Case Study: Katwijk aan Zee

Performance analysis of a multifunctional flood defense

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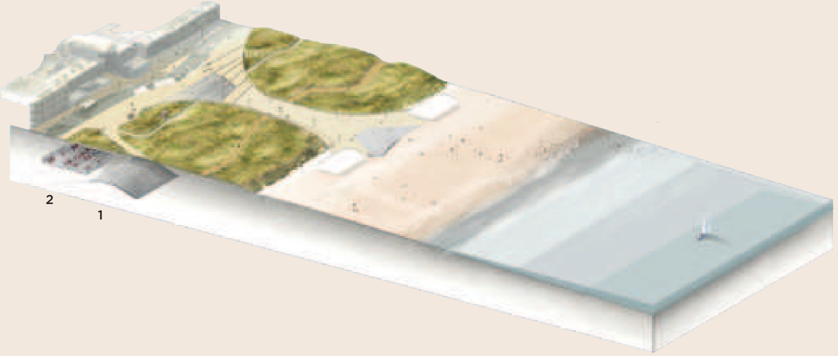
Figure 1 (below). The first plan for an integral flood defense in Katwijk, including a co-located sea dike (#1) and parking garage (#2) (Image courtesy OKRA Landschaps-architecten)

Figure 2 (below below). The second plan comprising a co-located parking garage, flood wall and restaurant (CURNET, Multi-waterwerken 2011).



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CASE STUDY: KATWIJK AAN ZEE

PERFORMANCE ANALYSIS OF A MULTIFUNCTIONAL FLOOD DEFENSE

Katwijk is a small coastal town located at the old mouth of the River Rhine and along the North Sea. The national flood safety inspection of the coastal area demonstrated the need for the construction of a new sea dike to protect some 4000 people living in the city centre. The dune-covered coastline near the town is a tourist area that lacks sufficient car parking. To make best use of space and funds, the municipality and coastal authorities decided to combine functions and use the dune-area for both flood protection and parking. As this was a first-time project, it was yet unknown how interdepencies of functions would affect the performance of this multifunctional flood defense. In this research project we customized an existing performance analysis method to look into this issue.

Multifunctional flood defenses are a promising solution for dealing with the conflicts of flood protection and urban development as well as increasing the cost-effectiveness of interventions to reinforce the defenses. The environment in which a multifunctional flood defense system operates is dynamic, constantly evolving, and not fully predictable. Maintaining the desired performance of multifunctional flood defenses under changing circumstances, both expected and unexpected, requires a clear understanding of the interactions between the components of the system, as well as the interactions between the system and its environment. These dynamic interactions can have both positive and negative impacts; these need to be taken into account in order to increase the system's flexibility and ability to handle future changes.

Combining flood protection with other urban functions as for example a parking garage and/or restauarnt, links the performance of each of the elements, which can create functional interdependencies. Additionally, once the functions are combined, they become part of a broader socio-technical context. The functioning of the total system now depends not only on its technical performance, but also on the humans who operate, inspect, maintain and use the system. To analyze the performance of multifunctional flood defenses, it is necessary to capture the complexity of the relationship between human actions, technical functions, and the environment.

Anvarifar et al. (2017) propose a method for performance analysis of multifunctional flood defenses, which can identify how the interdependencies associated with the multifunctional use of flood defenses, can strengthen or weaken the system when faced with environmental changes. This proposed method is a customized FRAM (Functional Resonance Analysis Method) approach and consists of five steps, which describe and visualize the functions of a multifunctional flood system and their interdependencies:

Step 1. Identifying and describing the functions.
Step 2. Generating the scenario
Step 3. Characterising the performance variability
Step 4. Identifying the potential impacts
Step 5. Synthesising and applying the results

We applied this method in the case study of the multifunctional flood defense in Katwijk, where we compared four alternative designs based on two initial proposals. The first plan (see Figure 1) proposed to the city council involved constructing a parking garage along with a new sea dike. The parking garage and the sea dike would ultimately be covered by sand, so this alternative was called 'dike in dune' Two versions of this design were developed (A1 and A2, explained below).

A later plan proposed constructing a parking garage on the landside of a flood sea wall and a restaurant on the water-side of a flood wall (see Figure 2). This combination of the three functions in close proximity provided the basis for two new versions of the design (B1 and B2, explained below). The different versions represent different levels of dependency between the functions of a multifunctional flood defense.

Description of cases A1 and A2
In both cases, a parking garage is built on the landside of the dike (Figure 3). These two alternatives are aimed at investigating how different degrees of geographical dependency between elements of a multifunctional flood defense affect the flood protection function. Both A1 and A2 represent the same types of functions, but with different levels of geographical dependency between the two structures.

Description of cases B1 and B2
In these two cases, the multifunctional flood defense comprises a parking garage, a floodwall and a restaurant. In both cases, the restaurant is on the water-side and the parking garage on the land side of flood wall (Figure 4). The flood defense of B1 and B2 is not a dike, but a floodwall (a concrete structure). In case B1, the parking garage nor the restaurant contribute to the flood protection. B2, on the other hand, has three tightly connected structures, with the restaurant and parking garage sharing a wall with the floodwall. The parking garage supports the floodwall and holds it in place. The restaurant is flood proof and expected to resist high water levels. The cases B1 and B2 are aimed at investigating how a secondary function may impact the flood protection function.

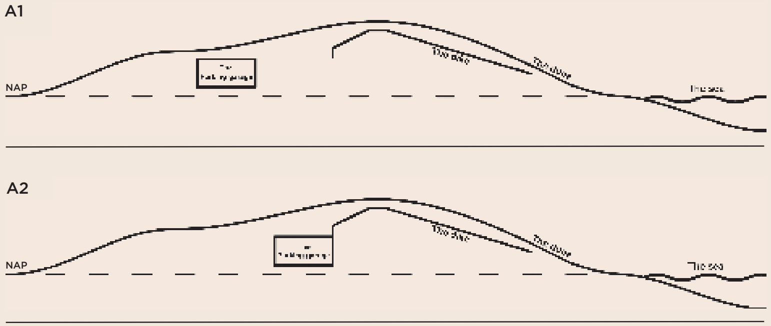

Figure 3. The cross sections of cases A1 and A2, in which the parking garage is located in the land-side of the dike.

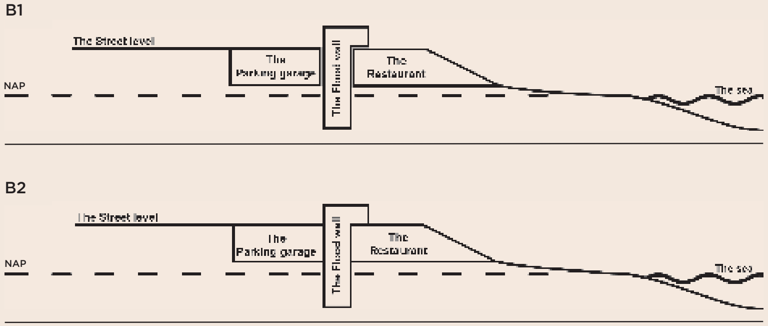

Figure 4. The cross sections of cases B1 and B2, in which the parking garage is located on the land-side of the flood wall and the restaurant is on the water side. The difference between the two alternatives is in the way the parking garage and restaurant are attached to the floodwall.

Flood protection levels

Applying the five-step method in cases A1 and A2 shows that the actual levels of safety provided in A2 may even be higher than A1. Contrary to the common belief that the close proximity between the two functions of a multifunctional flood defense can reduce the level of flood protection, we found that constructing the secondary function and the flood defense as two independent structures close to each other (as in A1) can actually result in a lower level of safety compared to constructing them as fully connected structures (as in A2).

Applying the proposed method in cases B1 and B2 shows that if the secondary functions of a multifunctional flood defense are constructed in such a way to contribute to flood protection (as in B2), it will actually be easier to reinforce the flood wall than when the positive contributions of the secondary functions are ignored (as in B1). Further elaboration on the effects of multifunctionality on flood safety in the case of Katwijk, can be found in Anvarifar et al. (2017).

Conclusions

Based on the case study, we can conclude that combining the flood protection function and one or more secondary functions increases the potential interdependencies. These dependencies increase the complexity of the design and the number of issues that need to be addressed when developing the system. It does, however, appear that these dependencies can actually improve the desired performance of the system. Using the proposed 5-step method make it possible to track both the potential dependencies and their positive or negative impacts. When negative impacts are identified, this is a signal that something needs to be done to prevent these potential dependencies or to prevent the dependencies having these impacts. On the other hand, if the potential interdependencies have positive impacts, the possibility of improving the performance of the flood protection function should be seized.

The proposed method seems a promising way to identify the threats and opportunities associated with different design alternatives of multifunctional flood defenses. Using it during the conceptual design phase provides a qualitative tool for the developers of multifunctional flood defenses. It offers them a broader view, analysis, and visualization of possible internal and external changes to the system, as well as human, technical and environmental interactions. Thanks to a unified terminology, it is a convenient framework for developers of multifunctional flood defenses from different domains. Additionally, it can help to identify ways in which the system can be made more flexible, so that it can properly respond to unexpected events, whether caused by human interventions or environmental changes.

This text is based the journal article: Anvarifar F., Voorendt, M., Zevenbergen C., Thissen W., (2017) 'An application of the Functional Resonance Analysis Method (FRAM) to risk analysis of multifunctional flood defences in the Netherlands' Journal of Reliability Engineering and System Safety. 158 (2017) 130-141.

Figure 5. Entrance of parking garage in dune in Katwijk (Photo courtesy Mark Voorendt).