

Unit 11: Risk Management in a Multi-objective Framework

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Structure

- Objectives
- Introduction/background
- Multi-objective approaches (methodology)
- Application
- Summary
- Conclusion

Objectives

- Risk management tries to identify options to reduce the risk
- Secondly: Options are evaluated by a set of criteria
- Choose the options where you have the best result

Risk management

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Risk management

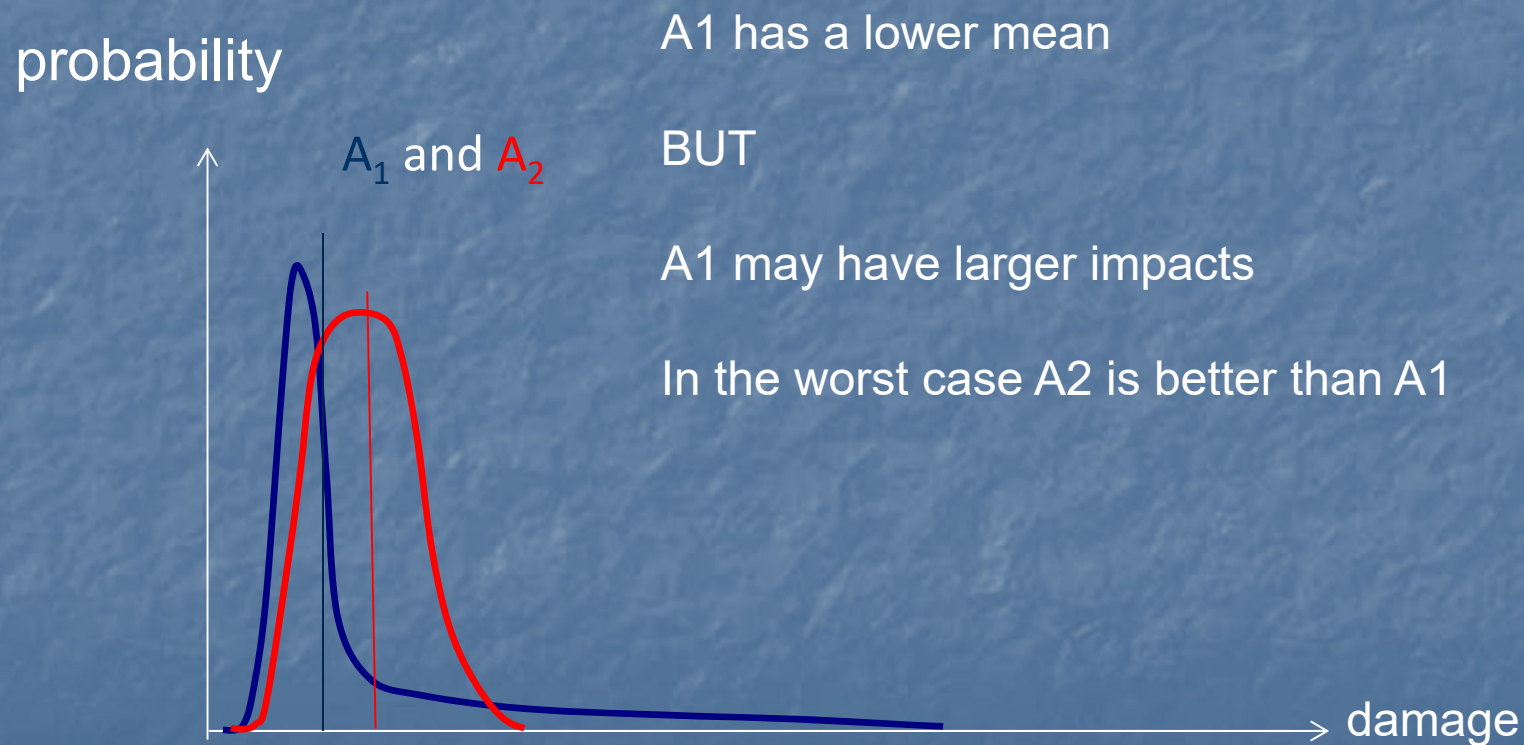
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Risk management

- Every decision is related to economic, social and environmental objectives
- Every decision faces uncertainties
- Origin of uncertainties
 - Data are limited (in time and space)
 - Data are contaminated by measurement errors
 - Models describe only part of reality
 - Social preferences are not perfectly known
- Therefore we have to trade-off different objectives (outcomes) with uncertainties

Comparison of two uncertain alternatives

- e.g A1 (nuclear power plant) and A2 (thermal power plant)



Decision under risk

2 alternatives with uncertain outcomes

Net benefits (k€) and probabilities

	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

Which alternative is better ?

The decision depends on the perception of risk

mean	4 333	4 266
Max	6 400	4 900
Min	2 500	3 600

Comparing two uncertain outcomes

- Possible Decision Criteria

$$\text{Max} \{ \sum w_i \text{NB}_{ik} \}$$

$$\text{Max} \{ \text{Max}(\text{NB}_{ik}) \}$$

$$\text{Max} \{ \text{Min} (\text{NB}_{ik}) \}$$

Decision criteria

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

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

$$K_{1,1} = 4\,333 \text{ k€}/a$$

$$K_{1,2} = 4\,266 \text{ k€}/a$$

Decision criteria

- Risk friendly decision: given a certain risk probability (with e.g. 33% you will win) choose the alternative with the higher outcome
- $K_2 = \text{Max} \{K_{2,i}\} = \text{Max} \{\text{Max}(\text{NB}_{ik} \text{ with } P > p_{\text{crit}})\}$
- $K_2 = 6400 = \text{Max}\{K_{2,1} = 6400, K_{2,2} = 4900\}$
- Gambler's attitude

Decision criteria

- 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

Some examples

- Quantifying risk is associated with economic losses, human impacts, environmental impacts, social disruptions
- Risk management tries to minimize economic losses, to preserve environmental quality, to reduce social disruptions,.....

Example of objectives and sub-objectives

Improve regional and national economy

minimize total losses

(direct and indirect losses, costs of protection measures,..)

- Reduce disparity among regions

(income, job opportunities, infrastructure,...)

Example of objectives and Sub-objectives

- Preserve/improve environmental conditions
preserve/extend aquatic wetlands
(area (ha), natural diversity (index)...)
preserve/improve groundwater quality
(nitrate conc. (mg/l), dissolved iron (mg/l),
heavy metals (mg/l), recharge (m³/a)
preserve/stabilise endangered species
(number (#), reproduction rate (%))...

.....

Example of objectives and sub-objectives

- Minimize human losses
(# of fatalities, number of injured people...)
- Improve/preserve living conditions
(reduce disruptions of social life, ensure basis supply functions, preserve job opportunities (#/a), recreational opportunities (# people/day).....)
- Improve equity within society
benefits and adverse project impacts should be balanced within the region

Example of objectives and sub-objectives

- Preserve cultural heritage
(number of monuments exposed, age, quality, importance and uniqueness of monuments,...)

Multi-objective decision making

- Overview of the concepts applied in MCDM
 - One decision maker
 - quantitative (Compromise Programming) and qualitative criteria (ELECTRE I-IV)
- analysis of pro's and con's
- applicability

Techniques

- Distance-based techniques
- Outranking techniques (for discrete alternatives only)
- Value- or utility-based techniques
- Graph model
- Alternative Dispute Resolution

Distance based techniques

- Require quantitatively expressed criteria
- Require preferences (weights and scales)
- Number of alternatives may be infinite (optimisation)

- Yield a full ranking of alternatives
- Might be iteratively applied

Procedure

- **Impact table:**
expresses the consequences of each alternative with respect to each criterion in measureable units
- **Efficiency or payoff table**
transformation of impacts into efficiency measures (scaling)
- **Estimation of the overall efficiency („best solutions“)**

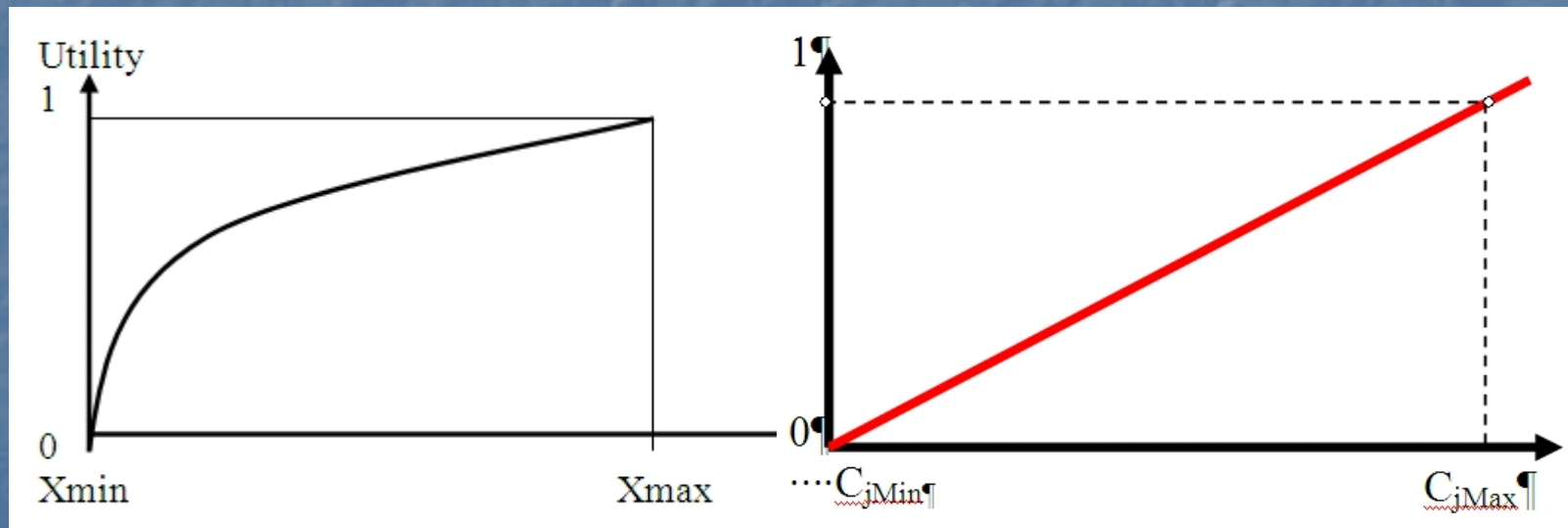
Impact table

full set of alternatives A

<u>Criteria</u>	<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>Ai</u>	<u>AN</u>
C1 (€)	c11	c12	c13	c1i	c1N
C2 ...	c21	c22	c23	c2i	c2N
C3 (mg/l)	c31	c32	c33	c3i	c3N
Cj ...	cj1	cj2	cj3	cji	cjN
CJ (ha)	cJ1	cJ2	cJ3	cJi	cJN

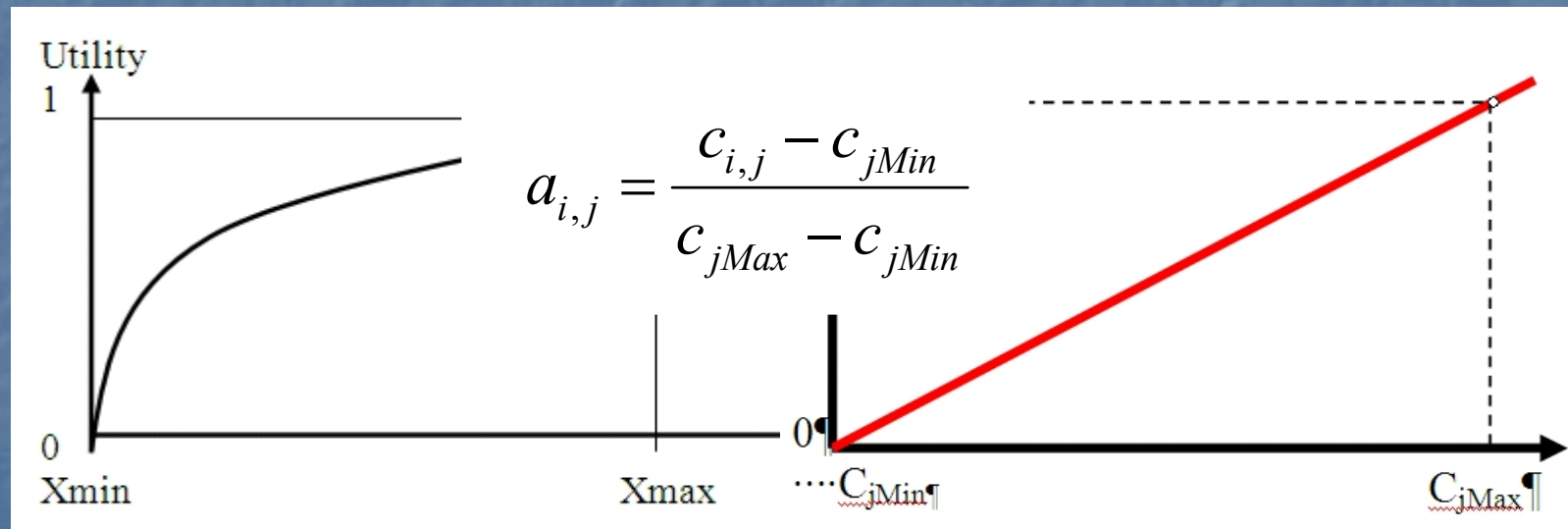
Payoff table

- The physical outcomes have to be transferred into appreciation values (often the efficiency in reaching an objective is used)

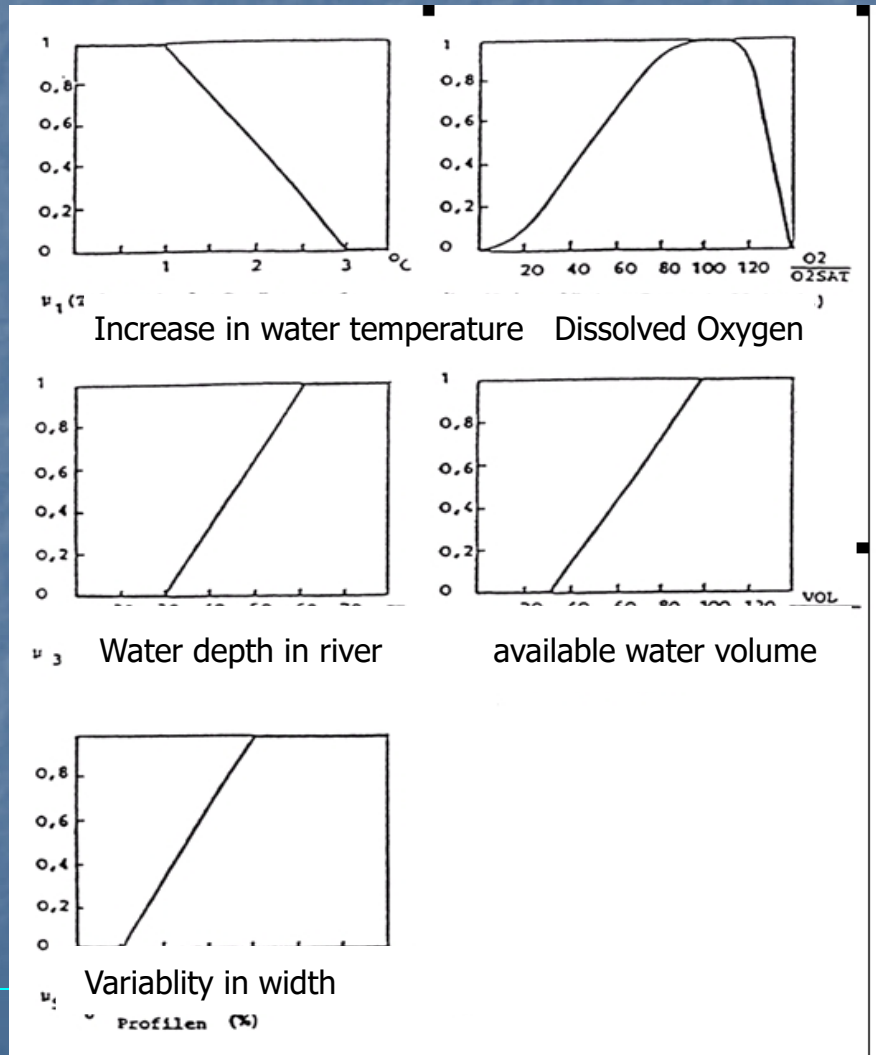


Payoff table

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Sometimes utility and membership functions are used



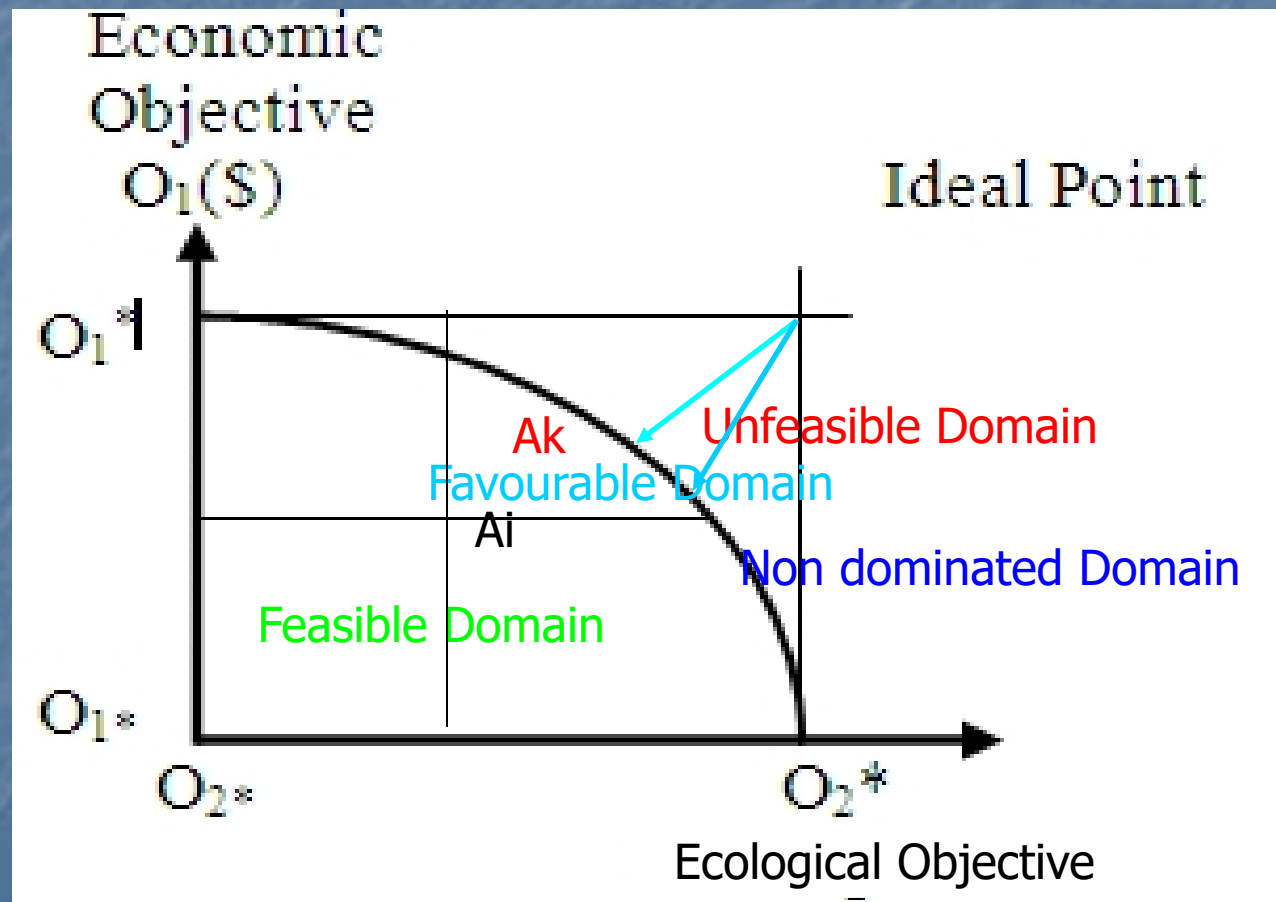
Efficiency or payoff table

full set of alternatives A_i

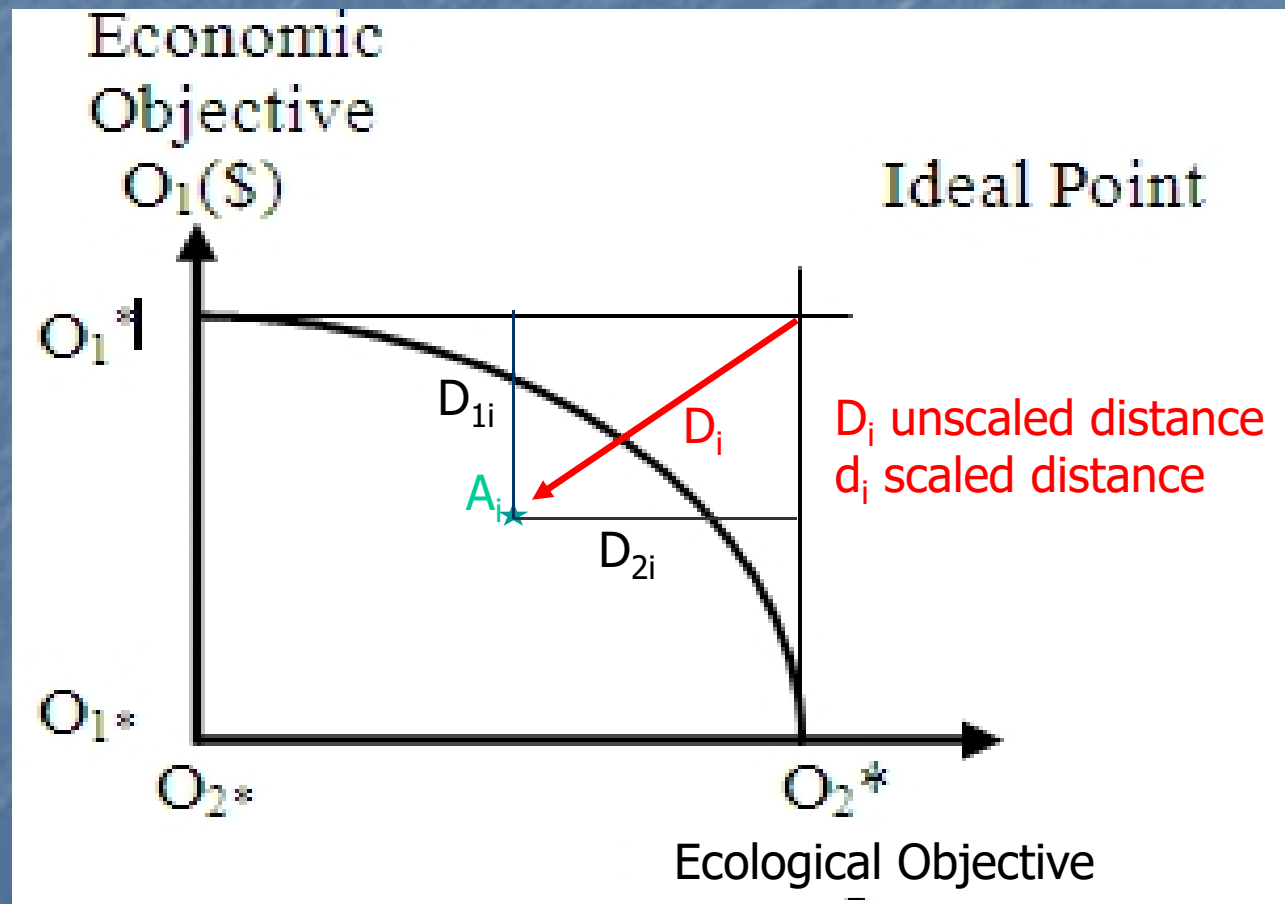
now the $a_{i,j}$ are in % efficiency

Criteria	A_1	A_2	A_3	A_i	A_N
C_1 (€)	a_{11}	a_{12}	a_{13}	a_{1i}	a_{1N}
C_2 ...	a_{21}	a_{22}	a_{23}	a_{2i}	a_{2N}
C_3 (mg/l)	a_{31}	a_{32}	a_{33}	a_{3i}	a_{3N}
C_j ...	a_{j1}	a_{j2}	a_{j3}	a_{ji}	a_{jN}
C_J (ha)	a_{J1}	a_{J2}	a_{J3}	a_{Ji}	a_{JN}

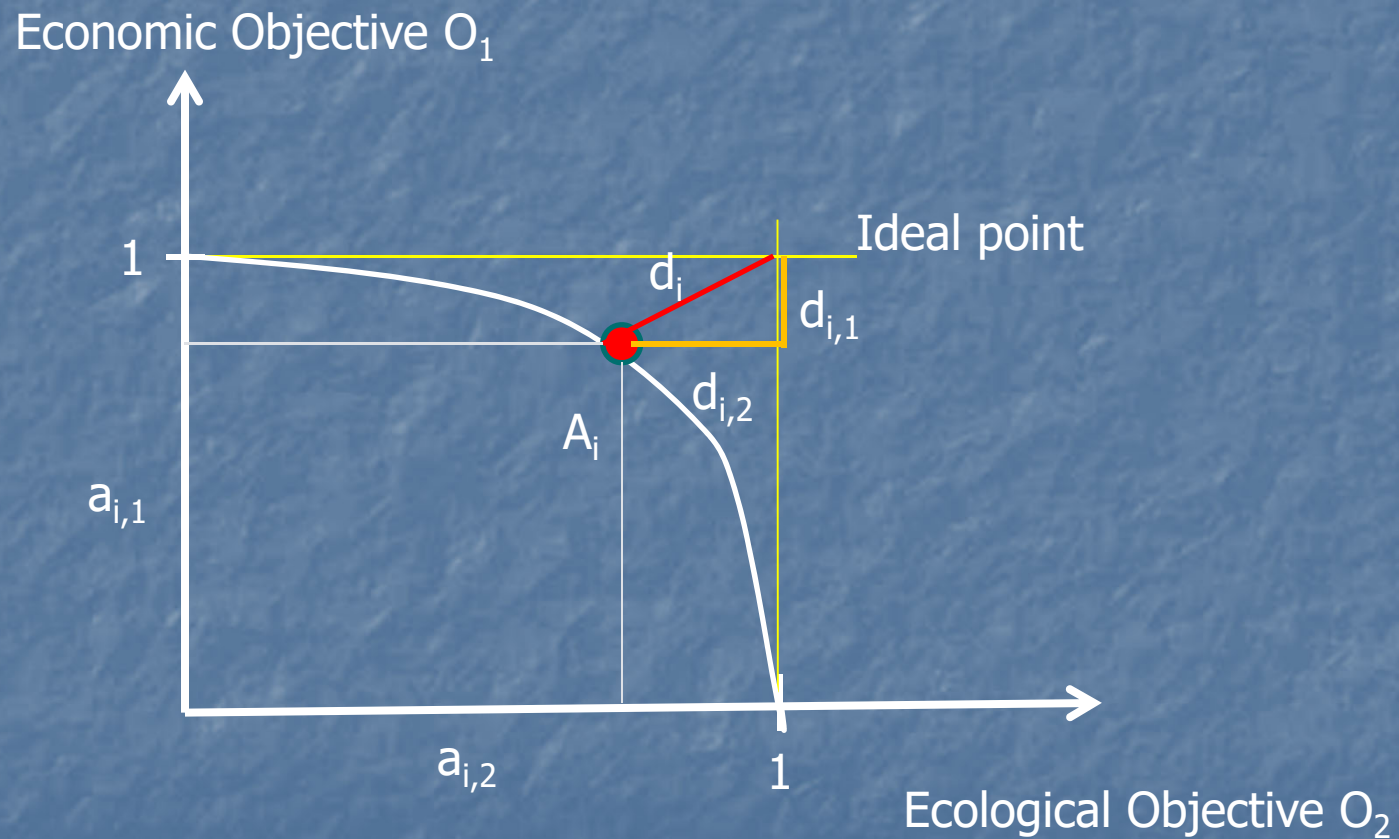
Distance based techniques



Distance based techniques



Scaled Representation



Distance based techniques

$$d_{i,j} = 1 - a_{i,j}$$

$$L_i(p) = \left[\sum (w_j \cdot d_{i,j}^p) \right]^{1/p}$$

Distance with respect to one criterion

Overall distance

w_j weights

p trade-off factor

Outranking techniques

- Often, a pairwise comparison of alternatives is performed
e.g. $A3 > A4$, $A5 > A4$, $A4 > A2$, $A3 > A2$

In ELECTRE (I) only an incomplete ranking can be achieved

In ELECTRE (IV) a complete ranking is achieved

Both approaches require weights and scales for describing the preferences.

ELECTRE I

- Simple example: 2 alternatives, 3 criteria

	A1	A2	W	S
C1	c11	c12	w1	s1
C2	c21	c22	w2	s2
C3	c31	c32	w3	s3

ELECTRE I

C1 NPV in (Mio €)

C2 (mg/l) water pollution

C3 (# of created jobs)

ELECTRE I

- Impact table

W weight

S scale

	A1	A2	W	S	Best	Worst
C1	1.5	1.8	0.5	10	2.0	1.0
C2	10	20	0.2	10	0	50
C3	100	120	0.3	10	200	0

ELECTRE: concordance and discordance

- Concordance expresses the dominance of $A_i > A_j$
- Discordance expresses the weakness of $A_i < A_j$

$$CI(i, j) = \frac{\sum_{A_i > A_j} w_k + \frac{1}{2} \sum_{A_i = A_j} w_k}{\sum w_k}$$

$$DI(i, j) = \text{Max}_{k=1, J} \left\{ \frac{Z_{ki} - Z_{kj}}{\text{Max}(Sc)} \right\} \text{ for all } A_j > A_i$$

- Definition of threshold values C^* and D^*
- Identification of alternatives with high C and low D

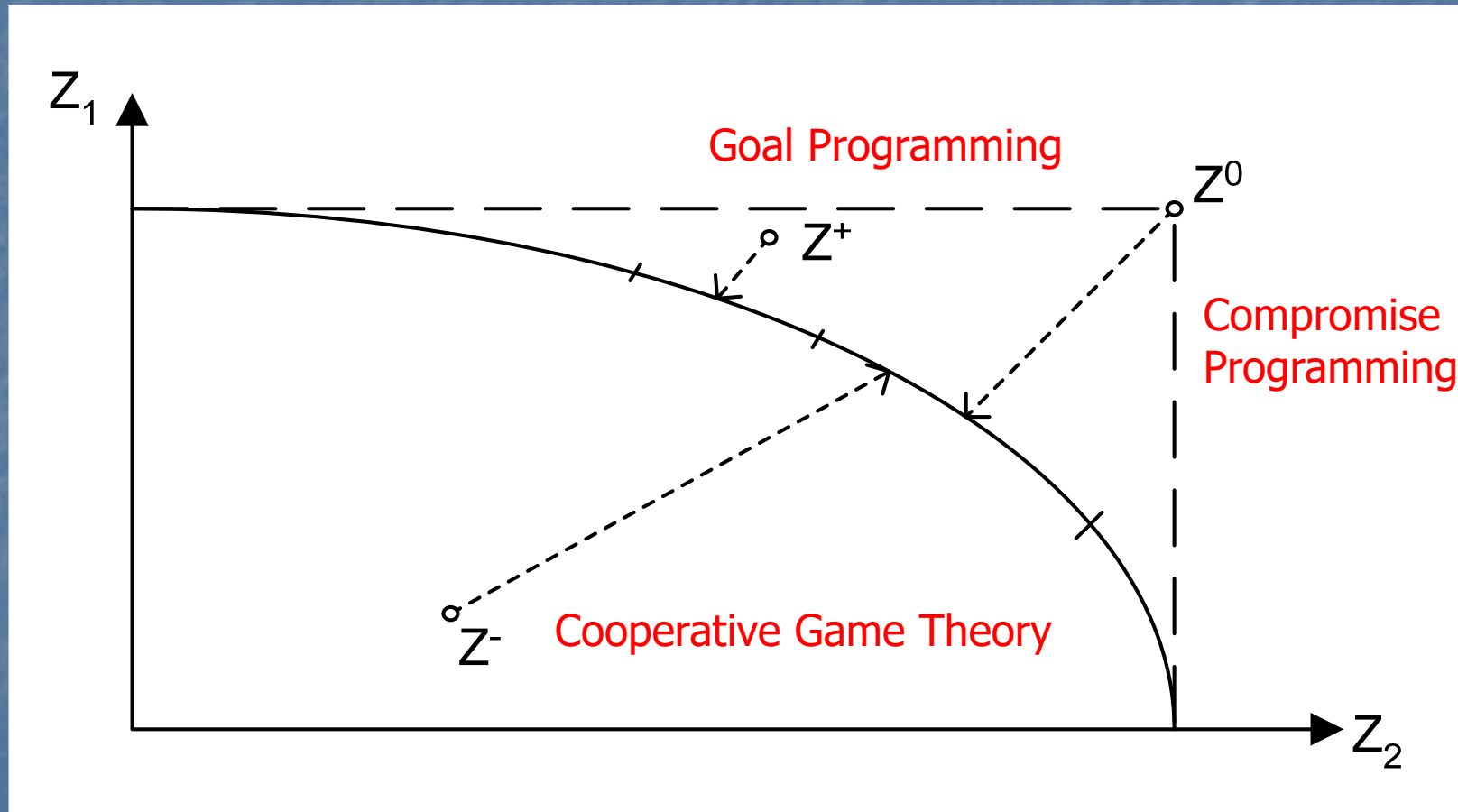
ELECTRE I

- $CO(1,2)=0.2$, $CO(2,1)= 0.8$
- $DI(1,2)= \text{Max} (0.3, 0,1)=0.3$
- $DI(2,1)=\text{Max}(10/50)=0.2$
- Finally two matrices $CO(,)$ and $DI(,)$ are obtained
- A threshold level CO^* and DI^* is introduced (e.g. $CO^* = 0.75, DI^*=0.2$ then $A2 > A1$)

Conclusions

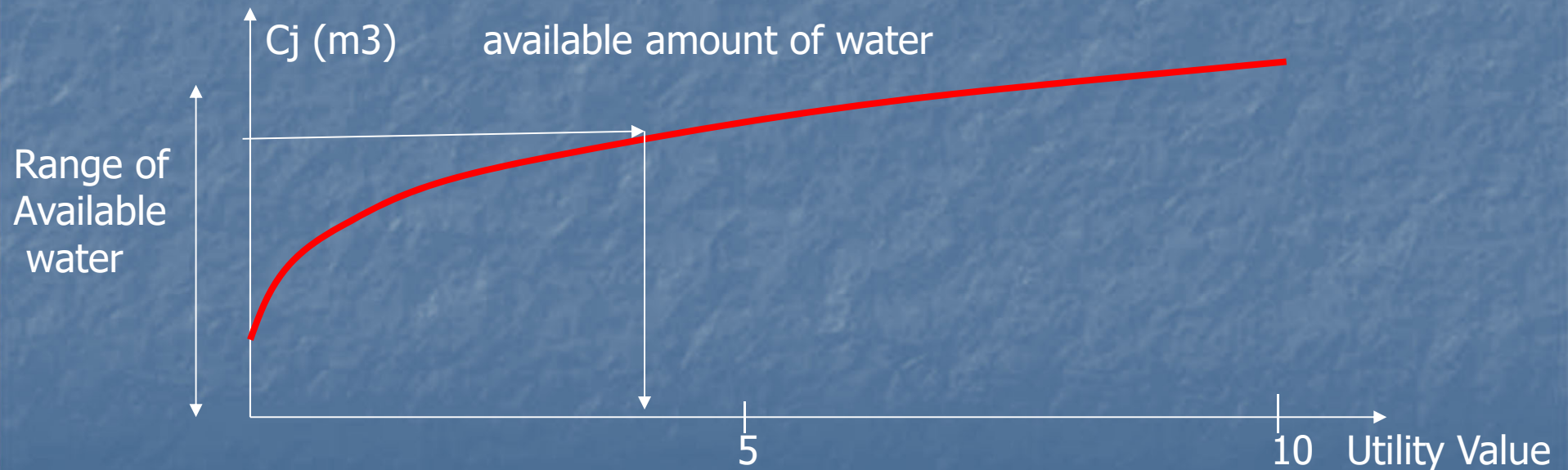
- Numerous methods exist for conflict analysis and resolution
- Multi-objective decision making is a daily problem
- The concepts of multiple objectives is found in many international/national documents
- The major steps are in the problem definition in the impact assessment in knowing about the preferences
- The numerical methods are helpful in improving the understanding of the problem and the exploring the feasible domain

Distance based techniques



Utility based techniques

- Often single attribute utility theory is applied
- If possible, MAUT (Multi-Attribute-Utility Theory) should be applied



Utility theory

- (1) Impact matrix
- (2) Transformation of impacts into utilities
- (3) Definition of weights for each criterion
- (4) Overall utility value UV_i of alternative A_i is

$$UV_i = \sum_j w_j \cdot uv_{ij}$$

1-D and 2-D Utility Functions

