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Guy Dupuits

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 defenses. 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.

In Figure 3, the optimal safety level is indicated by a horizontal line at a certain level. This level is determined by finding the point where the cost-benefit curve intersects the vertical axis. The optimal safety level is then the level at which the cost-benefit ratio is maximized, indicating the point at which the benefits of increased safety outweigh the costs.

In Figure 4, the cost-benefit curves for different safety levels are plotted, with the cost of increasing the safety level on the y-axis and the reduction in flood risk on the x-axis. The optimal safety level is indicated by the point where the curve is at its lowest, indicating the level at which the benefits of increased safety outweigh the costs.

In Figure 5, the interdependencies between flood defense systems are highlighted. The interdependencies are illustrated by the horizontal lines connecting the different points on the graph, indicating the connections between the systems. The interdependencies are important to consider when assessing the optimal safety level, as they can affect the overall cost-benefit ratio.

In conclusion, economic cost-benefit analysis is a powerful tool for determining the optimal safety level for flood defenses. By considering the costs and benefits of increased safety, we can find the level at which the benefits outweigh the costs, indicating the optimal safety level. Interdependencies between systems must also be considered when assessing the optimal safety level, as they can affect the overall cost-benefit ratio.
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 Bruyn 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 $5^4 \times 26$. 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 2000 and 62,500, 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 - Hoornbolte in Lake IJssel, The Netherlands (Photo courtesy: Jesse Allen, NASA images)