



Robustness analysis for flood risk management

robust and risk-based decision making, exemplified for the Meuse River (Netherlands)

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Flood risk management challenges



Context:

- Increasing flood risk because of 1) climate change and 2) socio-economic development (demography)
- Planning for the long-term: fundamentally uncertain

Character:

- Risk-based: combination of probabilities and consequences
- Netherlands' Delta Programme + EU Directive on flood risk management

Key issues:

- Which strategy?
- How to decide?



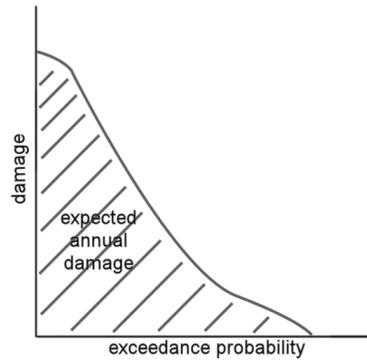
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Key objective and criteria for decision making

→ Acceptable flood risk against societally acceptable costs

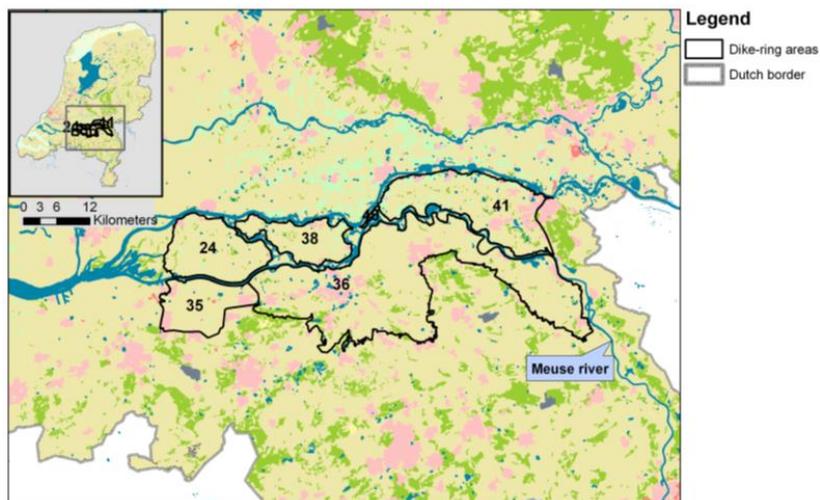
Decision criteria:

- Benefit/Cost ratio
- Total societal costs
- Side-effects
 - People
 - Profit/ economy
 - Planet/ ecology
- Opportunities
- Robustness
- Flexibility/ adaptability



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Case: non-tidal Meuse River valley



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Lowland polders between embankments (dike ring areas)



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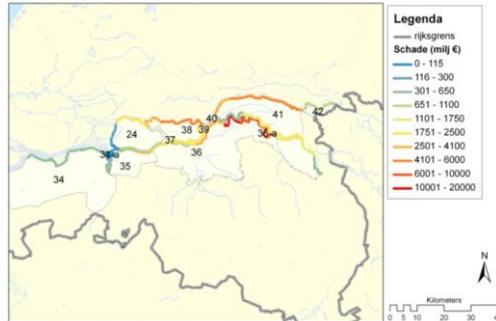
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Present situation

Protection level 1: 1250 years (all embankments equal)
 Actual flood probability?

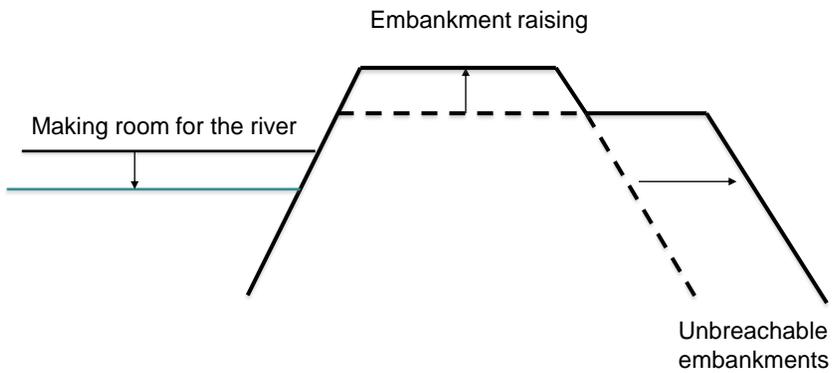
Consequences (modelled damage in 2000 ← HIS-SSM) in case of flooding:

- DR 24: 1,1 B€
- DR 35: 2,0 B€
- DR 36: 10,7 B€
- DR 38: 2,2 B€
- DR 41: 10,2 M€



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Alternatives in a nutshell (and what they achieve)



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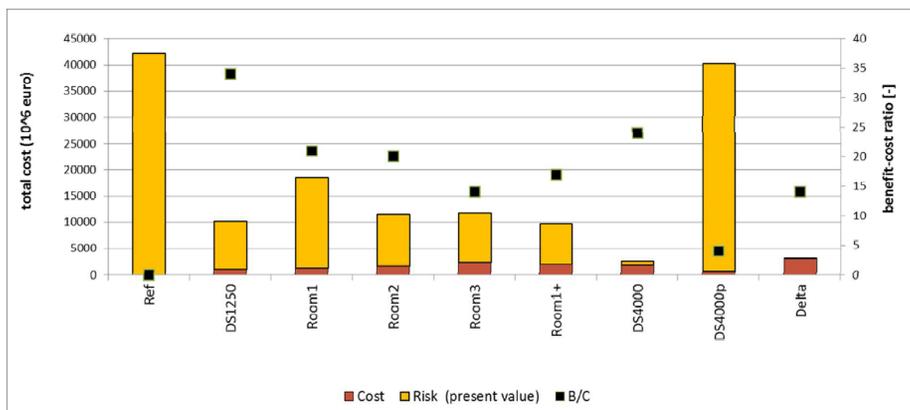
Strategic alternatives for the future

- 1 Reference (do nothing)
- 2 Maintain protection level 1: 1250 years
- 3 Make room for the river package 1
- 4 Make room for the river package 2 (more measures)
- 5 Make room for the river package 3 (again more measures)
- 6 Make room for the river package 1 + maintain 1: 1250 years
- 7 Raise protection level to 1: 4000 years
- 8 Differentiate protection level (1: 4000 where damage > €2*10⁹)
- 9 'Unbreachable' embankments ('delta dikes')



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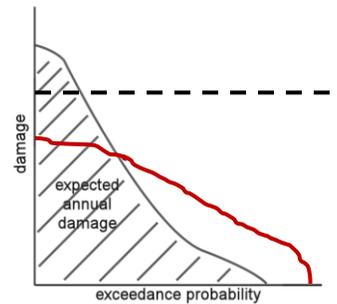
Results B/C and Total Societal Costs (incl. risk)



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The 'flaws' of focus on *risk only*

Low probability and large consequences
 =
 High probability and small consequences



- Focus on individual protected areas (dike-ring areas), not the 'whole system'
- No differentiation in protection standards in view of interactions ('whole system behaviour' or load interdependencies)



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Different focus: system robustness

A (flood risk) system is considered robust, when it can remain functioning under **a large range of** river discharges¹

System = river and floodplain (physical and socio-economic aspects)

It adds to a 'narrow' risk approach:

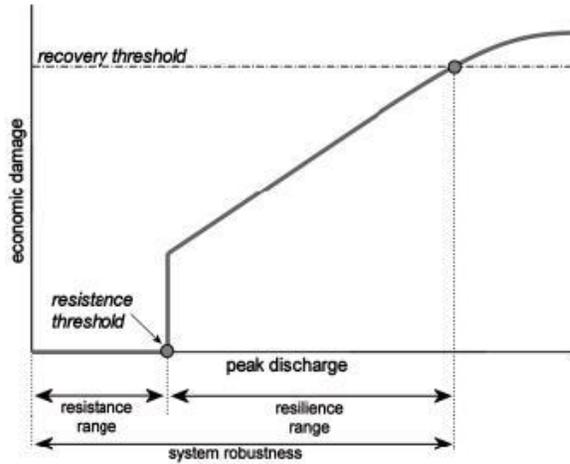
- Full acknowledgement of uncertainties
- it **questions acceptability of disastrous flood** consequences



¹ Mens, M. J. P., Klijn, F., de Bruijn, K. M. & Van Beek, E. (2011). The meaning of system robustness for flood risk management. *Environmental Science & Policy*, 14(8), 1121-1131.

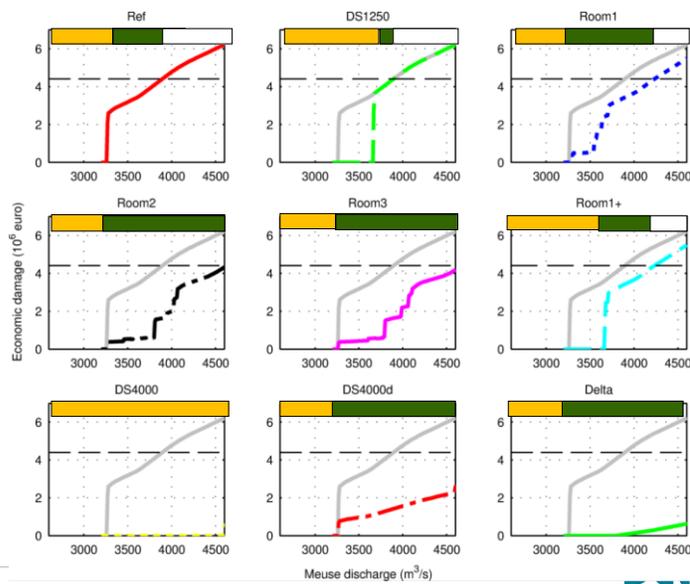
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Robustness: (damage over) the whole range



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Response curves



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Ranking of all strategies by 3 different criteria

Strategy ID	rank (total cost)	rank (B/C)	rank (robustness)
Ref	9	9	9
DS1250	4	1	8
Room1	7	3	6
Room2	5	4	4
Room3	6	6	3
Room1+	3	5	6
DS4000	1	2	4
DS4000p	8	8	2
Delta	2	6	1



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Conclusions/ statements

Choosing between options:

- Not simple to translate FRM objective (**acceptable risk against acceptable costs**) into one criterion
- Each criterion ranks differently (and has its advantages)
- Availability of funding may be an issue (B/C favoured above lowest Societal Costs), but ...

Robustness analysis has added value for FRM planning:

- An addition to traditional cost/benefit analysis/ may lead to different choices
- But complicates decision making further

Societal discussion needed about interpretation of FRM objective

- Acceptable consequences?



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