Delft University of Technology

SYSTEM RISK ETN

Deltares
Enabling Delta Life

Alessio Ciullo[1,2], Jan Kwakkel[2], Karin De Bruijn[1], Frans Klijn[1]
1 Deltares, Department of Flood Risk Management, 2 Delft University of Technology, Department of Technology, Policy and Management

Developing large-scale flood risk management plans under uncertainties about hydraulic system behaviour

Motivation and scope

Most large-scale river systems around the world are protected by dikes. It is well known that the presence of such structural defenses alter the hydrological regime: dike heightening at upstream locations exacerbates high water levels downstream and, on the contrary, dike failures upstream produce an unloading effect on downstream dikes. The aim of this work is to investigate the effect of hydraulic system behaviour, i.e. the change in hydraulic loads at one location as a consequence of the state of the dike system at other locations (Van Mierlo et al., 2007) on optimizing dike heights. This implies:

- A more uncertain system: breaching locations, breach growth dynamic;
- A more complex decision-making process: deciding on dike heights at one location requires accounting for interests elsewhere (as in the EU Floods Directive);

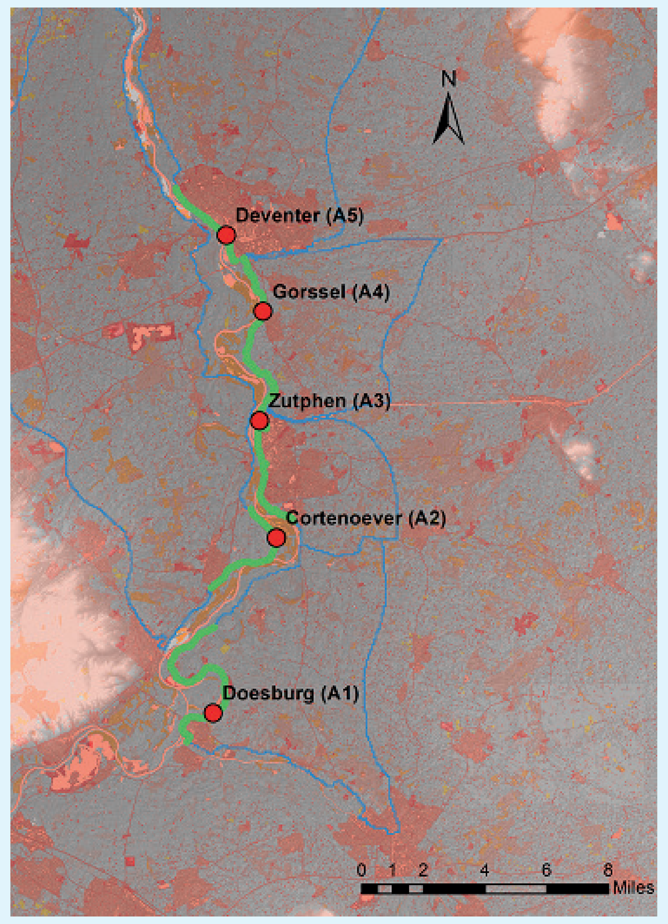
Method

The analysis is carried out applying the Many-Objective Robust Decision Making (Kasprzyk et al., 2013):

- Generate alternatives using Many-Objective Evolutionary Algorithms under a reference scenario;
- Stress-test alternatives under uncertainty analyze robustness and visualize trade-offs;

The decision problem, case study and simulation model

$$I = (c + bu)e^{-\lambda(W+u)}, \quad EAD_d = \sum_{t=1}^{T} \frac{\int_{H_{min}}^{H_{max}} p(H)L(u,H)dH}{(1+r)^t} \rightarrow \min I + EAD_d \;\forall \text{ location}$$



PRE-PROCESSING:
1. Calibration of the Muskingum parameters;
2. Adjustment of the fragility curves to the target failure probability (e.g. 1/1250);

EVENTS GENERATION:
1. Sampling of upstream high discharge events and generation of a flood wave;
2. Sampling of the embankment strength, final breach width and breach growth model;
3. Sampling of the embankment height increase;

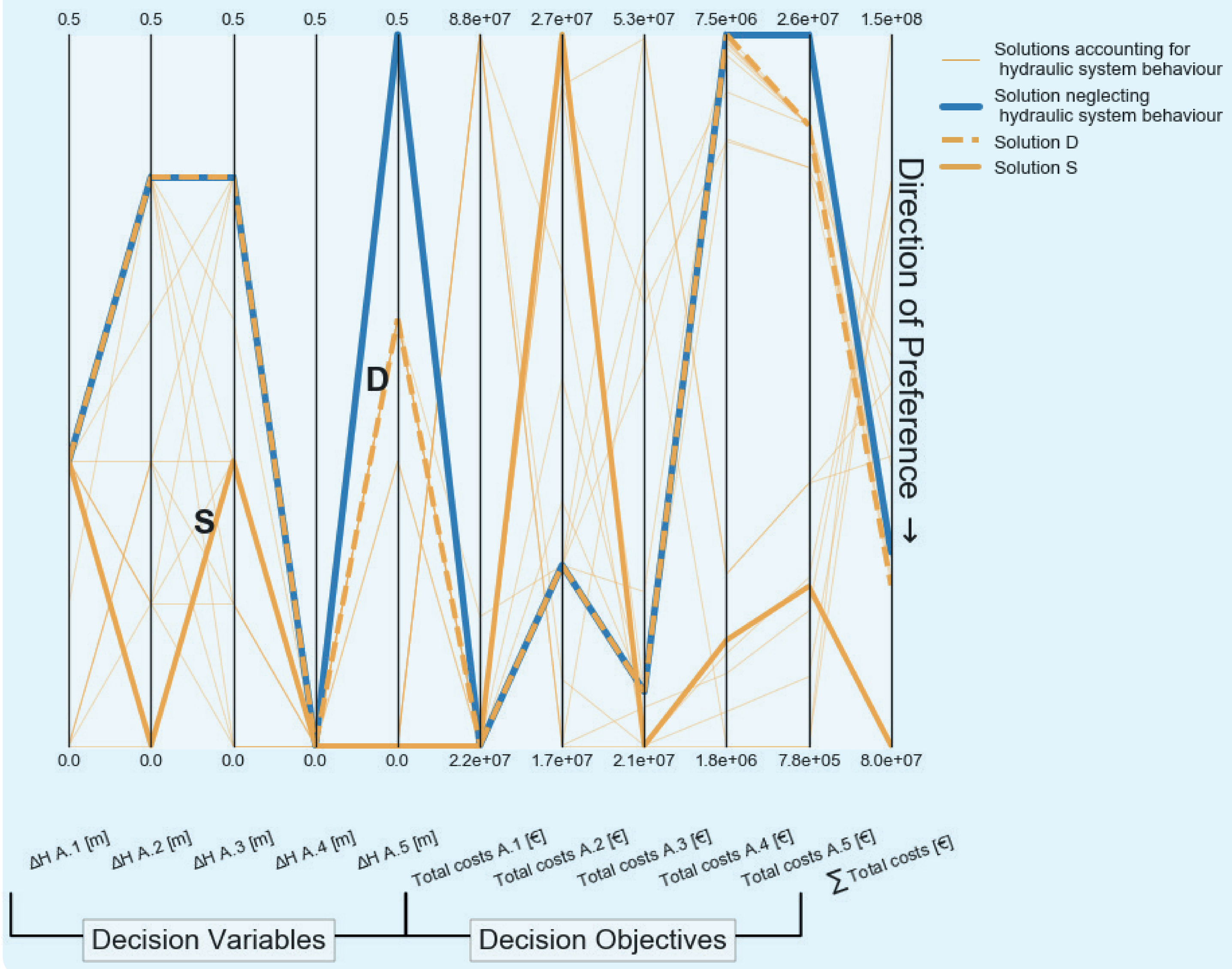
EVENTS SIMULATION:
Flood wave routing of each event from one location to the other following a Muskingum scheme;
1. Discharges are translated into water levels by using rating curves;
2. Embankment failure is evaluated by comparing water levels with critical water levels;
3. In case of failure, discharge through the polder is estimated through a weir formula;
4. When hydrodynamic system behavior is considered, the discharge flowing into the polder is subtracted from the main channel;

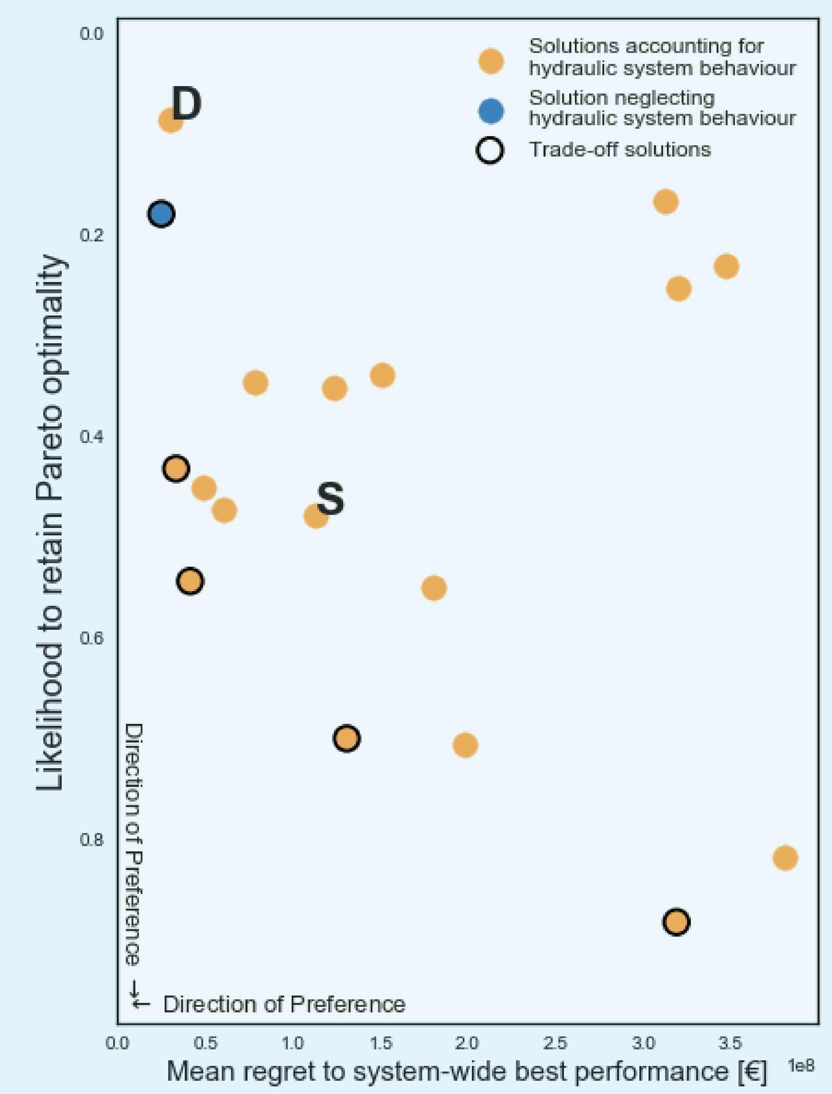
DAMAGE ESTIMATION:
Losses are estimated from VNK damage scenarios relative to the maximum simulated water level at each location for each event;

Cost function; Probability distribution function; → Expected Annual Damage, Investment Costs

Uncertainty	Range	Reference scenario
Failure	Fragility curve	0.5
Max width B	20 - 300 m	175 m
Time to B	1, 3, 6 [days]	3

Results





Conclusions

- Accounting for hydraulic system behaviour reveals a wider set of solutions. The current approach leads to decision myopia;
- The current approach leads to a solution which is Pareto dominated, mainly due to risk overestimation downstream, and sub-optimal from a system view-point;
- Under uncertainty, the current approach is very robust with respect to system-wide performances but scores poorly in retaining Pareto optimality. It is only one of a wider set of trade-off solutions;

Main references

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For more information
info@deltares.nl

Address
P.O. box 177
2600 MH Delft, The Netherlands