Course Unit 11

Handling Uncertainty

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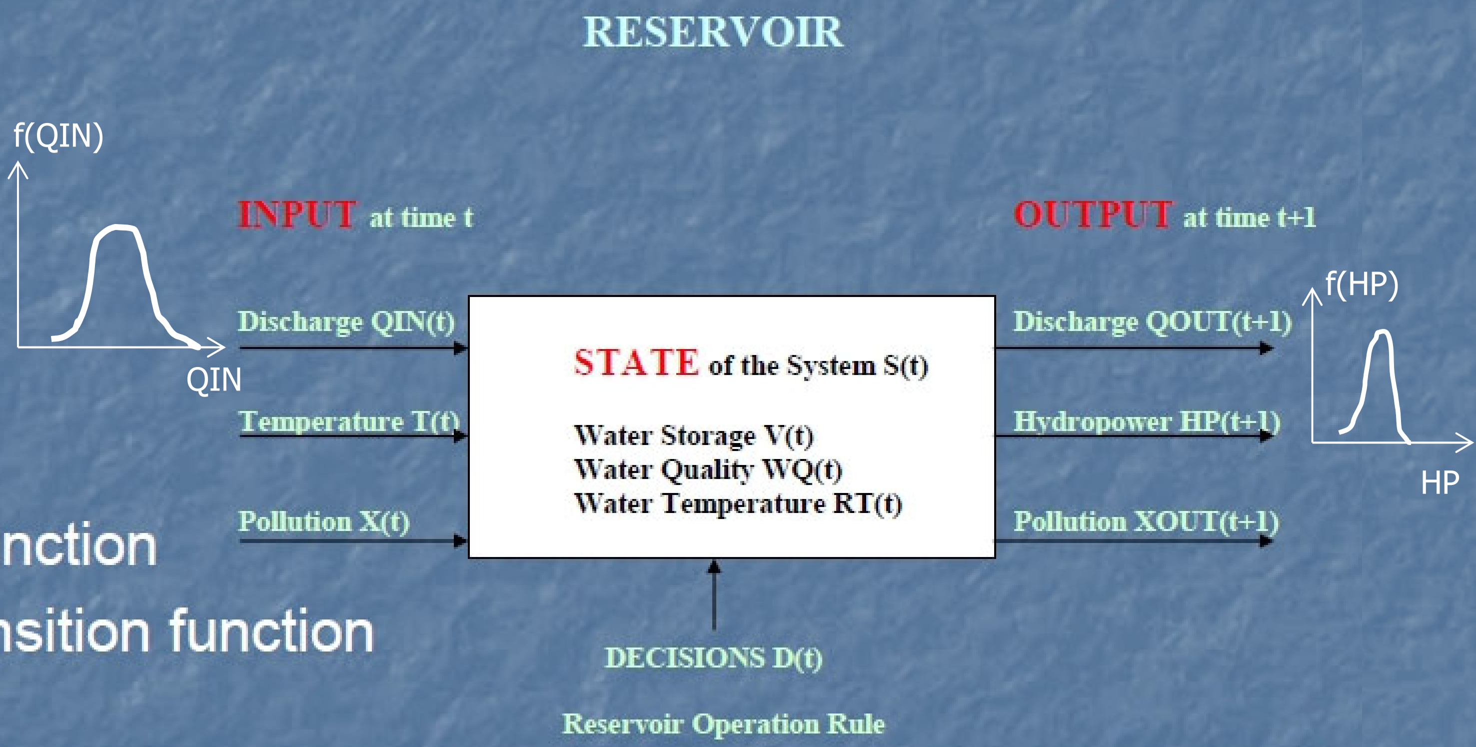
Sources of Uncertainty

- Data gaps, limited sample size
- Measurement errors
- Stochastic component in nature (climate, hydrology,…..)
- Modelling errors (limited scope, simplified equations, unknown boundaries and initial conditions, parameters)
- Changing preferences in our society
- Unknown development of technologies….

How to handle uncertainty and risk ?

- Input
- Output
- State
- Output function
- State transition function



If one of the input variables or the initial state is not precisely known then all the output variables and/or the state are also uncertain

Handling Uncertainties

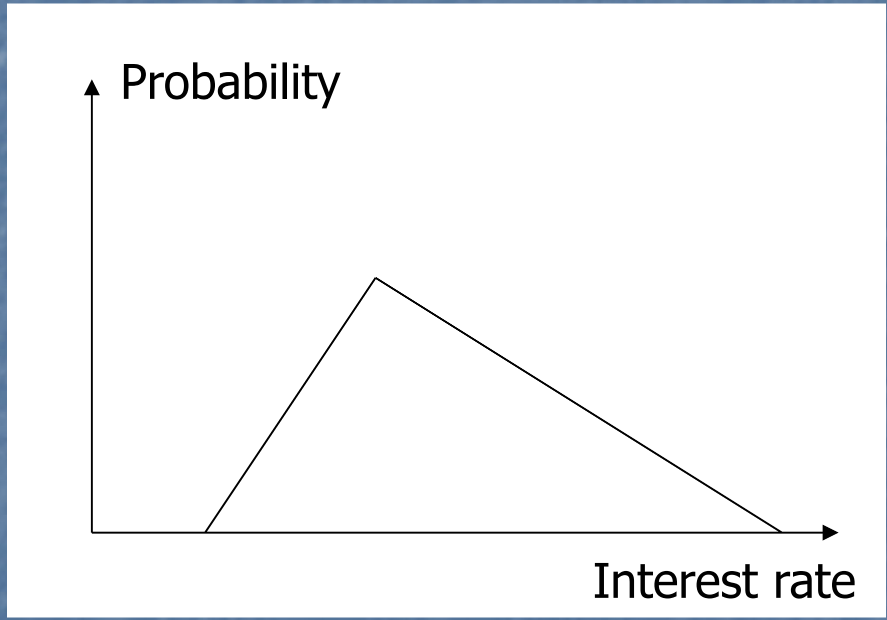
- All the outcomes of a project, the rankings are subjected to uncertainty: they have a range, a pdf

Handling Uncertainties

- Sensitivity analysis
- Simulation

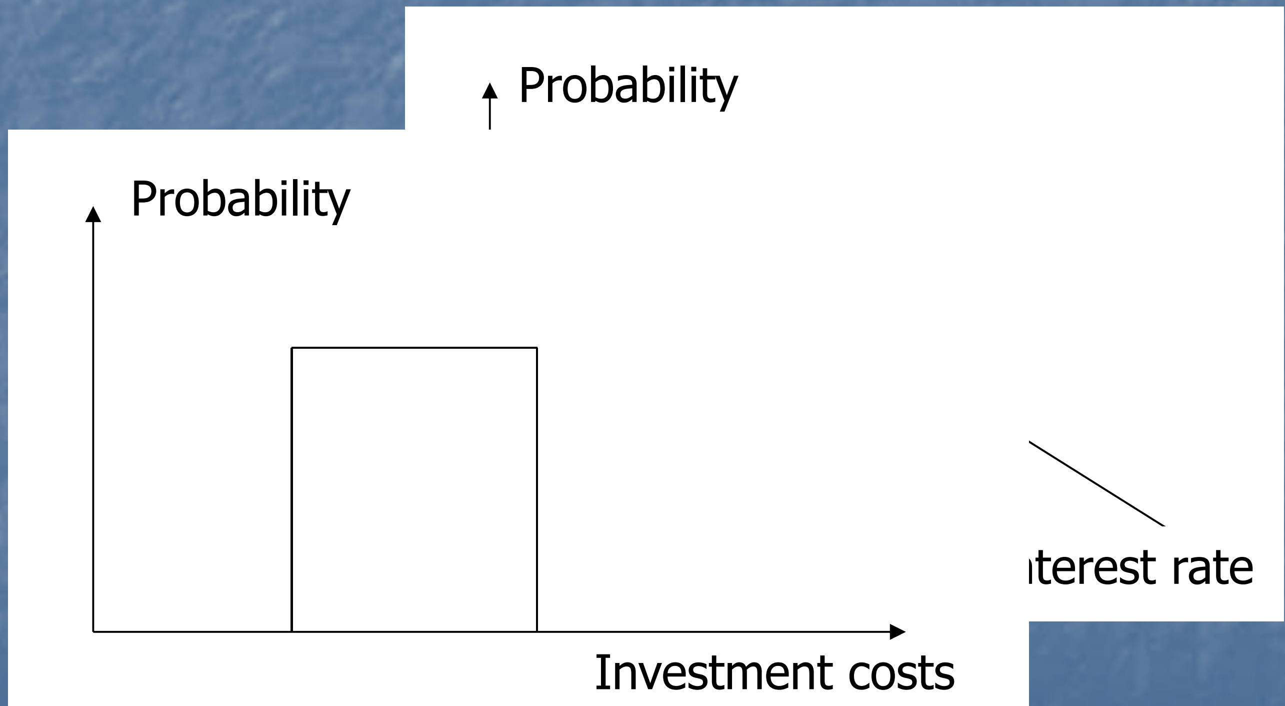
Simulation

- For each variable a pdf is assumed



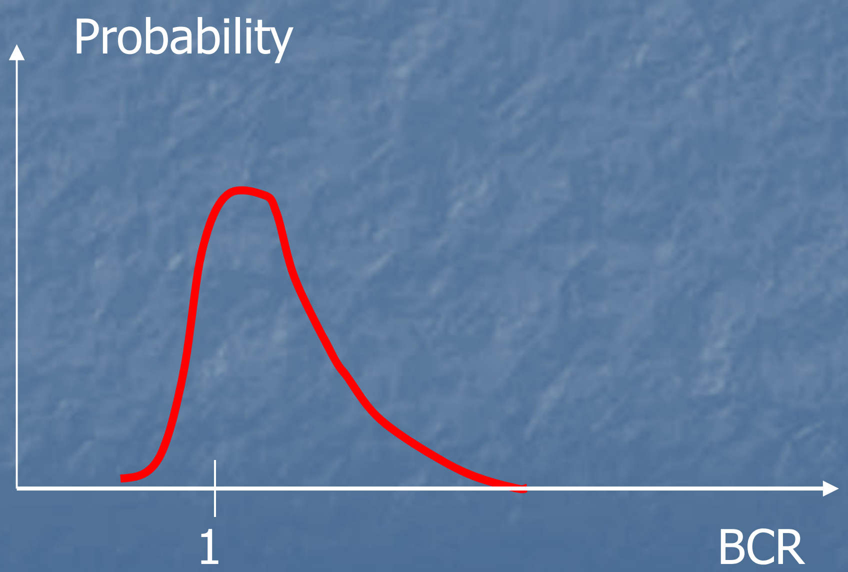
Simulation

- For each variable a pdf is assumed



Simulation

- For each variable a pdf is assumed
- Hundreds of simulations
- A pdf for the efficiency criterion is obtained



Simulation

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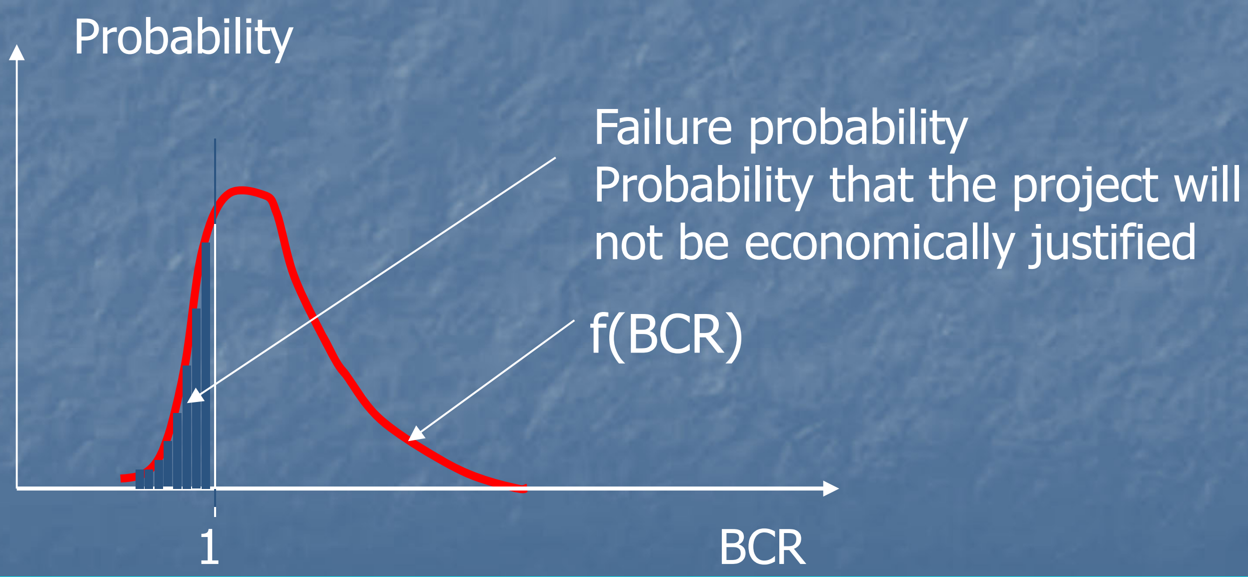


Handling Uncertainties

- Sensitivity analysis
- Simulation:
  We can estimate the failure probability

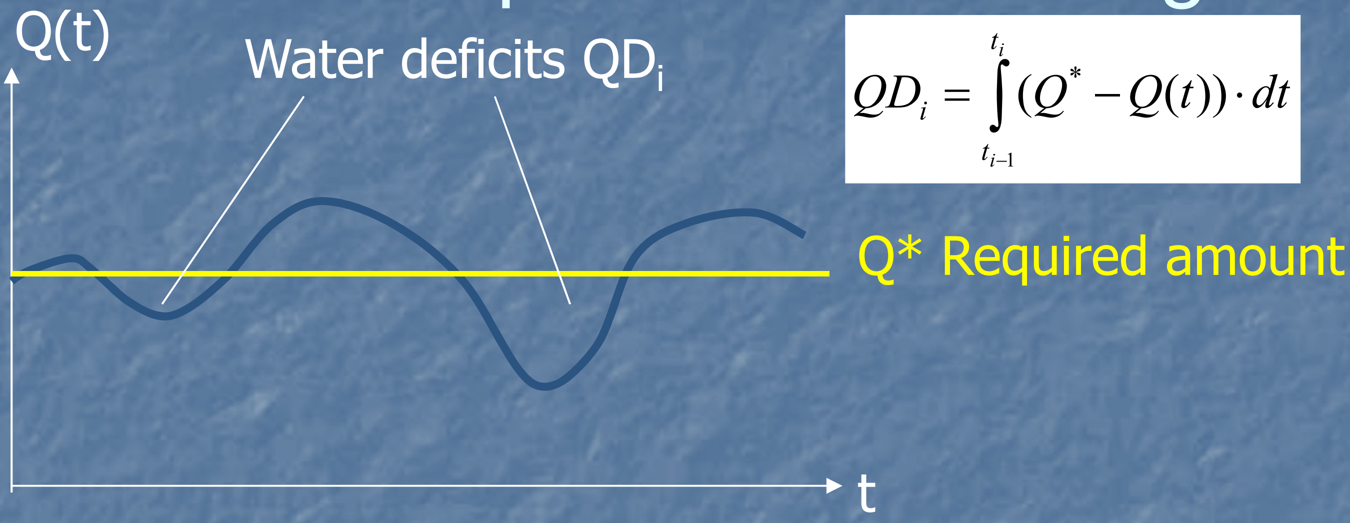
$$P_F = \int_0^1 f(x)dx$$

$$P_S = \int_1^\infty f(x)dx = 1 - P_F$$

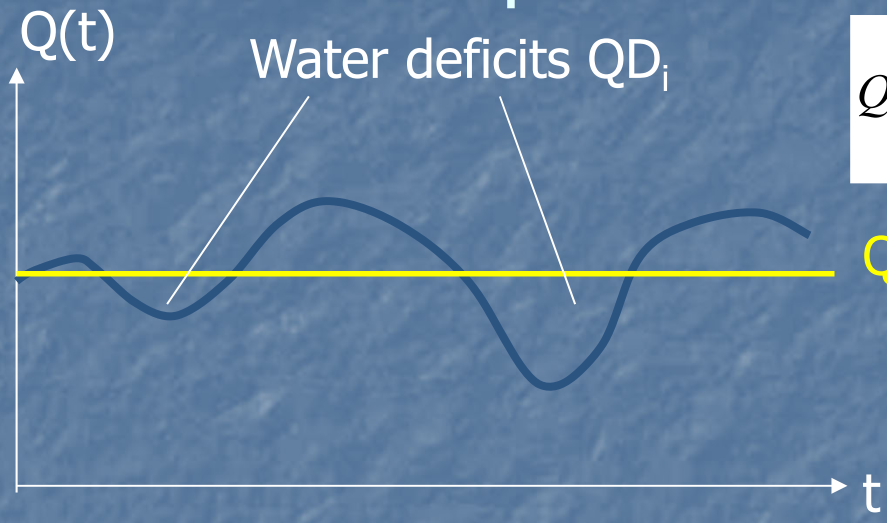
- We could prespecify a certain minimum probability of success.
  E.g. I would accept a project with a 90 % probability of sucess:
  P_S >0.9

Example: Water Shortage

$$QD_i = \int_{t_{i-1}}^{t_i} (Q^* - Q(t)) \cdot dt$$

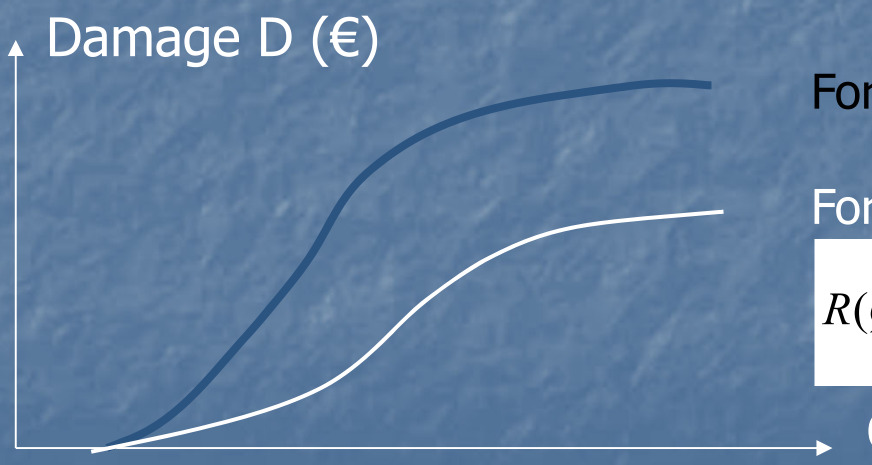


Example: Water Shortage



$$QD_i = \int_{t_{i-1}}^{t_i} (Q^* - Q(t)) \cdot dt$$

Q* Required amount



For a given Q*

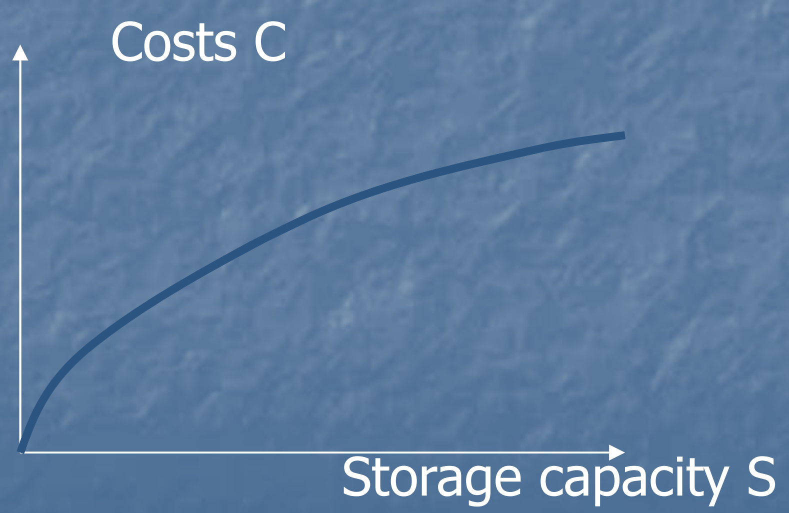
For a lower demand

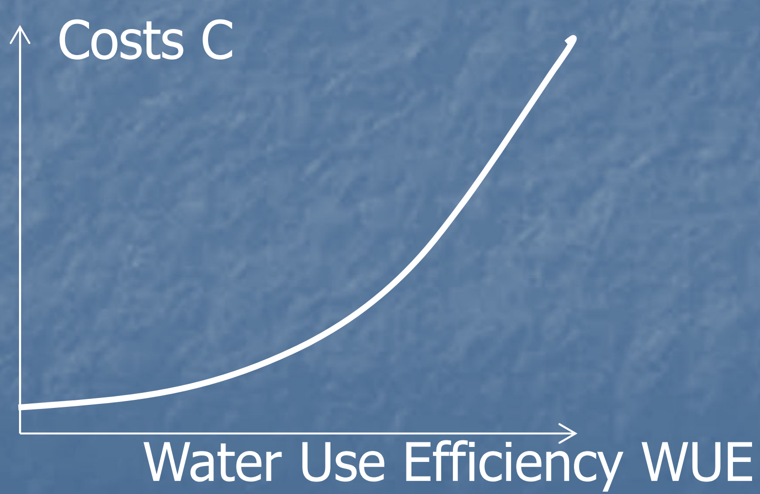
$$R(Q^*) = \int_0^\infty f(QD) \cdot D(QD(Q^*)) \cdot dQD$$

Example: Water Shortage

- Objective: reduce the risk

  Manage the demand (improve water use efficiency)
  Manage the supply (increase the supply rate by building/enlarging a reservoir)





Example: Water Shortage

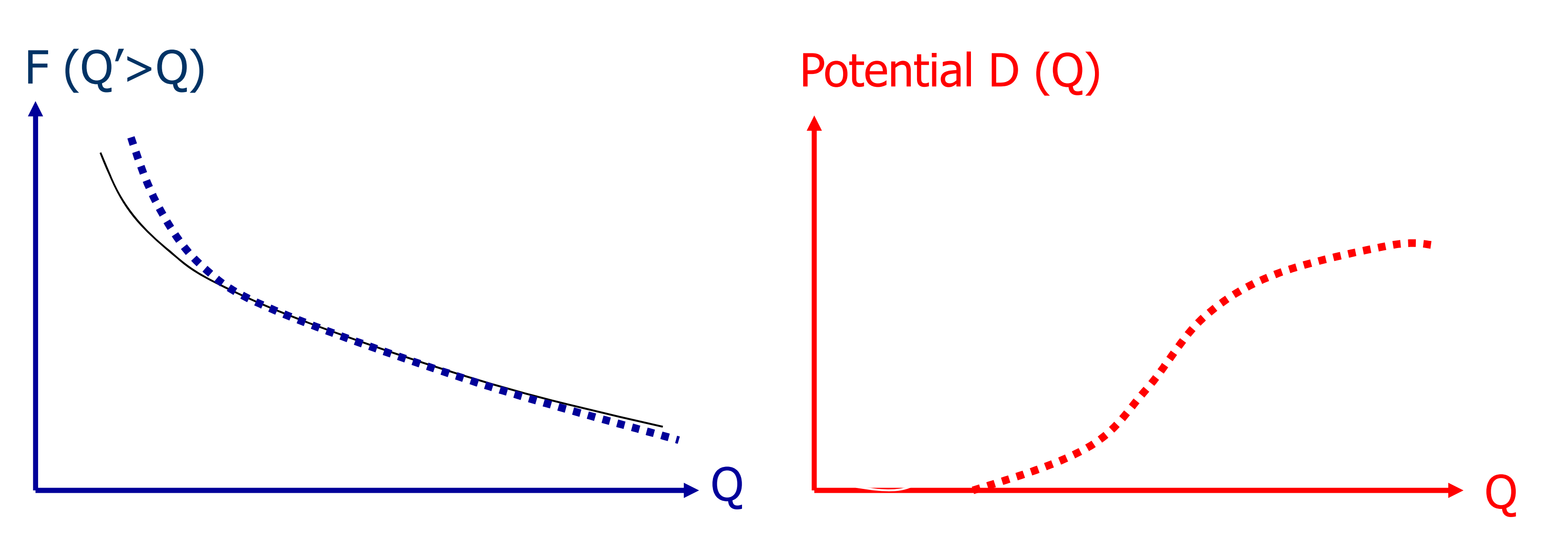
- What is the decision criterion ?

$$Min\{R(Q^*)+C(WUE)\}$$

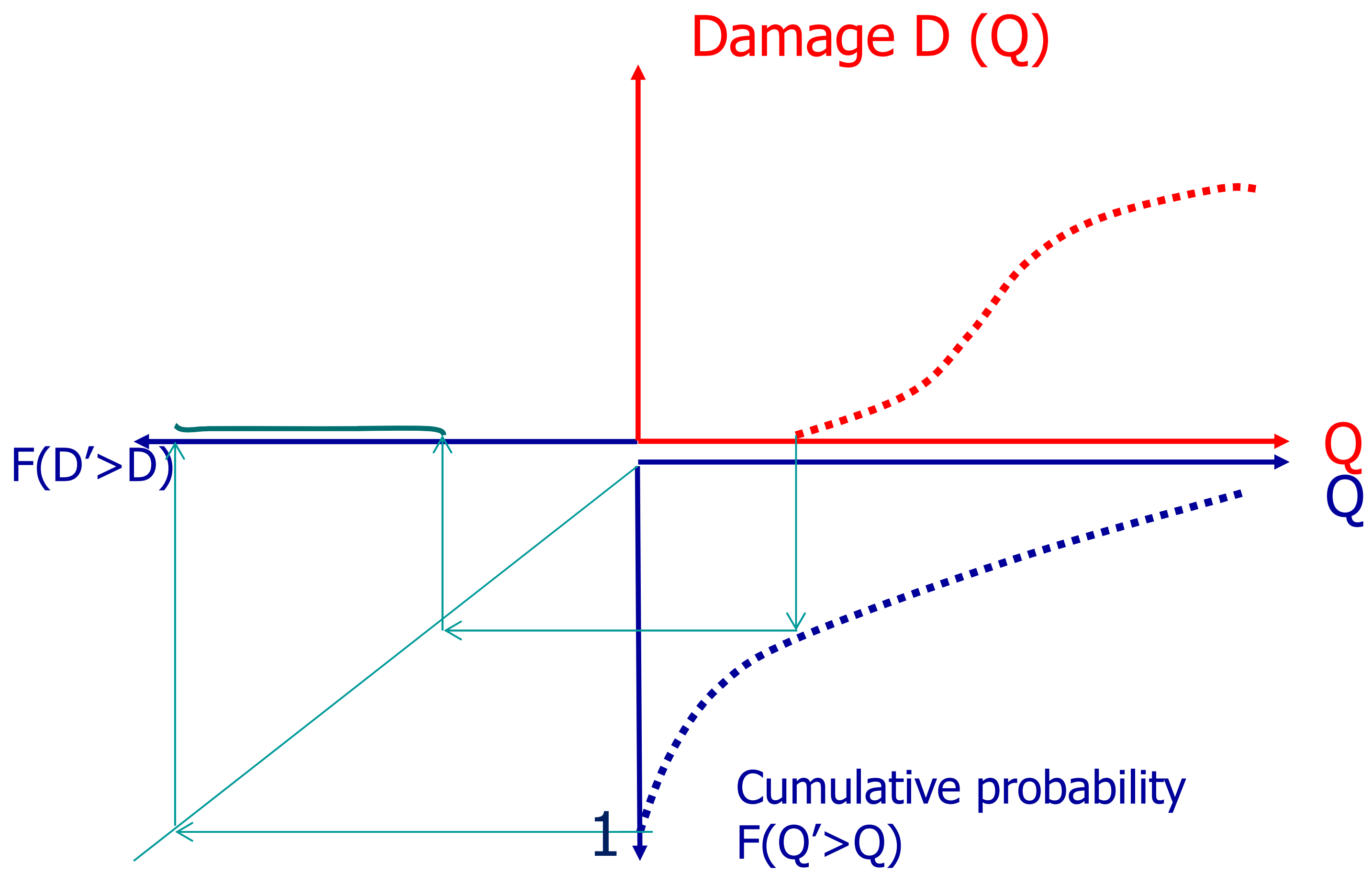
$$Min\{R(Q^*)+C(S)\}$$

What happens after building a levee ?

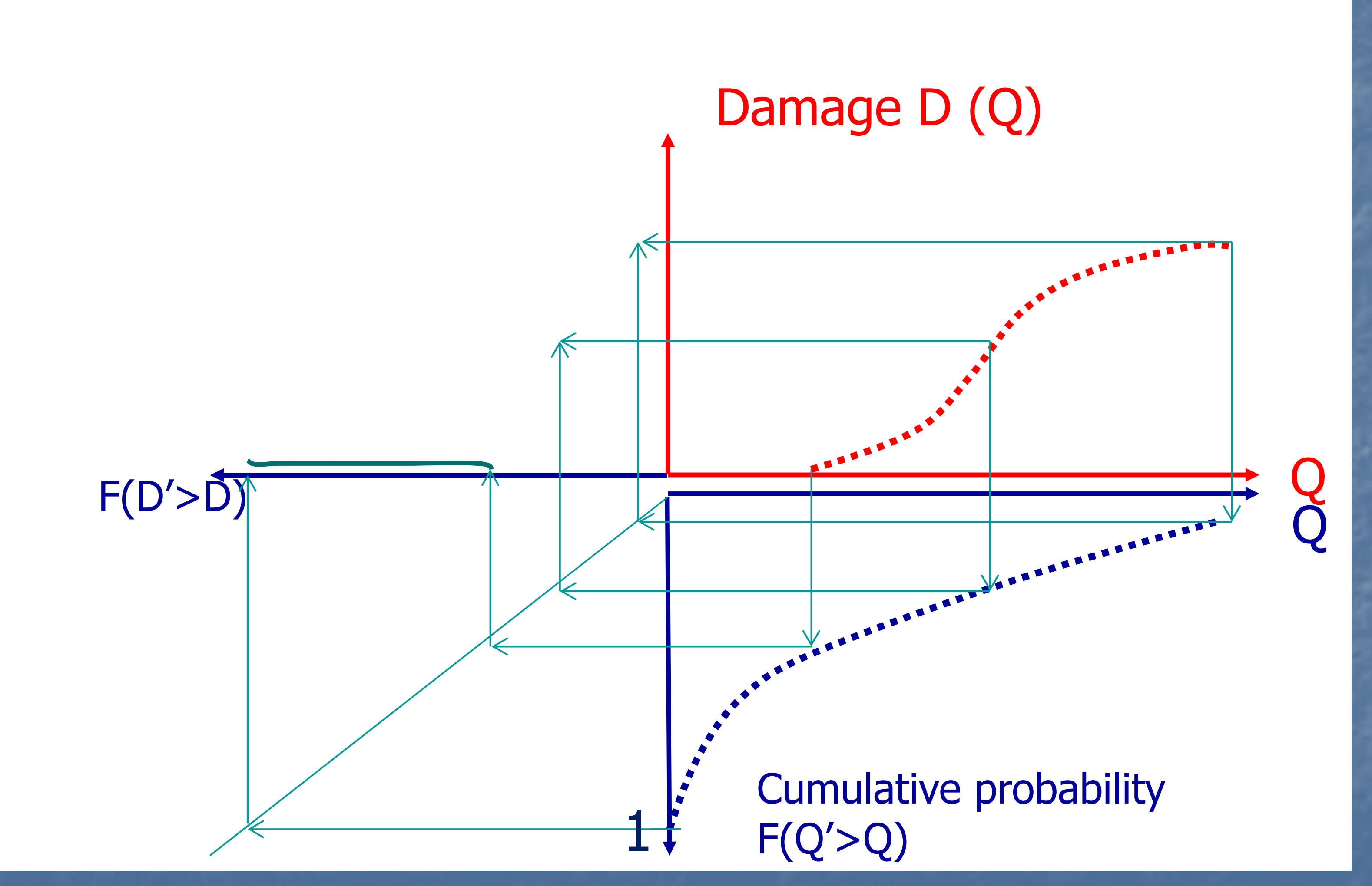
PDFs and Risk curves



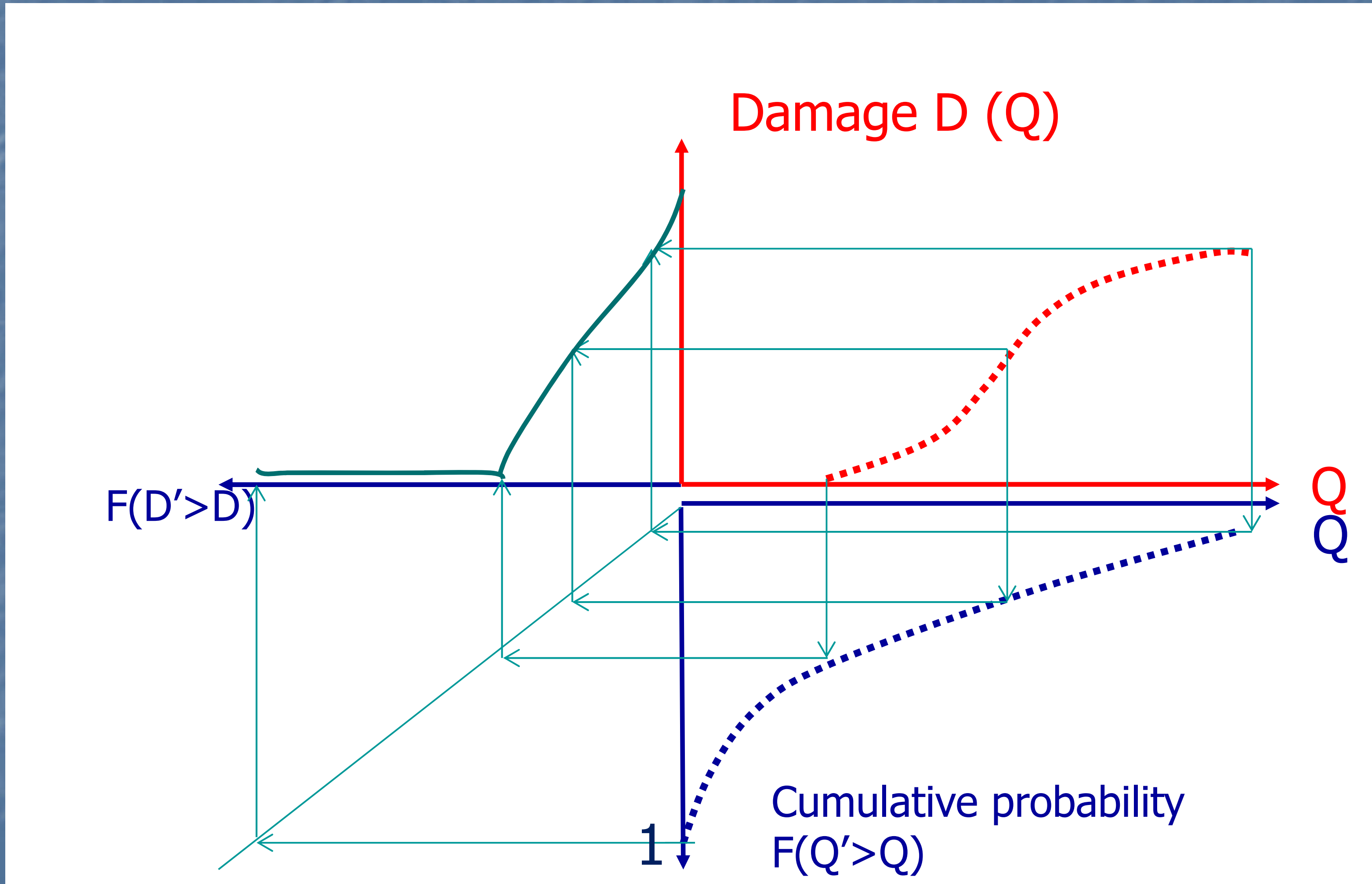
Risc curves



Risc curves

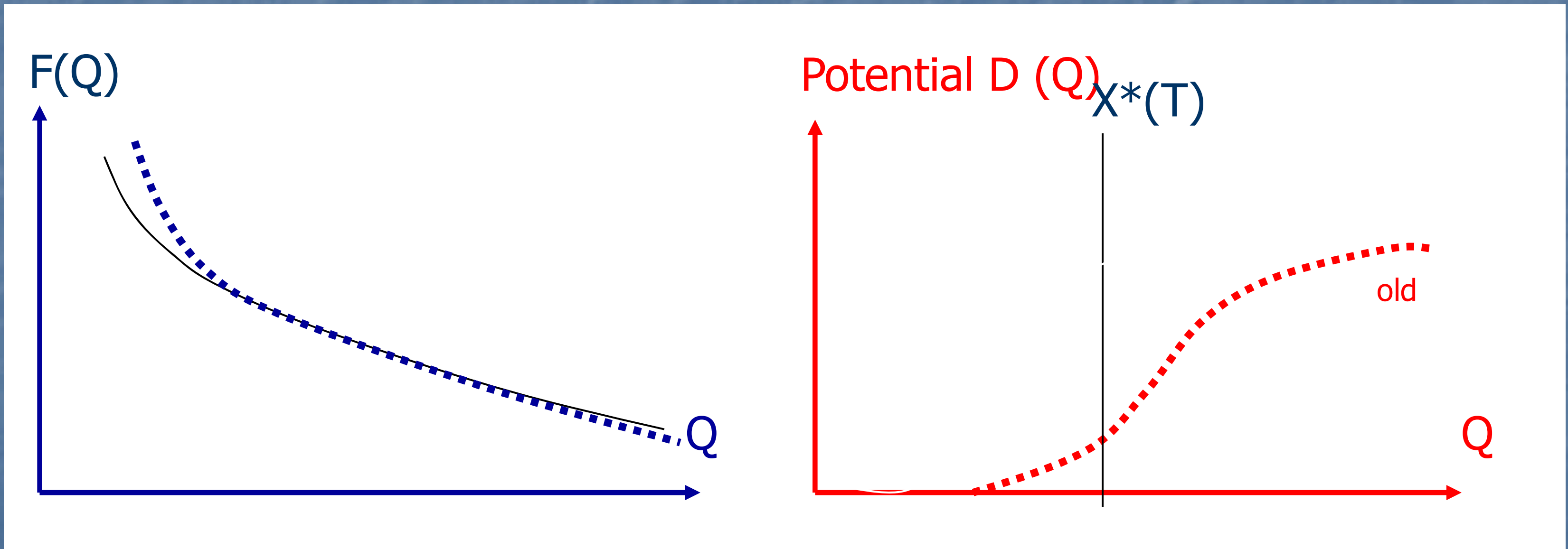


Risc curves



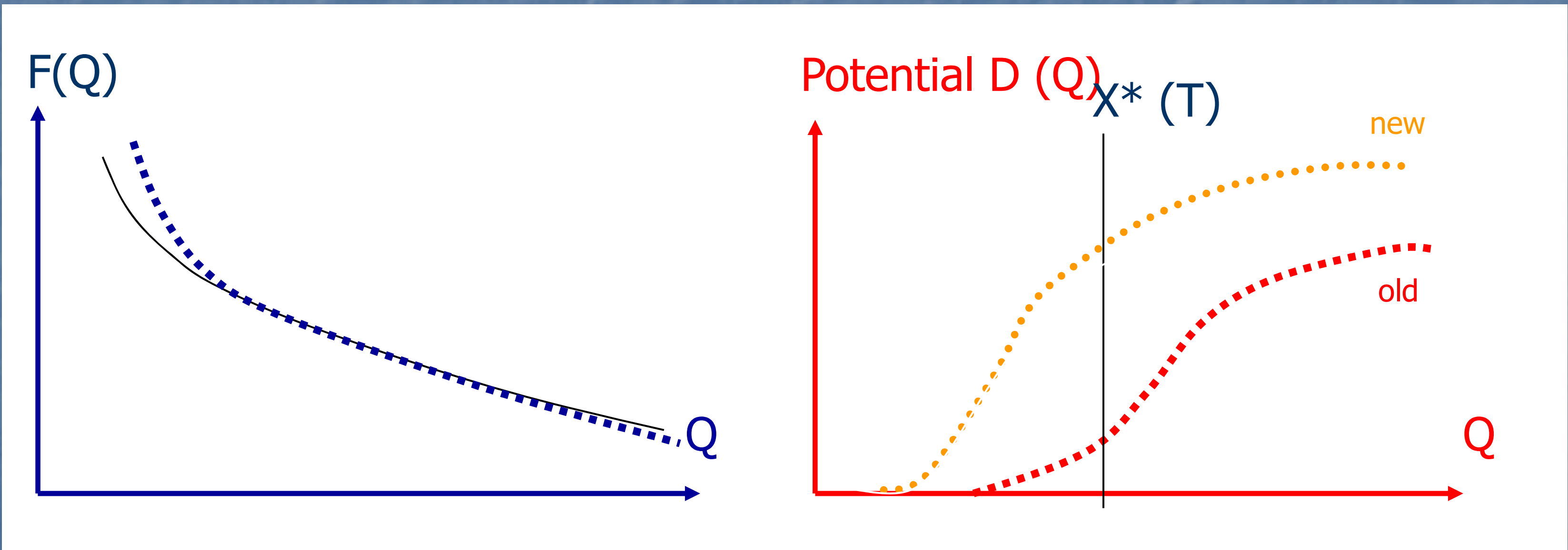
What happens after building a levee ?

PDFs and Risk curves

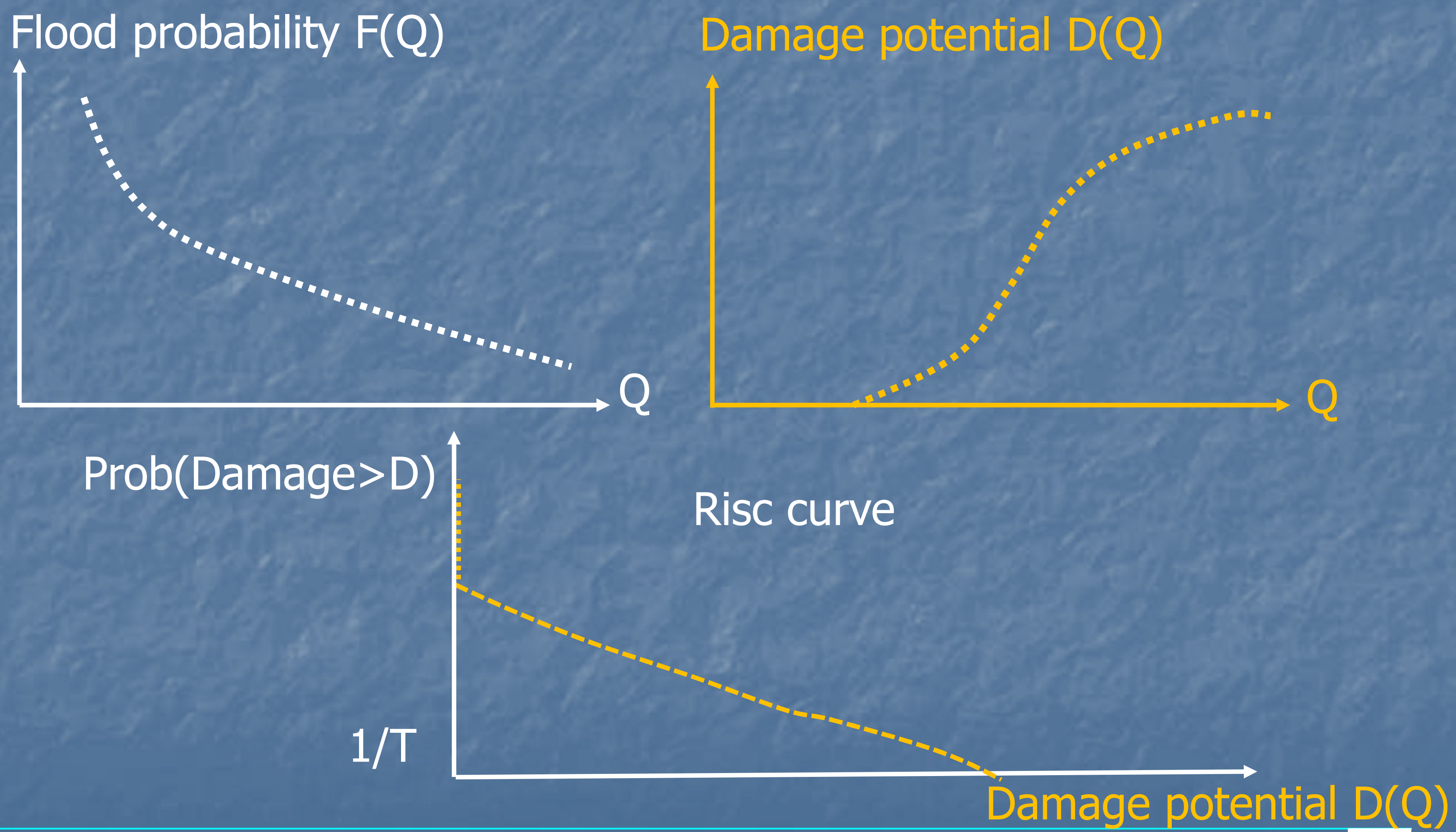


What happens after building a levee ?

PDFs and Risk curves

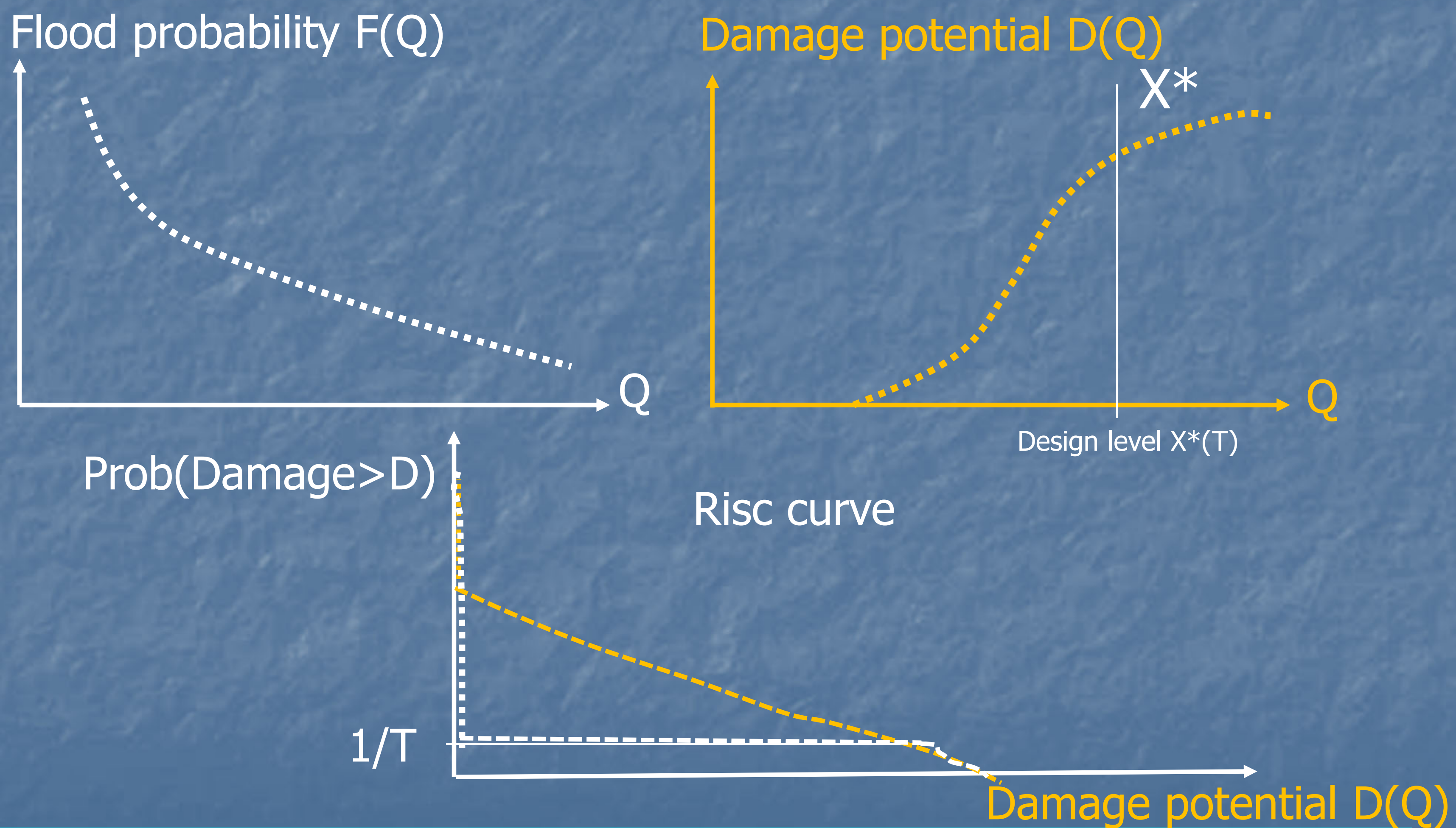


Risk curves



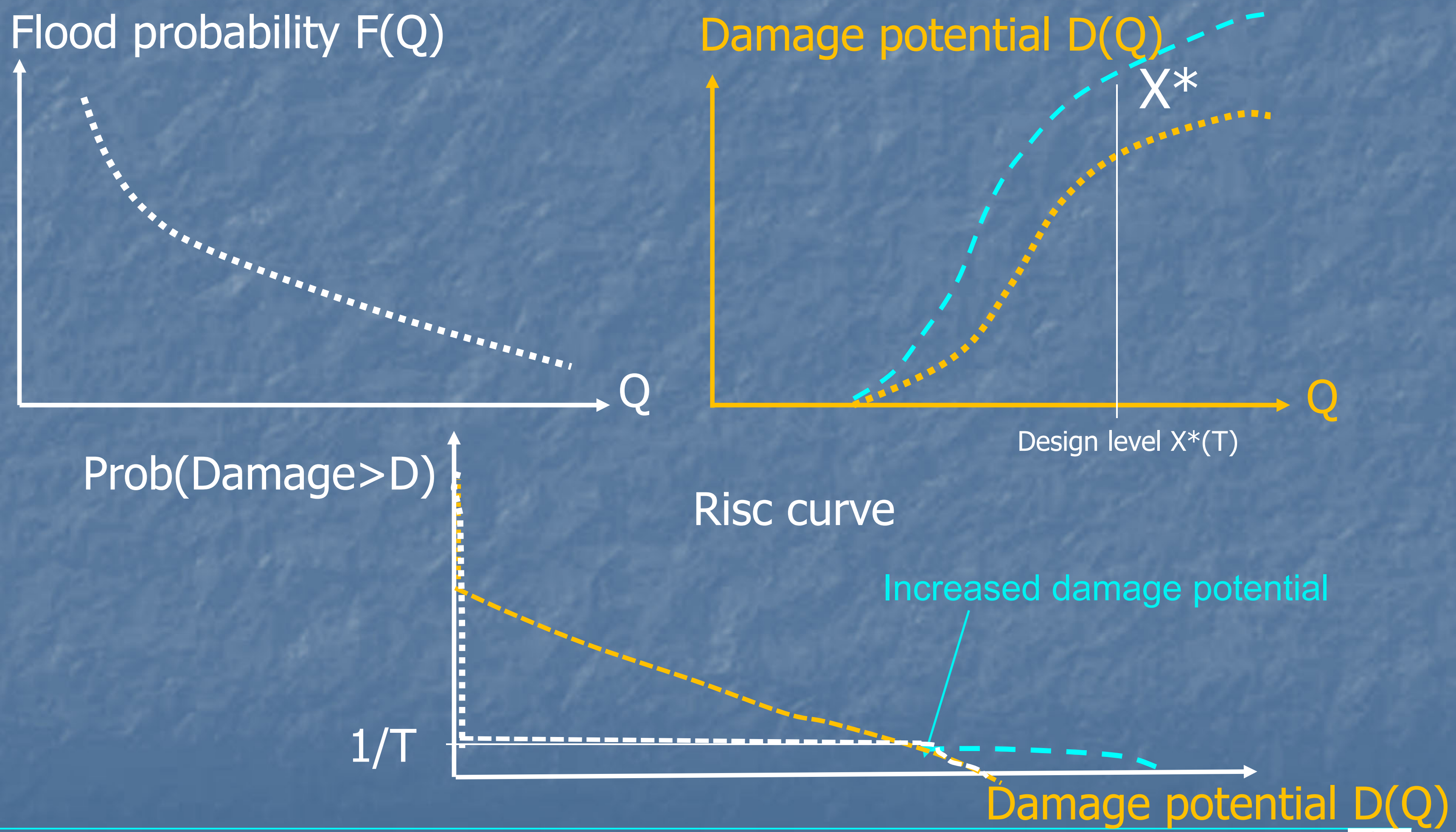
Flood probability F(Q)
Q
Damage potential D(Q)
Q
Prob(Damage>D)
Risc curve
1/T
Damage potential D(Q)

Risk curves



Flood probability F(Q)
Q
Damage potential D(Q)
X*
Q
Design level X*(T)
Prob(Damage>D)
Risc curve
1/T
Damage potential D(Q)

Risk curves


Flood probability F(Q)
Q
Damage potential D(Q)
X*
Q
Design level X*(T)
Prob(Damage>D)
Risc curve
Increased damage potential
1/T
Damage potential D(Q)

Consequences

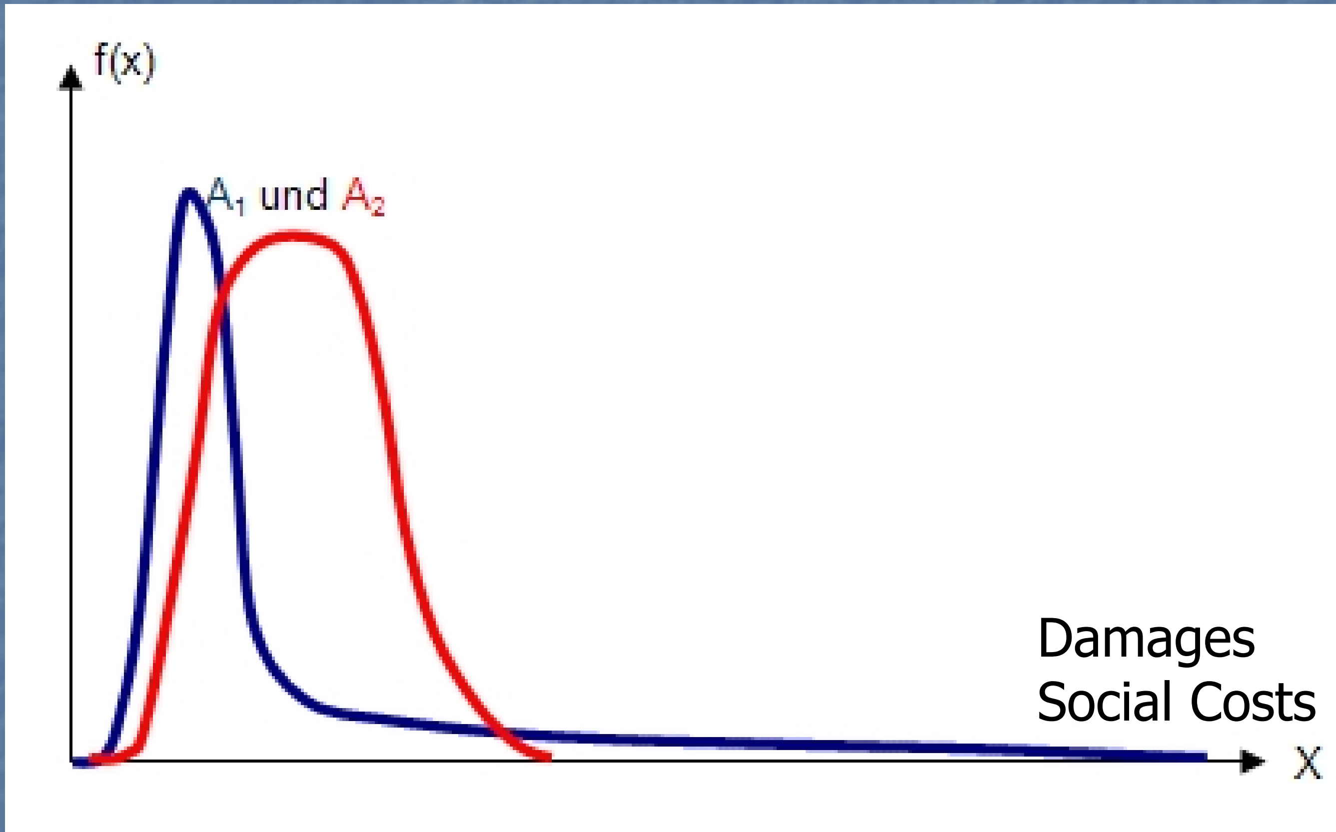
- The expected damages may be larger after flood implementation of flood protection measures
- Land management and development strategies are required
- Safety of dams and levees ?

History of dam failures around the world

Dam	Dam type	Country	Height (m)	Reservoir volume (10^6 m^3)	Date built	Failure		Deaths
						Date	Type	
Vega de Tera	CMB	Spain	34	7.8	1957	1959	SF	144
Malpasset	CA	France	66	22	1954	1959	FF	421
Vaiont	CA	Italy	265	150	1960	1963	L	2600
Baldwin Hills	Emb	USA	71	1.1	1951	1963	IE	5
Frias	Emb	Argentina	15	0.2	1940	1970	OF	>42
Teton	Emb	USA	93	356	1975	1976	IE	14
Machhu II	Emb	India	26	100	1972	1979	OF	2000
Bagauda	Emb	Nigeria	20	0.7	1970	1988	OF	50
Belci	Emb	Romania	18	13	1962	1991	OF	25
Gouhou	Emb	China	71	3	1989	1993	IE	400
Zeizoun	Emb	Syria	42	71	1996	2002	OF	20
Shakidor	Emb	Pakistan	--	--	2003	2005	OF	>135
Situ Gintung	Emb	Indonesia	16	2	1933	2009	IE	100

Dam type: CA = concrete arch, CMB = concrete and masonry buttress, Emb = embankment.
Type of failure: IE = internal erosion, FF = foundation failure, OF = overtopping during flood, SF = structural failure on first filling, L = landslide into the reservoir causing overtopping

Comparing two Uncertain Alternatives

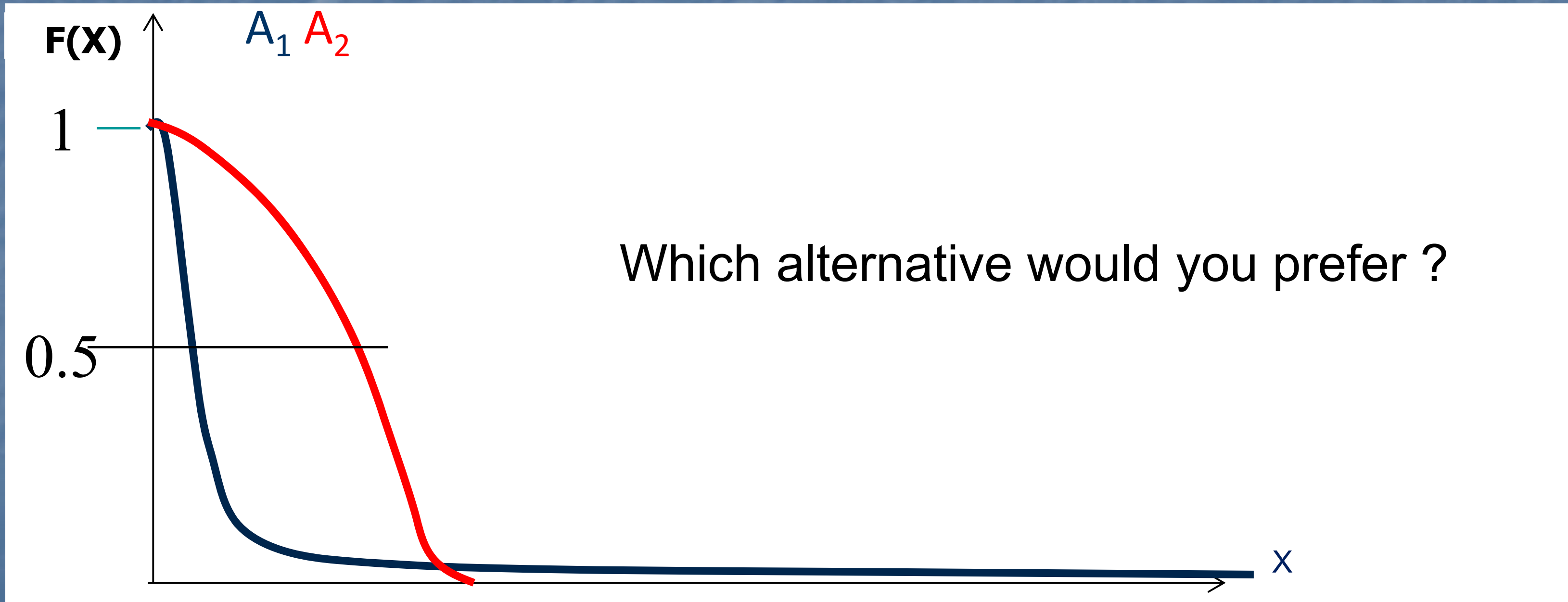


Comparison of different risk curves

- Comparison of two hazards with quite different consequences
- A1 very low probability of occurrence but extreme consequences
- A2 high probability of occurrence but lower consequences
- E.g. A1 nuclear power station and A2 thermal power station

Cumulative probability

A1 has a low mean value but is highly skewed
A2 has a higher mean but an upper limit



Comparing two Uncertain Alternatives

- The mean value of A1 < A2
- There is high probability that the damages vom A1 are smaller than from A2
- But it may happen that the damages from A1 are >>> than from A2
- Being risk adverse select A2

Comparing risks

- Two alternatives, A1 and A2, exhibit annual net benefits (k€) with a certain probability. The outcomes are A_{ik}
- Which one should be chosen ?

	A_1	A_2
$W_1=33\%$	6 400	4 900
$W_2=33\%$	4 100	4 300
$W_3=33\%$	2 500	3 600

Comparing two Uncertain Outcomes

- Possible Decision Criteria

Max $\{\Sigma\, w_i\, NB_{ik}\}$	Bernoulli Criterion
Max $\{Max(NB_{ik})\}$	Gambler Criterion
Max $\{Min\, (NB_{ik})\}$	Neumann-Morgenstern Criterion

Decision techniques

- Bernoulli criterion: choose the one where K_1 is better:

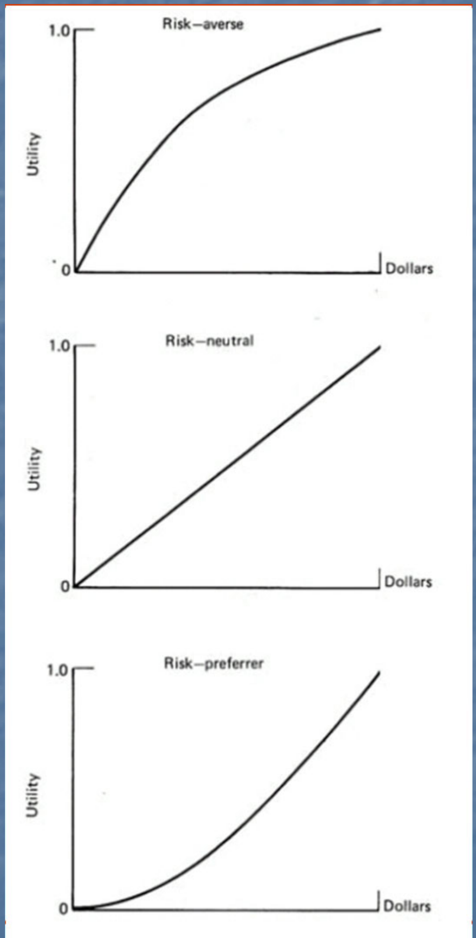
$$K_1 = \max \{K_{1,i}\} = \max \{ \Sigma w_k A_{ik}\}$$

$K_{1,1}$ = 4 333 k€/a
$K_{1,2}$ = 4 266 k€/a

Decision techniques

- Neumann-Morgenstern criterion: try to avoid losses or take a risk averse position
- $K_3 = \max\{K_{3,i}\} = \max\{\min(A_{ik}) \text{ for } w_k > p_0\}$
- Choose A_2 because the worst outcome is 3 600 k€/a which is better than the outcome of A_1
- Is a useful criterion for public investments, safe decision

Perception of risk



Summary and Conclusions

- Uncertainty is essential in DM
- All our decisions are subjected to uncertainty
- Several performance indicators were defined
  failure rate, reliability, risk
- Several strategies for risk management were discussed
  - Max average
  - Min losses (risk averse)
  - Max max (risk prone)