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Figure 1 (below). Vlissingen boulevard (Photo courtesy: Baukje Kothuis).

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CONCEPTUALIZING FLEXIBILITY FOR MULTIFUNCTIONAL FLOOD DEFENSES

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Tentative dissertation title:
'Towards flexibility in the design and management of multifunctional flood defences.'

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The very existence of the Netherlands and its prosperity is tightly linked to the provision of sufficient and reliable flood protection. Flood risk can change, as it is influenced by continually changing environmental and socio-economic factors. In such a dynamic situation, maintaining sufficient safety requires continuous investment in maintenance and reinforcement of the flood defenses. Often, flood defense reinforcement requires more space, which is scarce in densely populated urban areas. While the competing needs of housing, commerce, transportation, and agriculture have to fit in a relatively small surface area in the Netherlands, the safety of the living environment and the quality of the landscape have to be maintained as well. One way that has been suggested to deal with the conflict between flood protection and urbanization is by combining activities in the available space. This can be achieved by integrating urban functions into the flood defenses; these are referred to as multifunctional flood defenses.

Multifunctional flood defenses are long-lived, capital intensive and generally irreversible interventions. The performance requirements for these structures can vary considerably due to socio-economic, technological, and environmental developments. Since choices made today will influence those of tomorrow, the extreme difficulty of adjusting multifunctional flood defenses can lead to poor system performance with unnecessary capital and operational costs, or the need for expensive system upgrades to meet future demands. The changes that might impact the performance of multifunctional flood defenses in the future are highly uncertain. One of the best ways of enhancing a system's capability of handling uncertain future conditions is by increasing its flexibility. The question is thus how we can increase the flexibility of multifunctional flood defenses.

Flexibility is agreed to be a capability to change or be changed rather than being static in time, but there is no consensus about what characterizes flexibility and how to achieve and evaluate it. The proposed working definition of flexibility is as follows:

> *Flexibility is a system attribute that enables responding to changing conditions, in order to reduce the negative consequences of uncertainty and change, and exploit the positive consequences, in an efficient, timely and cost-effective way.*

The use of flexibility as an approach for coping with extreme climatic events is nothing new. In spite of the popularity of the concept, there is no consensus across the literature about what characterizes flexibility and how to achieve and evaluate it. Anvarifar et al. (2016) developed a framework aimed at enhancing the consistency and clarity in discussing, identifying and evaluating flexibility for multifunctional flood defenses. The framework consists of four self-consistent and step-wise questions. To help answering each of these four questions, eight characteristic features are distilled from literature: *change, uncertainty, goal, capabilities, temporal, mode of response, types*, and *enablers*. Each of these characteristic features is associated with the four questions of the framework:

Q1. *Why is flexibility needed?*
This question establishes the motivation for consideration of flexibility. This can be done by identifying the type of *change* (internal or external to the system) and *uncertainty* (e.g., sources, levels) that is chosen to be handled.

Q2. *What is it that flexibility is required for?*
This question seeks to describe the competences of flexibility to be specified as the *goal* of flexibility consideration (to handle the downsides or upsides of uncertainty) and the *capabilities* of flexibility to achieve its goal (via time, performance, cost penalties prevented).

Q3. *What are the dimensions of flexibility?*
This question indicates the extent to which flexibility can be achieved, from a *temporal* point of view (strategic, tactical, or operational) and the *mode of response* (proactive or reactive).

Q4. *What needs to change or be adapted?*
This question discusses the potential ways of achieving flexibility. In this research, flexibility *types* (or managerial flexibility) indicate the managerial actions and decisions that should be taken to consider and use flexibility while flexibility *enablers* (or design flexibility) refer to the sources of flexibility (or where flexibility is) embedded in the system's technical design.

The functionality and potential of this framework is explored in an illustrative case study in Vlissingen, where a series of buildings have been constructed on top of a sea dike (see pp. 86-87). Full explanation of the framework can be found in Anvarifar et al.(2016).