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Figure 1 (below). Dike along Western Scheldt at Ellewoutsdijk with green foreshore accomodating wave attenuating and recreational functions (Image courtesy Rijkswaterstaat beeldbank, Joop van Houdt).

Figure 2 (page 186). Multifunctional dike-in-boulevard at Scheveningen under construction in 2014 (Image courtesy Rijkswaterstaat beeldbank, Harry van Reeken).

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A MULTIFUNCTIONAL ANSWER TO MULTIPLE QUESTIONS

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When the MFFD program took off in 2012, its general goal was to gain a deeper understanding of multifunctional flood defenses, in order to provide a solid foundation for their design, assessment and management. As a point of departure, it assumed that a new generation of explicitly multifunctional flood defenses was the product of a need to accommodate competing spatial claims, and, perhaps, contribute financial savings by combining functions. Flagship projects like the Scheveningen Boulevard and Katwijk's 'hybrid' parking garage complement an older generation of multifunctional flood defenses, the traditional example being dikes with sheep grazing or a road on top. The contemporary multifunctional flood defense was viewed as a complex but desirable phenomenon: the answer to multiple needs, and therefore best studied from a multidisciplinary perspective.

What are the lessons learned regarding the design, assessment and management of multifunctional flood defenses in 2017, based on this multidisciplinary research? And to what extent does the MFFD program's experience confirm the known pros and cons associated with such multidisciplinary research efforts? Interdisciplinary research in all forms (ranging from non-committal knowledge-sharing to mandatory integration of parallel research trajectories) is known for its challenges: in particular, paradigmatic confusion between the natural and the social sciences, and the lack of possibilities for academic publication and prestige (De Boer et al., 2006). On the other hand, benefits are found in terms of innovation, greater applicability and societal acclaim.

With its ambitious point of departure - a multidisciplinary approach to a complex subject with a broad scope - the MFFD-program started as an academic experiment. It was designed in such away, that disciplinary insights could be integrated into shared case studies that addressed the practical needs of users (this model is known as 'goal integration'). The program's findings were grouped in three sections for this book, each relating to one of the program's original goals: risk assessment (risk, risk assessment and safety knowledge), design and planning, and governance & knowledge transfer.

In the first section, steps were taken towards *risk assessment* of multifunctional flood defenses, compared to their monofunctional counterparts. Chen studied the influence of waves on the safety of buildings on and within flood defenses (based on experiments in a hydraulic lab), while Voorendt developed a generic method to evaluate the reliability of multifunctional flood defenses. Both provide stepping-stones towards reliability analysis. Roscoe also investigated the reliability of flood defenses by applying Bayesian network techniques, which have the advantage of clear visual in graphics to communicate with users.

Voorendt also demonstrated that an integral design of a parking garage and a flood defense is in fact cheaper than two separate designs; however, the true bottleneck is that an integral design also requires integral maintenance. Aguilar Lopez showed that embedded structures have a significant effect on safety during storm events, both positive and negative. Hölscher focused on selected risks associated with wind turbines on dikes. Dupuits investigated the multiple-lines-of-defense strategy from an economic point of view, and developed new methods to optimize the combination of defenses and functions. Nonetheless, an overall perspective on the safety of multifunctional flood defenses remains beyond the scope of this book: in practice, multifunctionality has been realized in an infinite number of combinations, and is therefore hard to model. This should, however, not be considered an impediment to the implementation of multifunctional flood defenses.

In the *planning & design* section, virtually all contributions focus on the decision-making process in which a flood risk reduction strategy takes shape: how different aspects of this process structure the outcome, like boundary conditions, tools, steps and knowledge regarding future outcomes. Researchers from different academic backgrounds reflected different understandings of 'planning' and 'design'. For example, Voorendt emphasized the technical components of design, while Raaphorst focused on the visual. Both stress the collective action of design work, at least during the exploratory phases of the decision-making process. Design calculations should still be conducted by a specialist, although it should be noted that there is a difference between just doing calculations and making a design: in a design, all perspectives need to be integrated. Additionally, Van Loon made a plea to include salt marshes along the coast in the design of flood risk reduction alternatives. Contributions dealing with planning also reflected different conceptualizations of the same term. Brand considered spatial planning as a driver for multifunctional flood defenses, using the adaptive planning approach. Van Veelen and Islam, on the other hand, addressed temporal aspects of planning, using simulations to study the long-term workings of alternatives, to reduce the probability of possible future lock-ins.

The section on *governance & knowledge transfer* emphasizes the many obstacles different actors face when trying to collaborate, as well as the importance of perceptions (frames), and awareness of these, as a way to smooth decision-making regarding multifunctional flood defenses (Heems, Matos Castano). Hogendoorn and Matos Castaño argue that MFFDs are a means to address diverse interests, and also a way to overcome restraints in the decision-making process regarding flood safety. Tromp provides links to Brand and Van Veelen's contributions in the previous section, addressing the issue of coupling flood risk

management and spatial planning, and the opportunities this offers for synchronizing spatial developments or interventions for flood risk reduction. Studying knowledge transfer, Tromp, Kothuis and Heems emphasize the importance of trust between actors. Institutions have a direct effect on building and sharing of knowledge (Hogendoorn, Tromp).

In addition to a variety of single case studies, the program included two program cases: Rotterdam Roof Park (Dakpark) and a future flood defense strategy for the Houston Galveston Bay Region in Texas. Rotterdam Roof Park had the advantage of being a local, completed project, where the design and decision-making process could be reconstructed and analyzed. The Texas case dealt with international knowledge transfer on a regional-scale project, which is still in the planning stages; the advantage of this was that the decision-making and design process for multifunctional flood defenses could be studied as it evolved. The Roof Park is a construction where flood safety, recreation (park) and shopping (mall) are combined in the same site; this was studied using visual, urban design, structural and frames analysis. This confirmed the role of several interdependent actors, which resulted in a construction where the shopping mall and the flood defense were ultimately structurally separated for management reasons.

For the Houston Galveston Bay Region, contributions analyzed the role of political values in decision making, considered stakeholder-inclusive design and how governance and planning affect flood defenses and spatial adaptation, and investigated how wetlands can contribute in the design of a future strategy. Dupuits made a simplified analysis of the complex region's flood risk issues; the other authors analyzed boundary conditions for the design of a future strategy. Strikingly, while Van Loon concludes that a strategy based on spatial planning could be rewarding given the large amount of pristine wetlands, Brand concludes that the region lacks the proper tools and the political support for such an approach. The Texas case demonstrates not only how challenging the design of a flood defense strategy is, but also how conflicting interests and lack of instruments can obstruct solutions that would otherwise be feasible.

The experience of the MFFD project, as a multidisciplinary program, confirms some of the obstacles and benefits associated with multidisciplinary research. For example, it was a challenge to find a shared definition for multifunctional flood defense as a concept, as Kothuis demonstrated in her contribution on knowledge transfer. On the other hand, Van Veelen, Voorendt and Van der Zwet managed to create a shared classification of multifunctional flood defenses, based on the degree to which functions are integrated. The example of the Rotterdam Roofpark was classified at the lowest level of 'shared use'. In a separate contribution using a 'single' structural perspective, Voorendt even concludes that it would have been desirable to actually integrate the shopping mall with the flood defense. Management reasons led to the separation of functions; it did not benefit the structure's integrity, nor did it deliver the most efficient design in terms of materials and resources. Another reward of multidisciplinary research is when different approaches confirm the same findings. For example, the role-play between stakeholders in the design of the Roofpark was confirmed by Raaphorst's visual rhetoric analysis.

Still, the number of multidisciplinary peer-reviewed studies published in 2017 is disappointingly small, which demonstrates the challenging nature of multidisciplinary research as Kothuis discusses in connection to the Program Cases. For future research efforts, we recommend an independent management budget, shared workspace, and more time for experienced researchers to integrate their findings at the end of the programs' life. PhD candidates can then broaden their perspective by working with users and exchanging ideas about their individual projects on a voluntary basis with other researchers. Multidisciplinary programs demand more in terms of management than their single-discipline counterparts, in the first case, just to establish trust between participants from different backgrounds. Therefore, a key to successful multidisciplinary research is that researchers be allocated independent time-budgets to organize and integrate their work.

To conclude, the MFFD-program yielded practical recommendations for the design of multifunctional flood defenses and –strategies from a variety of disciplines. Voorendt suggests starting with an early collective design round, after which a specialist can make detailed calculations Additionally, Tromp recommends that water authorities should share their long-term spatial plans in order to allow other interested parties to synchronize their plans. This will make it easier for other functions to 'hitch a ride' with long-term flood safety plans. Van Veelen also warns that the possibility of shifting from one alternative to another in urban waterfronts is limited (for example, moving from incremental adaptation of existing non-flood retaining structures to district-wide protection in the form of flood defenses). Once a path of investment has been chosen it is not easy to switch to another.

As befits the complex nature of multifunctional flood defenses, many questions remain to be studied. Is the multifunctional flood defense a 'no-regrets' approach in all contexts? Are there long-term management risks that need to be considered? What is the best way to organize management and maintenance, and could an owners' association approach (as used in apartment buildings) be an efficient solution? Can implementing multifunctional flood defenses contributed to overcoming decision-making obstacles? For example, by reducing resistance towards flood defenses in areas lacking a long-standing flood safety tradition, and by building alliances that can construct and manage these? And who is best equipped to communicate with policy makers about multifunctional flood defenses? For example, hydraulic experts who focus on the structure itself, or specialists in public administration who focus on the process?

One thing, however, seems certain: multifunctional flood defenses serve a real demand, both in the Netherlands and abroad. We have clearly seen this in Texas, where the rhetoric of multifunctionality and co-benefits has entered the popular debate. With the anticipated rise in sea levels and the increased concentration of population in flood prone cities, we expect to see many more multifunctional flood defenses in the future.