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ECONOMICALLY EFFICIENT FLOOD PROTECTION LEVELS

EFFECTS OF SYSTEM INTERDEPENDENCIES

In the Netherlands, economic cost-benefit analysis plays an important role when deciding on safety levels for flood defences. The cost of increasing the safety level is weighed against the reduction in flood risk (the benefit). The optimal level occurs where the sum of the cost and benefits is at its minimum; this is shown graphically in Figure 2. However, when conditions change over time, due to for example economic growth, the optimal safety levels change as well. This is illustrated in Figure 3. An in-depth description of the current use of cost-benefit analyses in the Netherlands can be found in Kind (2014).

Specifically, economic cost-benefit analyses can offer support in decisions regarding to where, when and how much to invest. Where to invest can be identified by selecting locations where benefits outweigh the costs. For these locations, deciding on when and how much to invest can be supported by results such as shown in Figure 4. Additionally, the results of a cost-benefit analysis can be used to clarify the service levels presented by the government to the public.

The benefit part in an economic cost-benefit analysis is the reduction in flood risk. The flood risk associated with a flood defense is often defined as the flood probability times the flood damage. When flood defences are analyzed separately, each flood defense can have its own, isolated cost-benefit analysis. However, once flood defences are viewed as dependent on each other, for example if they form a system with multiple lines of flood defences, the interdependencies between flood defences also needs to be taken into account in the cost-benefit analysis.

In my research, the consequences of interdependencies has been expressed in terms of changes in the hydraulic loads. In order to quantify this, the various hydraulic loads need to be modeled, as well as potential breaches and potential flood damage resulting from such a breach. As the behavior of a river and its hydraulic loads are important when estimating flood probability, as well as possible damages, including interdependencies in the cost-benefit analysis improves the flood risk part of the cost-benefit analysis.

In order to quantify the flood risk associated with a flood defense, the interdependencies need to be incorporated in probability...
distributions of hydraulic loads. A straightforward method of moving from deterministic hydrodynamic simulations to probability distributions of hydraulic loads is by using a Monte Carlo simulation, for example as implemented by De Bruin et al. (2014). If we take the example in Figure 1, with a constant damage estimate for each flood defense, a flood damage curve with and without interdependencies looks like the graph in Figure 4. This indicates that the interdependencies in Figure 1 decrease the probability of multiple breaches during the same extreme discharge event.

Impact of including interdependencies on a cost-benefit analysis

As previously described, an economic cost-benefit analysis balances risk costs and investment costs. Therefore, a change in flood risk can lead to different economically optimal investments. With interdependencies, the total number of relevant system configurations can become large. For example, suppose the flood defenses in Figure 1 can have five possible heights per defense. Without interdependencies, a total of 5^4=625 combinations are possible. With interdependencies, the number of combinations rises to 5^4*4^25. This number increases further if the timing of investments is included. For example, in case of a time span of 100 years with yearly increments, the number of combinations rises to 2030 and 62,510, respectively. The challenge, therefore, is not only to find the optimal solution among many different options, but also to calculate these different options efficiently, in order to reduce computation time.

When interdependencies are quantified and incorporated in a cost-benefit analysis, the results can be compared with those of a simpler cost-benefit analysis without interdependencies. Though the results can differ significantly, the differences are heavily dependent on the specific characteristics of each case. Examples of such case-specific characteristics are the distribution of flood damages over the flood prone areas, or the ratio between risk and investment costs. Practically, results of a cost-benefit analysis with interdependencies can lead to different sets of optimal safety levels, as well as to different (“more efficient”) investment schemes for the flood defenses. Furthermore, the method is not limited to traditional flood defenses such as earthen levees; for example, emergency storage areas or storm surge barriers can also be included.

Figure 5. Example of multiple lines of defense - Houtribdijk in Lake IJssel, The Netherlands (Photo courtesy: Jesse Allen, NASA images)