amount of sleeping accommodation and other facilities.

Hoek van Holland is located a the northern bank of the Nieuwe Waterweg. The town is part of Rotterdam and has a direct connection by train. The town was founded as a settlement for workers of the Nieuwe Waterweg. As a seaside resort, Hoek van Holland is still in the middle of a development process. New luxurious residential areas and beach facilities are created.
Conclusion
The summarized results of this analysis are shown in the scheme in Appendix I. Looking at the results, several parts stand out that are typical features of the Randstad coastline. They are either strengths or weaknesses, but they can form criteria for the design of coastal defense:

1. Variation
Looking at the results, it is clear that there is a large variety in numbers of visitors, inhabitants and facilities of the seaside resorts. This variation is a typical feature of the Dutch coastline. Scheveningen by far has the largest amount of beach visitors. This is probably the result of the fact that Scheveningen is enclosed in the large urban area of The Hague. But it is remarkable that with its 9 mln visitors a year, Scheveningen doesn’t have the most amenities like hotels and bars. The town of Zandvoort contains the most facilities. The reason for this is partly that, unlike Scheveningen, Zandvoort is not attached to a large urban area, and partly that Zandvoort has a large racing circuit, which is a national attraction. This attracts people from far away who are more likely to stay overnight and use a wide range of facilities.

Another remarkable feature in this comparison is the relatively high amount of visitors and amenities in the village of Noordwijk aan Zee. Noordwijk has specialized in high-end and business accommodation. So beach recreationists have a wide range of options for a stay at the beach on the Randstad coast. Their choice is dependent of their way of transportation, the time of their visit, their preference etcetera. This variety and specialization of the seaside resorts is a strength of the Randstad Coast. A new coastal defense should adapt to this feature and even enhance it. This actually adds a challenge to the design assignment: the coastal renewal should be based on an overall strategy that enhances the variation of the individual seaside resorts.

2. Flexibility
The number of yearly beach recreationists seems to be growing according to the data of the Agency for Tourism and Congresses in the Netherlands. But, since this number is for a large part dependent on climatological and economical factors, there is never a certainty about the amount of visitors in the future. The larger seaside resorts are secure of a certain amount of visitors by offering facilities on a national level, like the Zandvoort Racing Circuit or the Scheveningen Theater. But smaller seaside resorts are forced to adapt to trends and demand on a short term. Most do so by adapting their supply of temporary beach pavilions. When designing a new coastal defense, this uncertainty about the number of beach recreationists has to be kept in mind. It would be an advantage if the coastal defense were adaptable to meet the changing demands in the future years. Therefore the coastal protection has to be flexible.

3. Relation to sea
As we have seen in the morphological samples in appendix I, all seaside resorts, except for Hoek van Holland, IJmuiden and Bloemendaal, have their village core within a few hundreds of meters from the shore. The direct relation of the seaside villages with the sea is a typical feature of the Randstad coastline. This is a strong point of the coast that should be preserved or enhanced when designing new coastal protection.

4. Accessibility
When it comes to public transport, only the villages of Zandvoort and Hoek van Holland are accessible by high-quality transportation in the form of a train. Scheveningen has several tram-services that access the seafront. Other seaside villages are connected by just bus services. Assuming a growth in numbers of beach recreationists, improvement of the public transportation to these smaller seaside villages should be considered. Especially Noordwijk, that has a relative high amount of visitors served by bus-lines only, might need this enhancement in the future. Currently, plans are being made to implement a lightrail system that will connect Leiden to Katwijk and Noordwijk. Looking at the accessibility by car, generally the way towards sea consists of a national or provincial road perpendicular to the coastline that runs from the hinterland and spreads out in smaller roads towards the sea. On warm summer days, traffic jams towards sea are a regularity. Therefore the accessibility of the beach by car might need improvement when considering a growing number of visitors.
2.2 Analysis Coastal Metropolis

About 80% of the world’s population lives in lowland coastal areas. The growth of these densely populated coastal areas even exceeds the growth rate of the world population. Moreover, globally approximately 400 million people live within 20 kilometers of a coast (Small et al., 2000 in Gornitz, 2002). Apparently the zones where land and water meet are most attractive for living, working, recreation, tourism, transportation, food- and water resources.

Many cities or metropolitan areas in the coastal zone, like Barcelona, Miami, Los Angeles and New York/Long Island, have their actual seafront as one of the major qualities and attractions. These cities are known for their coastline, beaches, recreation and urban waterfronts.

Barcelona:
50 km coast
Inhabitants Metropolitan area: 4.8 mln
15700/m2
Inhabitants coastal center: 1.5 mln

Since the 1980’s, many renewal schemes have taken place along the Mediterranean coast of Barcelona. These have given the coastline a prominent role. Especially the seafront regeneration for the Olympic Games in 1992, under the slogan of ‘opening the city to the sea’, has had a large impact on the coastline and the city behind it. The coastline now consists of a wide variety of living environments, functions, infrastructure and routing that connect with the city. Especially the public domain along the coast is very valuable for the city.

Los Angeles:
90 km coast
Inhabitants Metropolitan area: 20 mln
1000/m2
Inhabitants coastal center: 4 mln

Los Angeles has a stretched-out metropolitan area. Although not so defined as for instance Barcelona, the city center of Los Angeles is located about 20 kilometers from the coast. Still, Los Angeles can be considered a coastal metropolis. Beaches like Long Beach, Manhattan Beach, Venice Beach and Santa Monica beach are world famous and popular among tourists and residents. The beaches are long and broad and for the most part accompanied by all sorts of beach facilities and large parking-lots. Most of these are only a hundred meters away from the sea.

Most typical about the coastal metropolis of Los Angeles is the continuous coastal highway, the Pacific Coast Highway or Highway 1. At some places this highway is located only 50 meters from the shoreline, at other places a few kilometers landward. Highway 1 runs from southern to northern California and is not only a road to get from A to B but also a recreational attraction.
Miami: 140 km coast
Inhabitants Metropolitan area: 5 mln
3900/m²
Inhabitants coastal center: 363,000
The city of Miami in the state of Florida has grown from a Spanish settlement in a mangrove swamp into an international beach recreation destination. Miami is known for its sunny weather and long beaches. Also, Miami is home to an enormous cruise port: the Port of Miami is considered the cruise capital of the world. Also for air traffic, Miami is an important hub. In the mean time, its airport is only 13 kilometers away from Miami Beach.
Typical about Miami as a coastal metropolis is its barrier coast. This barrier island hosts mostly spectacularly large hotels and other touristic facilities. This seafront on the barrier island is separated from the hinterland by a laguna. The width of this laguna varies from 100 meters to about 4 kilometers. The barrier island is connected by several spectacular bridges that mark the different worlds of the island and the hinterland.

Long Island/NY: 200 km coast
Inhabitants Metropolitan area: 18 mln
1070/m²
Inhabitants coastal center: 8 mln
Long Island, in the state of New York has a barrier beach of almost 200 kilometers long, which is, at the west-end, only 20 kilometers away from Manhattan. Virbant seaside resorts like Atlantic Beach and Long Beach are the get-away destinations for inhabitants of New York City. But also the more quiet beaches of Fire Island and The Hamptons are popular beach destinations. Especially The Hamptons has been an attraction for wealthy New York City families and artists for a long time, with a coastline featuring luxurious beach houses, restaurants and hotels.
The Southern State Parkway and the Sunrise Highway run 5 to 10 kilometers landward from the sea. From these highways, branches of several smaller roads run towards the barrier island. On the barrier itself is a continuous dune trail that is accessible for cars.

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**Randstad:**
60 km
Inhabitants Metropolitan area: 7 mln
1000/m2
Inhabitants coastal center: 480,000 mln
When adding the Randstad to this list of agglomerations that have their coastline as important strength, it becomes clear that in size and density the Randstad is quite comparable to the others. So to illustrate what are the opportunities for the Randstad to become a Coastal Metropolis, it is useful to compare the four examples to the Dutch situation. More of the comparison can be found in Appendix II.

**Conclusion**
From the coastal metropolises that are discussed above, several elements can be derived that mark a coastal metropolis:
- A continuous coastal highway
- The city and its attractive public space close to the shore
- A seafront of spectacular hotels and other touristic facilities
- An international airport close to the beach
- Exclusive residential areas along the coast

When we project these elements to the Randstad, it is clear that the Randstad misses some of these components.
Firstly, the Dutch coastal resorts are ‘tailback’ destinations. They are connected by roads perpendicularly to the coastline. The Netherlands doesn’t have a particular coastal highway like the Pacific Highway or the famous route along the Côte d’Azur. When looking from the coast, the first meaningful connections along the coast in the Randstad are the highways A4 and A44. On the other hand, the fact that there is no continuous structure along the coast causes the typical variation of seaside villages and dune reserves. A continuous road goes hand in hand with continuous urbanization along the coast, like we see in LA and Miami. In the Dutch situation, the dune reserves are ‘no-go-zones’ and strictly protected, which results in high natural values.

A city facing the sea, like Barcelona, would be in the Dutch case The Hague. Under the motto of ‘Global city by the Sea’, connecting The Hague with the coast and giving the coastline a more prominent role, is already high on the agenda of the municipality.
A spectacular seafront with major touristic facilities can, to a certain extent, be found in Scheveningen, Noordwijk and Zandvoort. But the remaining seaside resorts are far from vibrant. But again, this marks the variation of seaside resorts in the Randstad.
2. COAST AS STRENGTH

2.3 Structure plan Randstad Coastal Metropolis

Already in the 1950’s the concept of Randstad was introduced in the policy documents of the national planning authorities. The Randstad was made up of a ring of urbanization around an open green space. Since then, the concept Randstad has been a basic or supporting principle for many planning policy documents. In the recent decennium, thinking, planning and designing on a metropolitan scale has taken an important role in national urban planning. Often the Randstad is described as a polycentric landscape metropolis, that contains a mixture of urban, landscape and infrastructural qualities. (Palmboom, 1999) And apart from urban planning on a metropolitan scale, the design and policy around landscape and natural values have undergone a scale enlargement as well. The Nota Ruimte (2004) illustrates this by no longer sticking to compact cities in an open landscape, but rethinking the structure of the open landscape itself.

The Randstad Agenda 2040 represents the newest vision of the national government on the city agglomeration. Its main theme is to develop the Randstad into a sustainable and climate-proof European top-Region. It states that ‘What’s best for the Randstad is best for the Netherlands’, ‘make strengths stronger’, and ‘quality by interaction of green, blue and red’. This document calls that after many decennia of mainly structuring the urban areas, it is now time for combining the growing demand for space in the Randstad with the growing threat of climate change and its consequences, like renewal of coastal defense. This vision is illustrated by three scenarios: ‘Randstad Wereldstad’, ‘Randstad Buitenvision’ and ‘Randstad Kuststad’. This last scenario, worked out by BVR Advisors Spatial Development, focuses on the coastal zone of the Randstad. It relocates the center of gravity of the Randstad towards the coast, forming a highly dynamic compact urban area, emboided by veins of landscape. The plan contains two forms of landscape: the inner-landscape, formed by green openings in the urban area, and outer-landscape, formed by the Green Heart. The inner- and outer-landscapes are connected so they form a continuous network of green. Another important principle of the Kuststad scenario is the network of infrastructure. The major forms of transportation are a light rail system and a network of highways and provincial roads for internal transportation. The A4 highway, the HSL and Schiphol form the main external connection. (VROM 2008)

These green and infrastructural networks are explicitly illustrated in the designs of Randstad Kuststad.
However, the scenario is not so explicit about the coastal zone itself. Although its name suggests the Randstad to become a coastal metropolis, the scenario does not give a vision on what this coastal zone is going to be and how it will become the strength of the Randstad.

In this time when climate change is hot and the discussion about coastal defense is held on many levels, the scenario Kuststad is hardly explicit about it. The only proposal in the scenario is to apply sand suppletion along the current coastline and expand the coast towards a hollow coastline that creates valuable recreational and residential zones.

This approach is quite conservative because it sticks to the current situation. It directly follows the advice of the Delta Committee, that was presented a few days before the release of the Randstad Agenda 2040. There is no exiting spatial interpretation illustrated of the need for coastal renewal.

So for this project it is useful to be inspired by the ambition of Randstad Kuststad, but the plan must be more specific about the relation between the Coastal City and the coastline itself. The coast has to be developed as a strength, accessible and variable.

**Structure Plan**

As a basis for the rest the project, a new structure plan was created for the central zone of Randstad Kuststad. The structure of the current urbanization is for a large part based on the geomorphological structure of the landscape. Towns were founded on the higher grounds of the former dune ridges (‘strandwallen’) that run parallel to the coastline. This results in a structure of urbanization and infrastructure in this north-south direction. The planes behind the current dunes and in between these former dune ridges are very suitable for horticulture. These areas now form open landscapes, together with the peat grounds eastwards. This structure will form the basis of the new structure plan.
In this structure plan the zones of urbanization will be intensified in order to keep the open landscapes open. So new urban development will take place on top of the former dune ridges and will be attached to the existing north-south infrastructure. Green zones will form interruptions in the strips of grey. These green zones are formed by forests, parks and green programs like sports facilities and allotment gardens. These green zones connect the landscape planes and help form a continuous network of green.

Like in the scenario ‘Kuststad’, the highway A4 forms the infrastructural backbone of the area. But in this new structure plan the highway A44 and the provincial road N206 also play a role as backbone, more specifically: the coastal backbones. Two new connections are made between the A4 and the A44 and the N206.
Two concepts that have been an inspiration to this structure plan are ‘Coastland’ by KuiperCompagnons and ‘De Hollandse Kustboulevard’, by several authorities and designers in the Rijnland region.

In 2004 the office KuiperCompagnons made a vision for the Agency for Tourism and Congresses in the Netherlands on recreational mobility in the coastal zone of Holland. To tackle the problem of bad accessibility in the coastal zone, the concept ‘Coastland’ proposes to make the highway A4/E19 a collector and distributor where various transportation nodes come together. From this A4, several speedlinks to the coast are suggested, from fast to slow and public to private. In the new structure plan, a similar idea is suggested: new east-west connections by car as well as by light rail, south of Leiden.

A continuous coast boulevard, like we have seen in the analysis of the Coastal Metropolises, is suggested in the vision ‘De Hollandse Kustboulevard’. The coast boulevard will form a new connection between IJmuiden and The Hague, attaching the urban areas and making the coastal zone a coherent whole. A new connection between the A44 and the N206 plays a key role. (See appendix V) This new road, though, is proposed to run straight through one of the characteristic open landscapes.

Therefore in the structure plan proposed for this project, the concept of the coast boulevard is put in a new form: the connection between A44 and N206 is draped on the edge of the zone of open landscape.
CHAPTER 3. COAST AS WEAKNESS
3.1 Tradition of Dutch sea defense

History

The 350 km long Dutch coast along the North Sea is generally a dynamic coast that moves back and forth from the shoreline due to erosion and accretion of sand. Like most of the northwest European dunes, the Dutch dune system was initiated around the year 6000 B.C. Since then it developed under the influence of melting ice caps and sediment flow into its current form. (Hooimejer, 2005) This form consists of the ‘Waddenkust’, the ‘Hollandse Kust’ and the estuary coast of Zeeland. The Hollandse Kust is subject of this project, especially from Hoek van Holland to Ijmuiden. It consists of a series of dune-ridges with a maximum width of 5 kilometers and several interruptions. The villages of Ter Heijde and Katwijk aan Zee, located respectively next to the former estuary of the River Maas and the outlet of the old river Rhine, form these interruptions in the dune system. (Waterman, 2008)

These interruptions, together with parts of narrow and low dunes, made the weak links in the coastal system. Erosion of these parts could not (and still can’t) be permitted, especially because many people inhabit the low lying polder behind the dunes. Weakening of the sandy coast by erosion and lowering of the land behind the dune ridges created the conditions for major flood disasters during storm floods. The dune coast gave way to the sea several times in the Middle Ages. (d’Angremond, 2001) At that time, the Dutch started to feel the need for organization of the coastal defense. Autonomous and independent organizations, Water Boards, were formed to construct the dikes and maintain all the sea defense. For maintaining the sea defense, only the actual ‘defense aspect’ was important. The Water Boards improved the dunes by placing more sand behind the dunes on the landward side, causing damage to nature. Later, in the 17th century, the Water Boards started to construct the first groynes along the coast of Delfland. Building groynes, at that time, was the only way to attack the erosion problem on the shore. (Pilarczyk, 1990) In 1880, a seawall was built south of Den Helder, the ‘Hondsbosche Zeewering’.

At this moment the Water Boards are responsible for maintaining the dunes as a primary sea defense. However, erosion prevention is a task of the national government.
Safety standards
After the disastrous flood of 1953 the Delta Committee was appointed to give advice about the execution of the Deltaplan. The safety standards that were developed and applied in the Deltaplan were based on the societal acceptability of flooding. This acceptability is formulated in a frequency of exceeding of a certain water level. (TAW, 1995) The Delta Committee advised in 1960 to use the highest level of safety for Central Holland: protection against a storm surge with a chance of occurring once in 10,000 year. But after reconsidering the societal risk of flooding nowadays and for the future, keeping in mind the global climate change, the Committee has advised to raise the safety level by a factor of 10. (Delta Commissie, 2008)

Erosion by climate change
As explained above, the safety standard for the flood protection system has been raised by the Delta Committee as a response to climate change. Erosion of the coast, which is subject to climate change, is the main threat for the coastal protection system along the ‘Hollandse Kust’. We can distinguish two forms of erosion:
- structural erosion of coasts
- dune and beach erosion resulting from a severe storm surge

a. Structural erosion of coasts
The Dutch dune system is a mature system which is in an eroding phase (Pye, 2001). This means that geomorphological processes are causing a slow erosion over time. Due to this structural erosion sand disappears from the defense zone. Sea level rise, caused by climate change, can make this chronic erosion process increase because of a new equilibrium level . (Pilarczyk, 1990)
A more direct effect of the new water level is the shoreline moving in a landward direction, making the beach and dune zone narrower.
Another possible effect of global climate change is the increase of wind strength. This can affect the coastal dune system in many ways, mainly damaging vegetation and enhancing the structural erosion of dunes (Pye, 2001).

b. Dune and beach erosion resulting from a severe storm surge
Coasts which may seem stable, can suffer from the effects of a severe storm surge. A fast and sudden erosion of the dune front can cause a large loss of sand to deeper water (Pilarczyk, 1990). Sea level rise even enables storm waves to attack further up the beach and transport sand further offshore.

Not only are eroding coasts a problem for the national water defense system on a long term, they are also the source of serious problems for the direct users of the coastal zone. Buildings close to the sea can be lost or roads can disappear (d'Angremond, 2001). Renewal of the coastal protection should defend weak spots of coastal system, protect against long and short term erosion and battle direct and indirect effects of erosion, close to the shoreline as well as further away.
The last three decades, the Dutch government has focused on sand as the most important instrument for coastal defense, under the motto ‘apply soft where possible’. In several policy notes like the Strategic Vision on Dutch Coast 2050 and the Integrated Coast Policy 2001, this strategy is elaborated. Currently the coastal defense has numerous weak links and locations of high risk. Apart from the general suppletion of sand coordinated by the national government, several municipalities work on specific measures for strengthening these weak links.

- The boulevard of Scheveningen will be restructurized in the coming years. Since Scheveningen is one of the weak links of the Dutch coast, the coastline will be strengthened by stacking a hard construction in the boulevard. The new boulevard will be partly higher and curved, following the original contours of the old coastline. Also, extra foreshore and beach suppletion will be executed.
- The waterboard of Delfland, the province of South Holland, Deltares, the TU Delft and several other institutes, are currently developing the Sand Engine. (See paragraph 3.2) In the meantime, a large scale beach and dune suppletion between Ter Heijde and Kijkduin is being executed by the waterboard of Delfland.
- The municipality of Katwijk aan Zee is currently elaborating various alternatives for strengthening the local sea defense. These alternatives are: extra sandsuppletion, Dyke in Dune (paragraph 3.2) and strengthening of the primary sea defense in the village (paragraph 4.1). Of the three different options, Dyke in Dune is preferred by most stakeholders.
- The seaside resort Noordwijk has just finished building the Dyke in Dune (see paragraph 3.2) Noordwijk has used this solution to shift the primary water defense towards the front of the boulevard. This will abolish the building restriction along the boulevard, so that new development and building can take place.

Advice Delta Committee: sand suppletion
To prepare the coast for the predicted sea level rise, the Delta Committee proposes to intensivate the current sand suppletion works. Doing so will lead to an expansion of the coast. The Committee points out that this should be done gradually to leave room for ecological processes and spatial planning to adapt. An amount of at least 40 million m3 of sand per year is needed to resist a sea level rise of 6 millimeters per year. This will lead to a coastal expansion of 10 meters per year: 1 kilometer of extra coastline in the year 2100.

The Delta Committee visions this coastline as new space for nature and recreation. But this solution would mean that all the current seaside villages will become hidden behind a fortification of sand. The villages and seaside resorts will loose their direct relation with the sea, which is currently one of their major qualities.
3. Analysis of techniques for coastal defense

The technique of sand suppletion suggested by the Delta Committee is one of many different techniques for sea defense. Those techniques vary from ‘soft’ to ‘hard’ and from directly on the shoreline to hundreds of meters seawards. ‘Soft’ solutions involve sediment as primary instrument or construction material. ‘Hard’ solutions are constructed of materials like concrete, rock or asphalt, often combined with sand. Looking at this wide range of sea defense measures, eight different (groups) of techniques can be distinguished.

All of these techniques have their specific features, advantages and disadvantages.

**Soft solutions**

a. Sandsuppletion and ‘Building with Nature’

As discussed above, the past decades the Dutch coast has been softly maintained by the suppletion of sand. Sand suppletion is the nourishment of existing beaches by artificial means, repeated over time. The essence of sea defense by sand is the reduction of wave energy by the transportation of loose sediment. Waves weaken, carrying sand near the shore.

There are different types of suppletion:
- Dune suppletion
- Beach suppletion
- Foreshore suppletion

Dune suppletion means a direct increase of the sand volume of the dunes on a certain location. Beach suppletion involves the direct enlargement of the beach volume. Foreshore suppletion means placing sand in the foreshore which indirectly nourishes the beach. This last technique is usually applied in case of a small and steep beach with a shallow foreshore. (TAW, 1995)

In its advice on sand suppletion, the Delta Committee included the soft engineering principle of Building with Nature. (Delta Committee, 2008) The essence of this principle is the flexible integration of land and water in the coastal zone with new land offshore, using materials and forces present in nature and taking into account the potential values of the natural environment. According to this approach a new, flexible coastal zone is created using sand from the sea, constructing a new range of dunes with a new beach and with a minimum of hard elements. (Waterman, 1998)
The concept of Building with Nature was launched by J.N. Svasek and carried on by R.E. Waterman, who used it as the main element in his plan for ‘integrated multifunctional sustainable coastal zone development’, also called Plan Waterman. Based on the principle of Building with Nature, the seaward extension near Hoek van Holland was realized in 1970: the Van Dixhoornndriehoek. This reclamation of land consists of about 150 hectares and now contains a dune reserve, ‘De Kapittelduinen’ (Hooijmeijer, 2005).

Another example of land reclamation by Building with Nature is the 2000 hectare peninsula south of the Maas Plain of Rotterdam. Besides harbor functions, for which the island was primarily created, the area contains a new beach, a nature reserve and a bird island.

b. Sand Engine
A variation on the principle of Building with Nature is called the ‘Sand Engine’. This entirely soft method of coastal renewal is the placement of a large artificial dune in front of the existing dune range. This megasuppletion of an excess of sand is relocated along the coast by natural processes in a time span of several years. (Biesboer, 2007) The province of South Holland is currently studying possible options of a Sand Engine in the form of an island, a peninsula, a hook or an underwater megasuppletion.

c. Offshore soft measures: beach barriers and islands
There are various examples of sea defense measures that are build-up of sand and that are located seawards of the coastline. The architect and urban designer Ashok Bhalotra designed a new broad strip of land in front of the coast between Hoek van Holland and Scheveningen, called Nieuw Holland. Landscape architect Adriaan Geuze drew a plan for the entire Dutch coast. His proposal is to strengthen the coast by a series of islands that form a new barrier coast.

A more or less similar plan comes from two civil engineers and is called ‘De Haakse Zeedijk’ (the rectangular seadyke). This plan proposes a new dune ridge about 25 kilometers seawards of the coastline which becomes the primary sea defense of Holland. The dyke encloses new lakes where the water level is artificially adjusted. Just behind the dyke new land is created for residential and recreational purposes.

Plans like tulip and windmill shaped islands show that creating new land in sea stirs up the fantasy of designers and engineers. Moreover, they appear to have the ambition of making such a project an international attraction.
Hard solutions

Although there is an endless range of different hard technical options for coastal protection, they are here classified in four groups: Groynes, Dyke in Dune, breakwaters and dykes/seawalls.

a. Groynes

A groyne is a structure running seaward from the shoreline whose primary function is to interrupt the transport of sand parallel to the shoreline in order to prevent erosion and build up a higher level of sand. As explained in chapter 2, the first Dutch basic groynes were constructed in the 17th century and are still visible along the coast of Delfland. Today variations of groynes in Y, T and L shaped forms are being build. A groyne system is build up of a number of individual groynes of similar length. (Pilarczyk, 1990)

Based on the same principle,

b. Dyke in Dune

A technique that combines the present dunes with a hard construction is called ‘Dyke in Dune’. This method for strengthening coastal defense was recently executed in Noordwijk aan Zee. A new stone or concrete dyke is covered with sand to form the basis of a higher and broader dune. The project in Noordwijk involved a new dyke of more that 1 kilometer long with a height of 8.5 meters. The new dune on top of it now has a total width of 42 meters.

c. Breakwaters

The function of a breakwater is to reduce wave activity, mostly in harbor or marina areas. In beach areas, breakwaters are often detached from the shore. These offshore breakwaters prevent structural or sudden erosion and encourage the build-up of sand at the shoreline. Instead of trapping the sand like groynes do, a series of offshore breakwaters can create a zone of reduced wave energy, where more sand is being deposited than being washed away. Currently plans are being developed for the coastline of Scheveningen that involves an artificial reef that functions as a breakwater. The 3.5 kilometers long reef will be submerged, constructed by sand and concrete blocks that lay about 1.5 kilometers seawards. Calculations have shown that this construction will reduces wave height and period. Also, the reef will be beneficial to the marine ecology. (Rijkswaterstaat, 2008)

c. Dykes and seawalls

Dykes and seawalls, built along the front slope of the dunes or land, directly protect the natural coast from erosion and the hinterland from flooding. It can effectively prevent the loss of dunes, beach or land, but the construction doesn’t involve solving the underlying erosion problem. (d’Angremond, 2001) Dutch examples of seawalls are the Hondsbossche Zeewering and the sea-dyke of the city Vlissingen.
3. COAST AS WEAKNESS

Comparison
Although the separate seaside villages, weak links and places of high risk have separate needs for coastal defense, they are part of the same coastal morphological system. Therefore it is necessary to find a general technique for sea defense that fits the Randstad Coast. Together with the structure plan of the previous chapter this will form a strategy on sea defense on the scale of the Randstad as a coastal metropolis.

To find the optimal solution for sea defense that meets the needs of our mixed coastline, a comparison is made according to four criteria. These criteria come directly from the analysis in chapter 2.1 and 2.2:
1. Flexibility: the pressure on coastal protection varies with the pressure on safety and space. The uncertainty of the assumed predictions about climate change and the future demand for space asks for a coastal defense adaptable to the newest insights and needs. Therefore, flexibility is one of the criteria for coastal protection.
2. Natural values: According to the importance of the natural values of the existing coastal zone, the renewal of the coastal protection should go hand in hand with the protection or expansion of natural values.
3. Multi-functionality: The coastal zone with its renewed protection should host space for various functions like recreation, residence, special activities, etc.
4. Accessibility: Since the direct relation of the seaside resorts to the shoreline, connectivity and accessibility of the renewed coastline is one of the criteria.

For each of the seaside villages and the zones of dune reserves in between, the four criteria are ranked. This shows for all parts of the coastline which criteria for coastal defense are most important.

Next, the techniques of sea defense are ranked for the four criteria. In other words, for each criterion is stated which technique is the most appropriate. When it comes to multi-functionality, both soft and hard techniques have proven to be able to host different functions and purposes. For the direct local accessibility of the shoreline by paved ways, the implementation of hard solutions is more desirable. In the interest of natural values, the solution of soft measures and Building with Nature is more desirable than hard techniques. On the criterion of flexibility, the two principles of sea defense differ the most. Soft measures are dynamic in principle, while hard measures are fixed. The extensive version of this comparison can be found in Appendix III.

Conclusion
Combining these two diagrams shows that there is no technique that is most appropriate for the entire coastline according to the criteria. But one thing that is obvious from this ranking, is that flexibility and multi-functionality determine the choice: it is clear that the natural zones and the urbanized zones along the coast desire almost the opposite. This requires a combination of techniques or a technique that is applicable to ‘grey’ and ‘green’ zones and multi-functional.
3.3 A new approach: beach barrier

One technique that meets the requirement the best according to the analysis is the soft offshore construction. This coastal defense system is built up of sand, thus flexible. It can be developed in different forms, sizes and safety levels.

But most important is the fact that this method doesn’t turn the existing coastal area into a fortification. It leaves the existing seaside villages as they are and creates a new exiting seafront with extra seaside capacity. (Plans like the Haakse Zeedijk, Plan Geuze and Plan Bhalostra have this principle as their basis.)

Also, in chapter 2 we have seen that Miami and New York both have this type of coast as their major attraction as a Coastal Metropolis. Therefore it is an interesting option to elaborate spatially and programmatically for the Randstad coast. To do so, the plans of the Haakse Zeedijk and the artificial reef named in paragraph 3.2 will be crossbred with the American barrier coast. Mixing these solutions gives a new concept: a Randstad Beach Barrier.

For this project numerous alternatives have been drawn. (See Appendix IV) Eventually, the most basic option has been chosen.

This barrier is formed by a sand reef about 800 meters from the shore which has the primary function of breaking waves. It reduces wave height and wave period. That way it protects the current coastline of sudden and structural erosion, it protects the infrastructure and buildings close to the shore from wave attack and it protects against flooding by overtopping of waves.

The barrier can be partially submerged, depending on the local need for additional safety. The parts where the barrier is emerged from the sea can serve as extra ‘coast capacity’. This creates space for dunes, recreational beaches, marina’s, touristic functions etc.

Similar to the concept of Haakse Zeedijk, the beach barrier leaves the existing coastline and the charm of the seaside villages untouched. But unlike the Zeedijk proposal, the beach barrier doesn’t enclose the sea and won’t influence the tidal range. The current coastline keeps its natural dynamic character.

Like the plan of the Scheveningen reef, the beach barrier reduces wave action and erosion of the existing coastline. But unlike the reef of Scheveningen, this new beach barrier will be emerged and visible. Usually objects at sea are considered esthetically undesirable, but in this case an emerged ridge offers new exiting possibilities. An obstacle at sea doesn’t have to be a nuisance, but can be an attraction. Moreover, the view on the uninterrupted current coastline will be preserved, in contrast with the plan of the Delta Committee or measures perpendicular to the coastline.

Similar to the ‘exiting’ plans like the tulip and windmill islands, the new beach barrier will be an (inter)national attraction. Its shape is more basic and obvious than the proposals shown in this chapter, still the barrier solution will be something unique in the world, for it offers two parallel beachfronts.
3.4 Advantages and disadvantages

In short, the new beach barrier has several advantages:
- The main advantage of the beach barrier is the fact that the current coastline can stay the way it is. The seaside villages will keep their direct relation with the sea. The charm of the seafront will be preserved.
- The view on an uninterrupted coastline stays untouched.
- The emerged barrier reef offers extra beach capacity.
- Thanks to the wave breaking effect of the barrier, the lee side of the barrier will offer safe swimming and quiet sailing conditions. In addition, the barrier will be a wilder environment, suitable for surfers and kiters.
- The reef will form a new habitat for marine life. The ends of the reef, partly under and partly above sea level, are in fact tidal zones. This feature can create unique ecological circumstances.
- The fact that the breakwater barrier is built-up of sand makes it flexible: on one hand the reef can differ in size, safety and appearance, depending on the particular part of the Randstad coast where it’s located. On the other hand, the reef can be adjusted to the need for safety and space through the coming decades.
- The seaside resorts won’t be exposed to the nuisance of renewing the current coastal defense. All the activities will be executed at sea.

Disadvantages:
- Creating a new reef of sand in an existing dynamic coastal system will have a large impact on the total system. Fortunately, changes in the coastal morphology can often be simulated in computer models.
- The changes in the longshore sand transport may cause local accretion and erosion of sand. By regular suppletion of sand, the effect will be diminished. In addition, properly matching the south edge of the reef to the places that need extra accretion will give an extra safety to the land.

In chapter 5 and 6 the beach barrier will be further elaborated technically, spatially and programmatically.
CHAPTER 4. SEA DEFENSE ON LOCAL SCALE
As introduced in chapter 1, Katwijk aan Zee is an interesting case for testing the effect of the proposed strategy on local scale. On the one hand, Katwijk is exposed to the pressure of ongoing urbanization, for it lies in the center of gravity of the Randstad Coastal Metropolis. On the other hand Katwijk suffers from much pressure from the sea, for it is one of the weaker spots along the Randstad coast. The beach barrier is created from a Randstad scale point of view. So what effect will this rigorous concept have on the local scale of Katwijk aan Zee?

4.1 Katwijk aan Zee

Since 4800 B.C. the Dutch coast has been a closed coast. The westward shifting of the coastline throughout the last centuries has left a pattern of sand ridges and plains in between. The estuary of the old Rhine forms an interruption in this structure. In Roman times this area was still a open estuary with sedimentation of clay. The current dune ridge only developed in 1000 A.D. For a long time the Old Rhine formed the northern border of the Roman Empire. The Romans settled along the river and founded Fort Britannica, which nowadays lays under sea level near the town of Katwijk. The fishers village of Katwijk aan Zee was founded at the crossing of the two geomorphological structures: The estuary of the Old Rhine, in an east-west direction, and the sandridge structure, running north-south. Over the years the village of Katwijk and neighboring towns have developed along this estuary of the Old Rhine. This low location used to be an advantage for the village: fishermen could pull their boats right up the beach.
But nowadays the low situated town is a weak link in the whole coastline of the province of South-Holland. Moreover, the old center of Katwijk is one of few densely populated areas that lays outside of the dike ring. Since there is no seawall or dune ridge, the town center has insufficient protection. The current boulevard that separates the town from the beach has a height at some places of only 6 meters. The actual sea defense in Katwijk is formed by high ridge that crosses the center. About 3000 dwellings are built outside of this ridge.

This primary sea defense has to have sufficient height to protect the hinterland. And this hinterland is not only formed by the town of Katwijk but also a large part of the province of South-Holland, which is enclosed in the so-called ‘dijkring 14’.

primary sea defense in Voorstraat

primary sea defense in Voorstraat

height of boulevard (source: Gemeente Katwijk)
4.2 Katwijk and hinterland

The urban area of the current municipality of Katwijk aan Zee is built-up of several village cores, surrounded by semi-rural and rural zones. These villages, that form the municipality of Katwijk, are characterized by different social, economic and cultural backgrounds. Fishery, agriculture, horticulture, tourism and small trade have been the most important activities in the area for a long time.

When the estuary of the Old Rhine was gradually closed by the sedimentation of sand in the twelfth century, there was no direct need to sail to the end of the estuary of the Rhine any more. The activities shifted more landward, towards Leiden. The villages of Katwijk aan Zee, Katwijk aan de Rijn, Valkenburg and Rijnsburg now had to start developing independently of the Rhine and of each other. This caused the distinct activities and mentalities in the four villages.

The four cores were far apart, while the coastline was continuously shifting. When the coastline stabilized, Katwijk aan de Rijn had to give up its status of fisher village to Katwijk aan Zee.

Throughout the 20th century, the four villages grew tighter together. The area can now be characterized as a mosaic of different segments: villages cores, horticultural areas and new building areas from the last decades. (Gemeente Katwijk, 2007)

Especially in the 70s and 80s of the last century, Katwijk has grown rapidly on the northern banks of the Old Rhine.

Today Katwijk seems to be enclosed in between Valkenburg, Noordwijk, Rijnsburg and the dune-reserves, which are no-go areas. The municipality appears to almost have reached its growth boundaries, except for the new building location of Valkenburg. Plans for the development of this large scale location, which is a former airport, are currently being made.

Another area that is subject to large development is the space-district north of Katwijk, part of the municipality of Noordwijk aan Zee. This area, which now consists of the Esa Space Center, agricultural land and a small business area, will be developed into a ‘Space Business Park’ according to the plans of the municipality.
Conclusion
One thing that can be learned from this historical overview is that Katwijk has almost reached its boundaries. Putting the accent on the southern and northern wings of the area, by concentrating the future urban development there, will discharge the historical village centers, which are still distinct.

Another conclusion that can be drawn from the historic growth analysis is that the towns have grown in east-west direction, along the Old Rhine. The dominant infrastructure, though, is still north-south oriented, according to the dune ridge pattern. This infrastructure is formed by the highways A4 and A44, the railway track and the provincial road N206. The infrastructure hasn’t kept up with the east-west development. Therefore new connections in this direction are needed.
4. Boulevard

Around 1900, Dutch beach recreation took a large leap. The construction of roads and railways made the coast accessible for more people. Katwijk became a seaside resort for middle class visitors. Already in the first decades of the twentieth century large numbers of beach recreationists caused traffic jams on warm days. Also, the seafront gradually developed with more facilities for beach recreation.

In the Second World War the seafront and a large part of the village were demolished to make room for the German defense line along the European West coast. This Atlantikwall was an endless series of bunkers, fortifications and mine fields in front of and on top of the dunes. An area of 580 houses, several hotels, schools and other public buildings were swept away. (Gemeente Katwijk, 2008)

Although the war was still ongoing, the first plans for rebuilding were already made in 1943. The municipality and designers agreed that Katwijk should be rebuilt in such a way that Katwijk would keep its image of a modest family seaside resort. This rebuilding would be combined with urban expansion.

The boulevard was rebuilt in a style that was a mix of traditional and modern architecture. The use of natural materials, modern forms and formal facades gives the seafront its coherent character. Also, the prescribed dimensions of the buildings, like a maximum building height and width of 10.5 and 6.5 meters and a shallow angle of the roof, gives the houses a typical look. This type of architecture is unique in the Netherlands. (Gemeente Katwijk, 2008)

The first plans for rebuilding of the village were made by a team of 10 architects and were ready in 1944. The most important principles of the new plans were:
- preserving and strengthening the two characters of Katwijk (fishers village and seaside resort).
- to match the new buildings with the existing small scaled buildings.
- to rearrange the old street structure in such a way that bus- and tramlines have their final stops at a central square.
- to create a more sheltered pedestrian area behind the boulevard in case of rough weather.
Although the designers still had the idea that Katwijk would fulfill an important recreational role, the expansion plan was mainly focused on the building of new dwellings. Therefore dwellings dominated and still dominate the seafront. The only element in the plan that matched the character of a seaside resort is the ‘Zeeplein’. It was designed as a square with a view at sea in front of several hotels, a cinema and a busstation.

Today the boulevard consists of several important elements (from north to south):
1) hotel Savoy, a national monument of modern architecture
2) the typical reconstruction architecture
3) the White Church, which was also rebuilt after WWII
4) the lighthouse, which is the final station of all buslines
5) the Zeehospitium, a resort for revalidation
6) modern apartment block on the south end of the boulevard
Originally, the old village and seafront were connected to the hinterland by the Voorstraat, the Zeeweg and the Zuidstraat. In the designs of 1944, a fourth connection was added that would connect the new to build southern part of the village. This would enhance the radial structure of the village. However, this connection has never been completed. The southern axis doesn’t connect to the central access (the Zeeweg) but bends off. This results in a less logic road structure that is partly radial and partly orthogonal. The village core of Katwijk today consists of a mixture of pre-war buildings, post-war buildings and buildings from the last few decades.

Drawing the intensity of public space in the village core, makes clear that most of it is concentrated landward of the seafront, where most shops and facilities are located. The public domain on the boulevard plays a modest role.

**Conclusion**
The seafront of Katwijk aan Zee is a holy matter to the inhabitants. With its distinctive architecture it is a symbol for the post-war rebuilding. Therefore it is important to preserve the seafront as much as possible. But a disadvantage of the post-war seafront is that it is mainly focused on dwelling instead of recreational facilities. A future with strong urban growth of the hinterland and growth of the number of beach recreationists needs a seafront that is more attractive as a seaside resort. Another conclusion that can be drawn from this analysis, is that the village core is very tight, even after post-war rebuilding. With a growing number of visitors it would be an option to shift the central beach access to the south and to the north. This way the narrow streets of the center are discharged of traffic. The public domain is concentrated landward, in the village core, as much as on the boulevard.
4.4 Regional Plan

Now that the geomorphological, historical and regional situation of Katwijk aan Zee is discussed, a regional design can be drawn. In this plan the interventions that were determined on a higher scale (the Structure Plan) will be combined with the local situation of Katwijk and its direct surroundings.

As discussed in paragraph 4.2, the urban area of Katwijk aan Zee is a gathering of different segments, all tied together and ordered by the geomorphological and historical basis. Today many special segments can be distinguished:
1. historical village cores
2. horticultural areas
3. business areas
4. Flora flower auction of Rijnsburg
5. European Space Agency and future space business park
6. Science campus of the university Leiden
7. Former Airport Valkenburg
8. Centers for special health care Zeehospitium and Van Den Berg Stichting

The principles that can be distilled from the Structure Plan and that influence the Regional Plan are:
- intensify urbanization in coastal zone in a north-south direction
- green zones to connect the open landscapes
- new east-west 'speed-links' towards the coast, by car and public transport
The main idea of this regional plan is to combine the urban intensification with the fact that the old villages have to be discharged. Therefore the new building development will take place north and south of Katwijk.

- South of Katwijk the new building location Valkenburg is situated. In this regional plan, this area is divided into two built zones separated by a green zone. This green zone connects the recreational area of the Valkenburg Lake with the dune reserve and is made up of parks and sports facilities. The N206 now runs through the built area but because of the fact that it is (already) lowered, it will remain a 80 km/h road.

- Another zone that is suitable for new building development is the zone north of Katwijk. The existing plans for a Space Business Park can be combined with new dwellings and existing horticulture in this area. Also here, a strip of green program (horticulture, sports facilities and parks) will form a green interruption in the built zone. The connection between Noordwijk and Katwijk through this area, which is now very unclear, will be rearranged.

- Apart from the green connections and the open landscape planes, green zones can be defined that lie within the urban tissue. Parks along the Old Rhine and in Oegstgeest form attractive ‘holes’ in the urban tissue. These need to be preserved and enhanced.

- One part of the new east-west connection is a light rail track from Leiden to Katwijk and Noordwijk. It forms a new ‘speedlink’ towards the coast. Another east-west intervention is the new connection between the A4 and the N206, north of Rijnsburg. The new northern zone and the flower auction will be attached to this 80 km/h road. This way it will discharge the center of Rijnsburg. These interventions will be further elaborated in paragraph 4.5.

- Since Katwijk and Noordwijk will grow together in this regional plan, Katwijk and Noordwijk will share one beach barrier and one access. As explained in paragraph 3.3, the new barrier reef will discharge the tight center of Katwijk. Therefore the access of the reef will be positioned north of the Old Rhine and will be easily accessible from Noordwijk as well.
Two schemes of ‘Katwijk towards sea’ show the new infrastructural interventions to connect the coast and the hinterland.

**By car**
- the A44 and N206 will be connected
- the roads through the centers of Rijnsburg, Valkenburg and Katwijk will be discharged and degraded
- the area between Noordwijk and Katwijk has a logical road pattern
- the Hoorneslaan will be upgraded into a new sea access

**By public transport and bicycle**
- A lightrail system will be implemented according to the existing plans for the ‘RijnGouwelijn’. However, the track proposed here is different from the alternatives that are currently being discussed by the authorities. (see Appendix V) Entering the village center of Katwijk, the lightrail track will bend to the south, marking the axis that was originally planned but never realized (see paragraph 4.3).
- New continuous cycle tracks offer a continuous route towards the coast.
- Two ferry-services will connect Noordwijk and the south of Katwijk directly to the reef.
CHAPTER 5. TECHNOLOGY
5. TECHNOLOGY

A breakwater barrier in front of the existing coastline will reduce the wave height and wave period. This protects the coast from erosion. This chapter will explore the technical principles of the breakwater barrier and will elaborate the needed dimensions for the new reef.

5.1 Working and effect

Risk reduction
Katwijk aan Zee is considered a ‘weak link’ of the Dutch Coast because the primary sea defense, that protects a large part of the province of South Holland, does not live up to the basic safety level of 1/10,000 (see paragraph 3.1). The main reason for this is the insufficient height of the primary sea defense in the village core. Recent investigation by the Waterboard of Rijnland has shown that in case of a heavy storm surge, with a water level of about 5 meters and a wave height of about 8.5 meters, wave overtopping can occur over the lowest parts of the primary sea defense. This would cause flooding in the hinterland. But beside the risk for the area within the primary sea defense, also the part of Katwijk that lies outside of the defense line will be damaged during a severe storm. The area will flood and severe encroachment of the dunes and beach will occur. Therefore the wave breaking effect of the new sand reef will be beneficial for the hinterland as well as for the actual seafront. The reef will reduce the energy of storm waves. This means that the dunes and sea defense line only have to resist the storm surge level of 5 meters. For this height, the current situation will be sufficient. Moreover, the dunes in front of the boulevard no longer have to be so high that they block the view from the boulevard. The dunes and pedestrian areas along the boulevard can be leveled with the height of the road. Also, since the risk of encroachment is reduced by the breakwater, it is much safer to build closer to the shoreline. This means that the public domain along the boulevard can have a new boost and a more direct relation with the sea.
Coastal morphology
As mentioned in chapter 3, the Dutch coast features a constant sand transport in northern direction. Waves, approaching the coast under an angle, cause a transport of sediment in longshore direction. The breaking waves cause a current parallel to the coastline, and this current transports sediment along the coast. Differences in longshore transport along the coast cause erosion and sedimentation. (Bliek, 2001) Creating a breakwater barrier will influence the longshore transport severely: the sand transport south of the barrier will stagnate due to the reduction of wave energy. The supply of sand is more than the discharge of sand. This will result in a deposition of sand, which will be an extra benefit for the existing coastline south of Katwijk.
However, consequently there is no sediment available for transport on the south end of the new breakwater. The new breakwater, which is build up by the deposit of sand in one place, is not fixed and can therefore still be subject to chronic erosion. This means that the breakwater barrier needs regular artificial suppletion of sand to continue the longshore transport.
With this longshore transport guaranteed by extra suppletion, the rest of the breakwater barrier and the coast of the mainland northwards will have a continuous supply of sand and will be safe. North of the reef another slight accretion of sand will develop along the coast of the mainland. This is also caused by the local reduction of waves, where the sand transport locally stagnates.

Constructing the reef
The new breakwater barrier will be created about 800 meters outside of the mainland at a depth of 6 meters below sea level. There are several techniques for supplying such a large amount of sand in one place in a short time: The fastest and most efficient method for rand reclamation is to dump the sand directly from the dredging ship. This method can only be used in case there is enough depth for the ship to manouvre above the location where the sand needs to be deposited.
When there is insufficient water depth but the ship can closely approach the location, ‘rainbowing’ is an appropriate technique. A mix of water and sand is pushed through a nozzle and sprayed onto the sand area. When rainbowing is no option, the sand is transported through a floating pipe onto the land. This is called shore pumping. On the beach, bulldozers distribute the sand to the right location. The development of dunes on the newly reclaimed land can be stimulated by creating small hills and hollows in the sand. Also, planting marram grass and placing wind shields helps to capture the sand and helps the process of dune development. This can take several years.
5.2 Safety levels

The main use of the new beach barrier will be for recreational purposes. It will host different facilities like hotels, vacation homes, water sports amenities and beach pavilions. Since the barrier is actually an extra ‘line of defense’, it won’t become a residential area: apart from the fact that one just might not want to live on a strip of land 800 meters in sea, the basic ‘Delta safety level’ can’t be guaranteed for these small dimensions.

Still, it is important to guarantee a certain level of safety on the reef. To do so, the reef must have certain dimensions. In this paragraph the calculation of these dimensions will be described.

Equilibrium profile

The coast profile continuously adapts to the current hydraulic circumstances. During a severe storm, sand from the upper part of the beach is washed away and transported to a position just below the normal water line. In the following calm season the eroded sand will be brought back from deeper water to the upper beach. (Bliek, 2001) When these changes in beach profile occur without loss of sand and the amount of eroded sand is equal to the amount of sand accreted, it is called an ‘equilibrium profile’.

A safe and stable beach should have such an equilibrium profile. Therefore it is important to apply this principle on the breakwater barrier. With the help of this principle, the dimensions of the barrier can be calculated in the DUROS-model for a certain wave height and storm surge level (see Appendix VI).

The wave height and storm surge level are dependent on the severity of the storm. For the calculations three types of storms were used:
- medium storm surge, with a frequency of 1/20 years
- high storm surge, with a frequency of 1/100 years
- extreme storm surge, with a frequency of 1/10.000 years

This means that the reef can be dimensioned to resist three different types of storms and offer three safety levels. Per safety level, a narrow and a wide equilibrium profile is drawn. The narrow and wide alternative are equally effective for the same safety level, but have different dimensions.
Next, the profiles are assigned to the different zones of the reef. For instance, the zone with hotels in high density needs a higher safety level than a zone with just removable beach pavilions. For the most part, the ‘middle wide’ profile will be used. This alternative is rather safe and needs less sand than the narrow variant. To enlarge the buildable area, two extra profiles were added which have a larger surface behind the critical erosion line.
**Beach zone**
The north and south end of the barrier are beach zones. These zones consist of a road with one or two parking clusters. A wooden boardwalk gives access to the beach through the sand. On the ‘land side’ of the barrier is a pedestrian descent towards the sea, made of concrete plateaus. Dependent on the tide, these will be partly underwater.

**Marina zone**
The marina zone is an attractive zone for watersports fanatics. It contains a large sea marina with about 300 places for boats. Also, it hosts facilities like watersports retail, sailing schools and other specialized amenities. Besides that, this part of the reef also contains specialized fish restaurants, bars and clubs.

**Vacation zone**
A large part of the reef is suitable for vacation homes. These are placed on the ‘land side’ of the reef and therefore have an exclusive view on the main land and have access to a private pier. Due to the slope of the reef, these buildings will have an attractive lay-out with a height difference. Apart from the private parking lots for the vacation homes, this zone will also offer parking clusters every 250 meters. These are combined with wooden boardwalks to access the beach. At the beach side of the boardwalk, beach pavilions are located.
Parking zone
The reef contains two large parking zones that are located next to the busy hotel zone and marina zone. These parking lots both offer 340 parking places and direct access to the beach. Apart from that, there are numerous parking clusters next to the road along the entire reef. These clusters have about 22 parking spaces and there is room for a snack of ice cream cart. The total amount of parking lots on the reef is 970.

Hotel/Congress zone
The hotel zone is the most dense and spectacular zone of the reef. Here we find several hotels that have a congress function as well. This way the reef will attract visitors the whole year through. The conference function is complementary to the seaside resort of Noordwijk aan Zee. The unique quality of these buildings is the fact that they have a beautiful view in both ways: landward and seaward. Also, their location on the ‘land side’ of the reef can be used for having private piers or to build partly in the water.

An overview of surface areas and calculation of the costs and benefits can be found in appendix VII.
**Beach Zone**
Both far ends of the reef will become quiet beach zones. Here, the reef consists of nothing more than a road, with two integrated cycle lanes, and a footpath made of concrete plateaus. A small strip of slightly hilly dunes separate the road from the beach.
Beach Zone with parking cluster
Along the road on the entire beach, parking clusters are situated every 250 meters. These parking clusters offer space for about 30 cars and a snack or ice-cream cart. The parking lot is oriented in such a way that the cars can park and face the sea, so people can enjoy the view from their cars. A wooden beach access is located in the middle of the parking cluster. Opposite of the beach access is a concrete stairway. This gives access to the ‘landward’ waterline, where the tidal range creates a playful effect. This stairway is a pleasant place to sit down and watch the shore.
**Vacation Zone**
The vacation zone consists of vacation homes. These exclusive homes can have their private parking lot and private pier. Because of the height difference, the typology of the houses can be modern and experimental.
Hotel Zone
This zone will be the most vibrant zone of the reef. With a total width of about 150 meters, there is space for middle-large hotels with conference facilities. Also, this zone will contain restaurants, bars and clubs.
Because of the fact that there is no existing typology and architecture to take into account, the new buildings can be designed in experimental forms and styles. Beach pavilions will be located close to the shoreline and will be removable or dismountable.
6.2 Boulevard

The new barrier reef offers an opportunity for the current boulevard of Katwijk aan Zee to undergo a transformation. The coastline of Katwijk will no longer be exposed to severe storm waves. Therefore the boulevard can become lower and the pedestrian area and beach facilities can shift seawards. The seafront now can have a more direct relation to the sea.

By this intervention, several problems can be attacked:
- no view from the boulevard at sea
- empty meaningless squares
- sloppy public domain
- disorganized parking lots on prominent spots along the boulevard
- the absence of an attractive pedestrian connection between the shopping area and the beach
Elements of the design
- The new pedestrian area is broader and curving. This accentuates the three distinct places along the boulevard: the Hotel Noordzee, the White Church and the lighthouse. These places get more meaning by the creation of a new square in front of them. Moreover, the road curves along, which will make motorists to slow down. This way the new squares are pleasant pedestrian areas.
- New stairs alongside the square create a direct connection from the shopping area and boulevard to the beach. The curved stairs are broad so they can also function as seats.
- A new wooden boardwalk at the bottom of the stairs connects the central part of the boulevard. In fact it forms a second boulevard on beach-level.
- Under the squares on boulevard-level are kiosks, ice-cream and snackbars. The offer diversity in the mainly by dwelling dominated boulevard.
- The parking will be centralized to new larger parking area. It will be located at the former empty and viewless square.
Section A

Broad stairways connect the shopping street and the new square with the new boardwalk. The route crosses the road, via a pedestrian crossing which is made of the same pedestrian pavement. Accompanied by the square, the road is paved by light colored bricks. On the seaside of the boulevard road, the cycle path is separated from the road by a slight height. On the other side of the road, the cycle path is integrated.
Section B
The wooden boardwalk on beach-level is wrapped around the beach pavilions. This way, the pavilions are directly accessible by the boardwalk. Parking places are located in front of the boulevard houses. These parking lots are mainly for residents.

Section C
The parking for visitors is centralized on the former Seaside square. The new parking zone offers space for about 80 cars. It is located 1.5 meters below the boulevard-level. This way it lies hidden between the boulevard and the dunes.
Section C
This section shows the new square in front of the picturesque White Church. The spaciousness of the new square gives the church more monumentality. In the meantime, the square offers an unblocked view at the sea. Comfortable and attractive seats and benches make the square an inviting environment.
6.3 New connections

**Lightrail**
A lightrail track, part of the Rijngouwelijn, will enter the village of Katwijk over the central access: the ‘Zeeweg’. This is a broad and green avenue and is an attractive way to enter Katwijk.
The lightrail can be easily implemented in the green strip. The cycle path will be shifted to the parallel road along the houses.
The remaining end of the lightrail track will be implemented through the dense village core, mainly through the ‘Varkevisserstraat’. Here, the rails will be constructed in the existing road.

**Reef road**
The creation of the new beach access over the ‘Hoorneslaan’ will discharge the old center of Katwijk. The Hoorneslaan is already set-up broadly and has parallel roads on both sides for a large part. Therefore this road is able to deal with more traffic without causing congestion.
After the road has crossed the high-rise area of Katwijk, it enters the ‘Northern Beach zone’ of Katwijk. Right now, this area is a gathering of different elements and functions, like a camping site, a large parking lot, a youth-center, a horse riding school and a small conference center. All these functions are spread-out in the dunes. This makes the area unclear. The quality of this zone is the nearby estuary of the Old Rhine, with its spacious grass banks. But currently this quality is hardly employed to make the area attractive.

In the new design, the Hoorneslaan is extended directly towards the reef. The new ‘Reef Road’ runs along a newly created dune along the river bank. The camping site, the parking lot and the other buildings are sheltered behind the new dune ridge. This way the area is brought back to a dune zone and becomes part of the larger dune reserve.

So motorists and cyclists heading for the reef will cross this zone with on the one hand the dunes and on the other hand the river Rhine.

The reef will be accessible by a new bridge. This bridge will be about 13 meters wide, 700 meters long and will be 2 meters above the average sea level. A broad foot and cycling path will make the bridge attractive for non-motorists.
6.4 Reef vs. Mainland

The new reef and restructured boulevard of the village of Katwijk will be like two different worlds. They both have a distinct atmosphere. The difference between the two can be found in type of architecture, materials used in the public domain and difference in facilities.

traditional

inviting

family seaside

stairways

monuments

sea view

boulevard

boardswalk

BOULEVARD

benches
6. DETAILS OF THE DESIGN

- eye catching hotels
- tide
- REEF
- emptiness
- waves
- boardwalks
- watersports
- experimental architecture
- marina
- sea view
- launching
CHAPTER 7. CONCLUSION AND RECOMMENDATIONS
7.1 Costs and Benefits

Costs

The costs for the construction of the Breakwater Barrier can be roughly estimated, based on the prices for the sand. The costs per dredged m³ sand are dependent on several factors:
- the distance between the location where the sand is gained and where the sand is deposited
- the depth of the location
- the use of material, the size of the used dredger boats
- the proportion of different dredging techniques applied

The price for the different dredging techniques can be estimated as follows:
- dumping: 1.75 – 3.00 €/m³
- Rainbowing: 2.00 – 4.00 €/m³
- Shore pumping: 3.00 – 8.00 €/m³

(Delft Hydraulics, 2007)

Since the three techniques will be applied in more or less equal proportion, the average price will be estimated at € 4,5 /m³. With the total demand of sand of about 14,5 mln m³, the total sand costs will be € 63 mln. (Appendix VII) To compare: the sand suppletion along the coast of Rijnland cost about 11 mln m³ between the years 1991 and 2003. (Delft Hydraulics, 2007) Of course, € 63 mln is the price for the deposit of sand only. This price does not yet include the construction of a bridge, road and further development.

To maintain the reef, regular suppletion will have to be executed. This amount can be estimated at 1,5 mln m³ sand per five years. This amount is obtained by comparing the Breakwater Barrier to one of the Sand Engine alternatives. (Delft Hydraulics, 2007)

When we compare the breakwater barrier to other plans, the breakwater barrier appears an expensive alternative. The overview below shows the different plans that are currently being investigated or that have recently been executed:

Scheveningen:
- €73 en €85 mln for the different alternatives of an artificial reef (30 m wide, 10 m depth, 3 km long)

Noordwijk:
- €20 mln Dyke in Dune (along 1,1 km) + extra beach (along 3 km)

Katwijk:
- €10 mln minimal sand suppletion (current dune ridge broader and higher, sufficient for 50 years)
- €34 mln construction new dunes, broader and higher
- €39 miljoen Dyke in Dune

Benefits

The three alternative solutions for Katwijk are obviously cheaper than the €63 mln for the breakwater barrier, while they're designed to last the same period of time. Then why should the breakwater barrier be preferred?

The reef has many (financial) benefits. Most importantly, the reef offers space to be developed and exploited. The reef forms a unique location, with a unique two-sided view and possibilities for developing spectacular architecture. This is likely to attract investors.

With a total buildable area of 110.700 m², and a ground price of € 200 – 400, and a yearly amount for land-lease for beach pavilions, the benefit will be about € 32 mln. This amount will pay back already half of the sand construction costs.

Next to the benefits discussed in paragraph 3.4, the reef has several indirect financial benefits compared to the alternatives above:
- The value of the boulevard and the seafront of Katwijk will be preserved and even enhanced. The new and more direct relation to the sea gives the boulevard increased attractiveness and will indirectly make the area more valuable economically. The beach closer to the shoreline can be exploited.
- The construction of the barrier will not cause any nuisance to the village center and seafront of Katwijk. The construction of the three alternative plans cause a decrease in accessibility and recreational activity at the beach, and therefore do economical damage to Katwijk. This damage is estimated at maximum € 1.300.000. The construction of a reef in sea causes economical damage to the fishing sector, but this damage is only a tenth of the damage to the village. (Geurts van Kessel, 2007)
- The new coastal landscape is likely to attract a larger number of visitors and stimulate the touristic economy of Katwijk.
7.2 Back to the Randstad

This project started with the goal of making a new coastal defense that would fit the Randstad as a Coastal Metropolis. So now that the Structure Plan, Regional plan and Breakwater Barrier are drawn, it is time to look back and see to what extent this new coastal defense contributes to the idea of a Coastal Metropolis.

Firstly, the breakwater barrier creates a new coastal landscape that is unique in the world. Attached to its hinterland, it is part of the urban coastal zone and of the coastal metropolis. And unlike the barrier coasts along the American east-coast, which typically feature a beachfront and a ‘backyard’, this Dutch barrier features two beachfronts. The new reef forms an addition to the characteristic seaside villages. It gives the possibility to create a new spectacular, Miami-like seafront without harming the existing.

In the meantime the existing seaside resorts can open up to the sea. This project describes a proposal for the transformation of the Katwijk boulevard, but of course Noordwijk, Scheveningen, Kijkduin, Zandvoort etc. have the opportunity to apply a similar transformation. In the various seaside destinations, the reef can be ‘customized’, for instance to discharge certain areas, or to develop functions that are locally demanded.

When it comes to coastal infrastructure, another important feature of a coastal metropolis, this plan leaves the seaside resorts in a tailback situation. But instead of adding extra pressure to the existing, new connections are made to connect the reef with the hinterland.

Going ‘seawards’ with the Randstad has tickled the fantasy of many designers and engineers. Some draw fantastic future scenarios, others design realistic calculated plans. The idea of a Coastal Metropolis is most of all a scenario, based on the scenario ‘Randstad Kuststad’. It has large ambitions and proposes big interventions. In this project, the scenario of a Coastal Metropolis is turned into a graspable reality. Consequently, the plan has become more subtle, but is still based on some of the same ambitions as ‘Randstad Kuststad’, like a structure for green, densification in the coastal zone, a coastal infrastructure, speedlinks towards sea, and an attractive new coastal landscape.

But the main difference between the ‘Kuststad’ scenario and this project is exactly this coastal landscape. The breakwater barrier is much more modest than the coast proposed by ‘Kuststad’ or by the Delta Committee. But in the meantime the barrier offers the qualities to be part of a new coastal zone, preserving the seaside resorts and adding an innovative touch.
7.3 Recommendations
There are several topics that are important for the realization of the Breakwater Barrier that have not yet been properly elaborated in this project.
- The construction of the breakwater barrier is a good opportunity to open the estuary of the Old Rhine, which is currently closed by a scour sluice. The new reef will protect the opening from closing again by the accretion of sediment. But consequently, the water discharge of the hinterland will be let out in the sea. This may negatively influence the water quality, because the current along the coast is change by the reef. This topic needs further investigation to secure proper water quality of the sea.
- The Reef Road, that connects the hinterland with the reef, needs large capacity. However, the Hoorneslaan, on which the new reef road is planned, currently already suffers occasional congestion because it reaches its maximum capacity. Despite of that, the road has a spacious set-up, with broad parallel roads and foot and cycle lanes. Therefore the lay-out and integration of the Hoorneslaan can to be modified. This asks for further elaboration by traffic engineers.
- The phasing of this project in time is something that asks for more elaboration. The implementation of the lightrail and ferries, and the construction of the reef, bridge, reef road, buildings on the reef etc. should be executed in a certain order to guarantee an efficient development.
- The accessibility of the south of Katwijk is a hot issue for the municipality. The implementation of a new road south of the village was recently ceased because of the sudden commotion about the borders of the Natura 2000 area. The dunes south of Katwijk are part of this European nature protection policy. Therefore it is hard to plan new development in this area. Still, the south of Katwijk needs a new connection to the town center and perhaps towards the boulevard and reef. So for planning this new connection, the political situation needs further elaboration.
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**APPENDIX I ANALYSIS SEASIDE RESORTS**

<table>
<thead>
<tr>
<th>Resort Name</th>
<th>Location</th>
<th>Distance from Sea</th>
<th>Beach Size</th>
<th>Facilities</th>
<th>Amenities</th>
<th>Development Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resort A</td>
<td>Area 1</td>
<td>5 km</td>
<td>500 m</td>
<td>Hotel, Spa</td>
<td>Pool</td>
<td>Under Construction</td>
</tr>
<tr>
<td>Resort B</td>
<td>Area 2</td>
<td>3 km</td>
<td>400 m</td>
<td>Restaurant</td>
<td>Gym</td>
<td>Completed</td>
</tr>
<tr>
<td>Resort C</td>
<td>Area 3</td>
<td>2 km</td>
<td>300 m</td>
<td>Bar, Shop</td>
<td>Sauna</td>
<td>Proposed</td>
</tr>
<tr>
<td>Resort D</td>
<td>Area 4</td>
<td>1.5 km</td>
<td>200 m</td>
<td>Picnic Area</td>
<td>Spa</td>
<td>Ready to Open</td>
</tr>
</tbody>
</table>

*Note: Distances and sizes are approximate.*
APPENDIX II ANALYSIS COASTAL METROPOLIS

Randstad

Santa Monica

Venice beach

Manhattan beach

Long beach

National wildlife refuge

The Hamptons

Jamaica Bay

Brighton beach

Villa Olympic

Miami Beach

Palm beach

Barcelona

Miami

Palm beach

Beach

NYC

Los Angeles

Randstad

Santa Monica

Venice beach

Manhattan beach

Long beach

National wildlife refuge

The Hamptons

Jamaica Bay

Brighton beach

Villa Olympic

Miami Beach

Palm beach

Barcelona

Miami

Palm beach

Beach

NYC

Los Angeles

Randstad

Santa Monica

Venice beach

Manhattan beach

Long beach

National wildlife refuge

The Hamptons

Jamaica Bay

Brighton beach

Villa Olympic

Miami Beach

Palm beach

Barcelona

Miami

Palm beach

Beach

NYC

Los Angeles
Comparison Coastlines
This figure schematically projects the coastlines of the four Coastal cities on the same scale. It shows:
- natural areas (green)
- urban areas (grey)
- touristic zones and attractive seafronts (red)
- ports and waterways
- city centers close to the coastline (black)

By putting them next to each other, the differences become clear. The variation between green and grey can be found in the Randstad and in Barcelona. In that aspect, Barcelona and the Randstad are quite comparable. However, the big difference is that Barcelona has its city center directly along the coast. Miami has a similar feature.

In the figure on the right, we can see a Randstad in Barcelona-style. This means that the variation of green and grey is preserved. But also, the city by the sea, Den Haag in this case, is promoted to Coastal center. Other seaside resorts are intensified and become attractive neighbor-resorts.

A typical feature of the NYC-coast is that it has a clear decrease in intensity of the urban area. The further you leave the city center behind, the more natural and quiet the coastal zone becomes. This has to do with the fact that Long Island is a ‘dead end’. So this feature is not comparable to the Randstad.

The coastline of Miami is perhaps the least comparable to the Randstad coastline. Miami features an almost continuous strip of hotels and other touristic facilities. Behind that lies a large urban area of mostly luxurious residence, separated by a laguna. When we project these features onto the Randstad, it would result in an almost continuous urban area with an uninterrupted touristic seafront, except for two protected dune reserves.
Flexibility
Soft – The essence of soft engineering measures and Building With Nature is the use of natural forces. The natural Dutch coastal system is dynamic, therefore the soft measures are flexible at a natural pace. However, only if the local natural processes are carefully studied, soft engineering is a sustainable protection (Philips, 2006). Soft coasts are resilient, which is of prime importance for any type of sea defense (Waterman, 1998). Also, beach nourishment is flexible in the sense that it can anticipate to the latest climate predictions. The amount of supplied sand can be adapted to the required safety level.
Hard – Constructions like seawalls, breakwaters and groynes are fixed and have no flexibility in the sense of responding to changed conditions. The hard construction itself can’t be moved while the sand in the coastal system is dynamic. In unpredictable dynamic systems, hard structures possibly even enhance erosion by the formation of rip currents (Philips, 2006). In case of damage due to an attack to the hard structures, they can be strengthened.

Natural Value
Soft – The principle of Building with Nature combines the use of biological, ecological and civil hydraulic knowledge. It includes using the values and forces present in nature and takes into account the potential natural values of the coastal zone. Therefore this method of coastal protection is desirable when it comes to enhancing natural values.
Hard – Although groynes and offshore breakwaters are place artificially, the beaches and dunes that accumulate as a result of the construction can be seen as natural landforms with natural processes. They have considerable value as natural habitat (Philips, 2006). In the case of seawalls there is little potential for the formation of natural landforms. They restrict the landward movement of the beach and prevent the hinterland from functioning as part of the dynamic coastal system. Narrow beaches, where seawalls are usually built, limit the possibility for the transport of sand and the built-up of dunes and valuable nature (Nordstrom, 2000).

Multi-functionality
Soft – Building with Nature is the primary element of an integrated multifunctional approach to coastal development (Waterman, 1998). The seaward extension of the coast of Delfland that is suggested in Plan Waterman is constructed by the principle of Building with Nature and contains recreational, residential, natural and economic functions (Waterman, 2008). The criterion of multi-functionality obviously applies to this plan. However, the natural, low density character of Building with Nature would be less compatible for the renewal of sea defense in vibrant coastal resorts.
Hard – Traditionally, hard sea defense solutions were designed from a safety and constructive point of view only, and had no multifunctional use. Recently, groynes and breakwaters are being used for the development of new harbor or marina areas. Also, they are used to change the orientation of the shoreline and beach. (Nordstrom, 2000). Next to recreational purposes, hard constructions can in some cases be combined with residential functions close to the shoreline. Examples are the seawall of Vlissingen and Super Levees in Tokyo.

Accessibility
Soft – Building with Nature contains a minimum of solid elements (Waterman, 1998). The construction of fixed structures, like roads and promenades, in a dynamic coastal area prohibits the free transport of sand. This means that the soft coastal zone has limited accessibility on a local scale. Since the erosion zone for seafronts in a situation of soft coastal protection is about 80 meters, it is undesirable to construct closer to the shoreline than 80 meters. The shoreline itself is not directly accessible.
Hard – The construction of hard elements in coastal protection has no constraint for a good connection between the coastal zone and its hinterland.

Time-efficiency
Soft – With the current basic beach nourishment, only 10% of the sand stays in the right place. Seaward expansion at once, instead of gradual suppletion, would be much more efficient (Biesboer, 2007). Still, the natural relocation of sand is a long term process. The natural development of a structure like the Sand Engine for example, with an eventual size of 75 hectares of new beach and dunes, will take about 10 years.
However, the need for coastal protection gradually increases and the Delta Committee and Randstad Agenda have long-term goals. Therefore, the gradual process of Building with Nature would suite the time-span of these plans.
Hard – Hard structures can be constructed in a relative short time. But the process of the build-up of sand takes longer, depending on the scale of the construction. Hard structures require a large initial investment and regular investments for maintenance (Philips, 2006). When the structure functions as expected, it can be an efficient long-term solution. However, if the structure doesn’t function properly or conditions change, it is difficult to modify (d’Angremond, 2001).
APPENDIX IV BREAKWATER BARRIER ALTERNATIVES

The concept of a breakwater barrier is a cross-bred between the two existing plans:
- Haakse Zeedijk
- Kunstrif Scheveningen

The Haakse Zeedijk is an extreme solution. It consists of 180 km of zand dykes about 25 km off the coast. Within the dykes there is much space for building, nature and tidal areas. This concept also proposes an airport within the dykes and large areas for windmill parks. The dyke encloses three smaller seas that are kept at a constant level with the help of sluices.

The main advantage of this proposal is that it literally fortifies the mainland and protects it from storm surges as well as sea level rise. Also this solution creates a lot of new land that can be used for all kinds of functions. By constructing the dyke at a distance of 25 kilometers of the coast, the view from the mainland at sea won’t be damaged.

But this proposal has many disadvantages too. Firstly, the fact that the dyke encloses the mainland makes the seaside resort lose their seaside character. The dynamic coastal system with salt water and tide will disappear. With a height of 9 meter above sea level, the dyke will be a true fortification and will cost a lot of sand, since it is constructed at a large depth. Another disadvantage is the fact that the new land is so remote and separated from the mainland, that there can hardly be any relation between the new and the existing. A ride of 25 kilometers to visit the nearest city is not desirable in a network city like the Randstad.

Currently the option of an artificial reef along the coast of Scheveningen is researched by the authorities. This technique is considered an addition to the policy of sand suppletion. The basic principle of a reef at the sea bottom is to reduce the energy of storm surge waves and protect the coast from sudden erosion. It will be constructed 1500 meters from the coast, at a depth of 10 meters. It will be made of a combination of sand, geo-textile and rocks.

The advantage of this plan is that the seaside resort won’t suffer any visual damage. The intervention will be entirely below sea level, so beach recreationists will have the same day at the beach as ever. In the meantime, the reef will cause interesting additional recreational possibilities like surfing, fishing and diving.

A disadvantage of the artificial reef is the fact that it has a large impact on the coastal morphology. Similar to the Breakwater Barrier, the artificial reef will influence the sediment transport and cause erosion of the coast of Wassenaar.
For the development of the breakwater barrier, several alternatives were drawn. The first designs, shown on this page, are based on the concept of a barrier coast. The advantage of a barrier coast is the fact that the longshore transport of sediment is not disturbed.

- central access
- urban development in the dunes opposite of the barrier
- narrow barrier

- broad barrier, more space for development

- central access and south acces
- curving coastline, with extra space for development and a marina

- Katwijk bay
- central and south access
- no continuous laguna
Creating an entire barrier coast is far from efficient, since only the weak links need additional protection. Another disadvantage is the fact that the laguna between the mainland and the new barrier reef will no longer have a tidal range and will become drabby and sensitive to blue algae.

The alternative of a bay-like barrier (see below) was elaborated further. But eventually this alternative was simplified into the Breakwater Barrier, which has more advantages.
APPENDIX V NEW CONNECTIONS

 Alternatives N11 trace (source: Beslisnotitie Rijnlandroute)
As referred to in chapter 2, the Province of South-Holland and several municipalities have been working on the improvement of the provincial infrastructure in the region of Leiden. In east-west direction this is Alphen aan de Rijn-Leiden-Katwijk, and in north-south direction this is A44-N206. The proposal of ‘Hollandse Kustboulevard’ is to let the A44 and N206 connect fluently to form a continuous coastal route. But this would mean that a large part of the open agricultural landscape north of Rijnsburg will be damaged. The north-south connection isn’t in fact a problematic issue in the area. Therefore the Regional Plan of this project only proposes east-west interventions. The province has several other options, see options A-F. The environmental impact of some of these alternatives, especially C and B are smaller that the Kustboulevard-plan, since they go through the built area. But consequently, their noise and nuisance impact is much higher. The complete comparison can be found in the Report ‘Verkenning Rijnlandroute’ by the Province of South-Holland. For the Structure Plan of this project, a combination has been chosen of the alternatives A and E. These connections have the largest capacity and can be wrapped along the urban area to diminish the environmental impact. Another important new east-west connection is the lightrail, part of the Rijngouwelijn. This track runs from Gouda to the coast. Also here, the Province of South-Holland is still investigating different options. According to the research, alternative 1 is the does the least damage to the environment. Alternative 3 is the fastest and runs parallel to the N206. For this project this alternative 1 is chosen, because it crosses the developing areas of New Valkenburg and the zone between Katwijk and Noordwijk. For the center of Katwijk, the track of alternative 2 is chosen. This gives access to the southern part of Katwijk and avoids the boulevard of Katwijk. A lightrail at the boulevard would make the boulevard lose its traditional character.
Hos = significant wave height = 8.7 m (source: Ruimtelijke verkenning Katwijk DHV)
Rekenpeil stormvloed Katwijk = 5.85 m (source: TAW basisrapport Zandige Kust)
Rekenwaarde Korrel diameter D raai 8700 Katwijk = 230 μm
(source: Ruimtelijke verkenning Katwijk DHV)

Valsnelheid w van duinzand in zeeewater = 0.0254 m/s
via: 10log(1/w) = 0.476 * (10logD)^2 + 2.180 * 10logD + 3226

Low safety level 1/20 (medium storm surge)
Storm surge level = 3.25 m
Hos = 6.5 m

y = 4.8 m
x = 211 m

Middle safety level 1/100 (high storm surge)
Storm surge level = 3.7 m
Hos = 6.9 m

y = 5.2 m
x = 228 m

High safety level 1/10000 (extreme storm surge)
Storm surge level = 5.15 m
Hos = 8.7 m

y = 6.5 m
x = 306 m

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<th>Variant</th>
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<th>Length behind crest (m)</th>
<th>surface section (m²)</th>
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frequencies of exceeding (source: Getijtafels 2009, Rijkswaterstaat)
## APPENDIX VII CALCULATION OF THE COSTS AND BENEFITS

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<th>beach hotel/congress</th>
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