Cost Benefit and Spatial Multi-Criteria Evaluation for Risk Assessment

SEVENTH FRAMEWORK PROGRAMME
THE PEOPLE PROGRAMME
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Cost-Benefit Analysis

Discounting and present value

What would you prefer?

- Money given to you now or money given to you 3 years later?
- How much your money now will be worth in the future, say 3 years from now?
- How much is the worth now of say, $ 100 that you will receive 3 years from now?

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Discounting and present value

Initial Money : B Interest rate : r Time invested: n	
Year 0	B_0
Year 1	$B_1=B_0 + B_0(r)$
Year 2	$B_2=B_1 + B_1(r)$
Year 3	$B_3=B_2 + B_2(r)$
Year N	$B_n=B_{(n-1)} + B_{(n-1)}(r)$

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Discounting Costs and Benefits

Discounting

- Nature of a project is such that benefits and costs occur at different points in time
- A given sum of money now is considered more valuable than the same amount received in a future period

Discounting is a methodology that allows comparison of benefits/costs occurring in different time periods in the future at the initial year of the project.

Important elements of discounting are the discount rate and time.

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General Principles

- The discounted benefits should be greater than the discounted costs over the economic life of the project
- Costs are generally incurred at the start of the project
- Benefits are generally derived after the completion of structures, installation of equipment, etc (operational stage)
- Full benefits will occur on various time periods for different types of project.

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Example in Conducting CBA for a flood control project

- Situation:
- A river that has been causing floods in the city every 5 years.
- The government decides to do mitigate the effects of the floods from the river

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Step 1. Enumerate the options that will prevent floods.

- Dikes
- River diversion
- Flood gates
- Others

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Step 2. Determine the efficacy of the options, that is, how much flood water can be prevented.

- How many businesses will be saved from the flood? How income of businesses can be saved?
- How many hectares of land will be saved from floods? What is the value of production that can be saved due to the project?

Step 2. cont'd

- How many houses, buildings and structures will be saved due to the project? How much cost of repair and reconstruction will be avoided?
- Will there be other benefits that can be derived?
  - income from businesses, etc.
- This can be done by preparing a feasibility study.

Step 3. Estimate the cost of each option

Costs	Year									
	1	2	3	4	5	6	7	8	9	10
Initial Investment										
1. *Land*										
1. *Engineering design*										
1. *Site Development*										
1. *Materials*										
1. *Equipment*										
1. *Labor*										
1. *Fees/Permits*										
1. *Others*										
Operating Costs										
1. *Personnel*										
a. *Manager*										
a. *Staff*										
a. *Others*										
1. *Maintenance*										
a. *Repairs*										
a. *Materials*										
a. *Others*										
1. *Utilities*										
a. *Electricity*										
a. *Water*										
a. *Communications*										
a. *Others*										
Interest Payments										
Others										
TOTAL										

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Cash flows of the project

Construction of the cash flow statement is generally preceded by the chronological organization of variables and data into three stages, with each stage corresponding to a plan:

1. Investment stage
2. Operating stage
3. Cessation-of-operation stage: Residual values

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Step 4. Analyse the benefits of the project.

Analyze the "with" and "without the project" situation.

Sector/Sub-sectors	Without the Project ($)		With the Project ($)		Net Value ($)
	Damages	Losses	Damages	Losses	
Agriculture					
Manufacturing					
Power					
The other sectors					
NET BENEFIT					

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Step 4. cont'd

- The potential benefits are the reduction in damages and losses (or savings) that will be generated from the potential damages and losses, which are the cost of reconstruction and repair; and the avoided production/income, foregone taxes and other losses of the government and various sectors.
- "The other sectors" refers to the sectors/sub-sectors covered included in the past training.
- Under "without the project", the values of damages and losses can be gathered from the past floods.
- Under "with project", the values of damages and losses should be estimated in the analysis of the options in preventing floods (the feasibility study).

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Step 5. Plot the Cost and Benefits of the project.

Costs	Year									
	1	2	3	4	5	6	7	8	9	10
1. Initial Investment										
1. Operating Costs										
1. Interest payments										
1. Others										
Total										
Benefits										
Reduction in damages and losses in:										
1. Agriculture										
1. Manufacturing										
1. Power										
1. The other sectors										
Total										
NET TOTAL										

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Step 5. cont'd

- The net total will be the sum of benefits less the sum of the costs.
- The benefits (value of damages and losses avoided) should consider the timing when it will be realized (using the probabilistic values derived from various methodologies)

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Step 6. Determine the Net Present Value (NPV) of the project

	Year									
	1	2	3	4	5	6	7	8	9	10
Costs										
Benefits										
NET TOTAL										

- Decision rule:
  - If NPV > or = 0, the project is economically desirable
  - If NPV < 0, the project is not economically desirable

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Step 7. Perform Sensitivity Analysis

- Adjust some possible changes in the assumptions on costs and benefits.
- What if costs escalate by 20%?
- What if floods will not happen in 10 years?

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Step 8. Analyse the other projects as options

- Following the same steps, analyse the NPVs of the other projects with the same purpose (like river diversion instead of dike).
- The project with the highest NPV is the most desirable project.

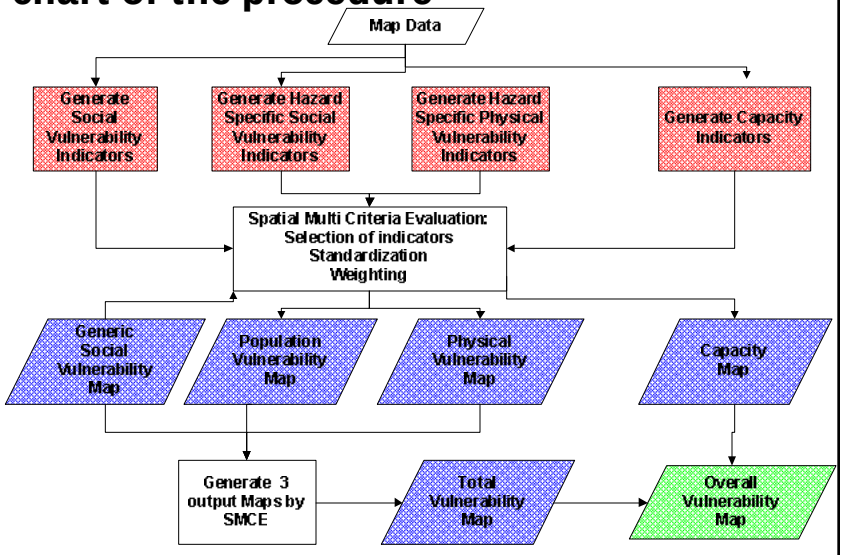
Spatial Multi Criteria Evaluation

Risk Assessment Methods

- Qualitative:
  - Overlay of hazard footprints and elements at risk
  - Using a simple matrix approach
  - Using indicator analysis (e.g. SMCE)
  - Using risk indices
- Semi-Quantitative:
  - Scenario-based loss estimation
  - Probabilistic loss estimation
  - Effect trees (what if)
  - R = H * V * A
- Quantitative (QRA)
  - Based on economic losses
  - Involving direct and indirect losses

RISK = HAZARD * VULNERABILITY * AMOUNT

Flow chart of the procedure



RISK = HAZARD * VULNERABILITY / CAPACITY

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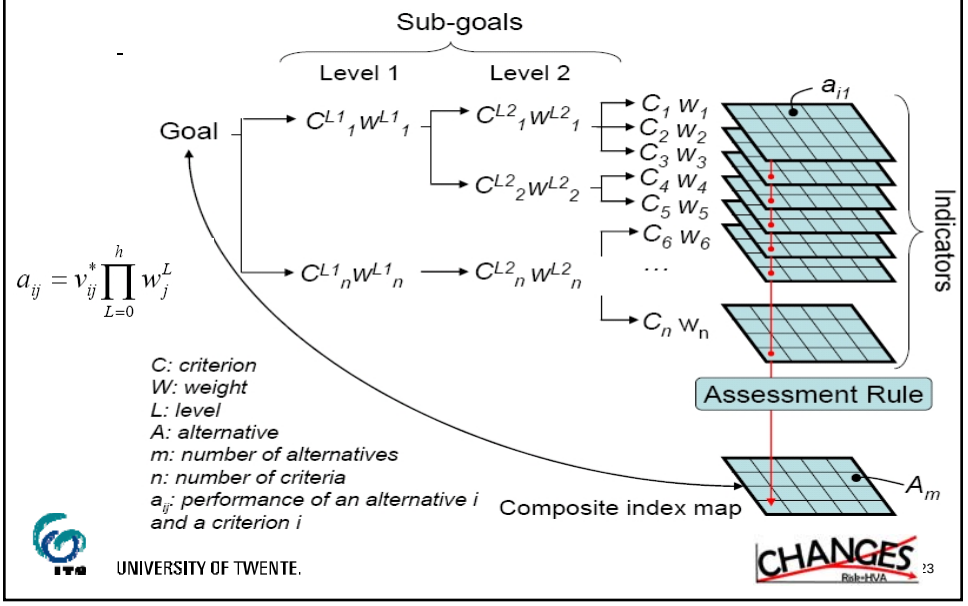
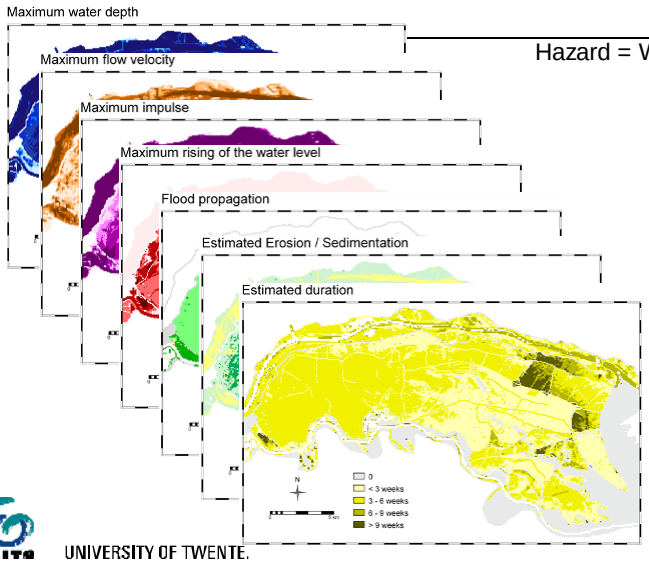
Spatial Multi-Criteria Evaluation



Flood hazard: A multi-parameter issue



Hazard = Water depth +

Flow velocity +

Impulse +

Rising +

Propagation +

Sedimentation +

Duration ?

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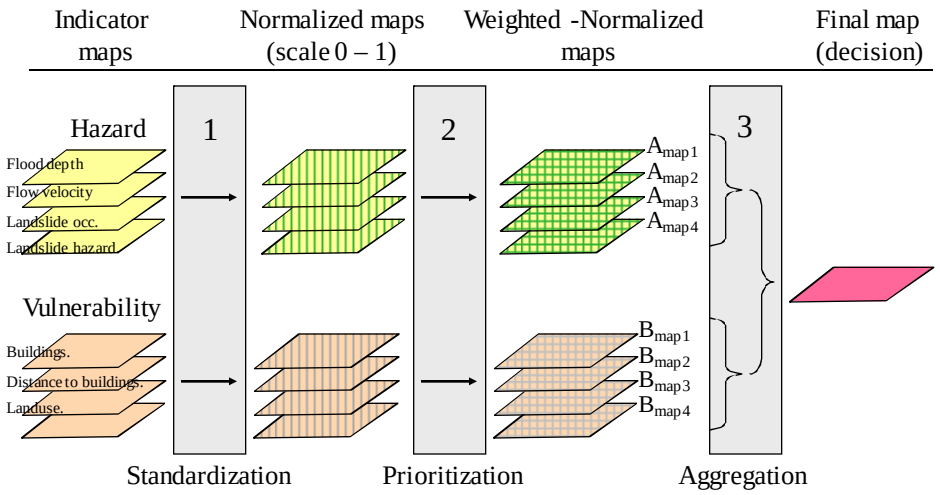
3-step SMCE procedure



Standardization: rescaling of the maps to a value range of 0 to 1 – inside the maps
Prioritization: Assignment of relative weights to indicate importance of the maps
Aggregation: Integration of all factors into a final output.

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Data and decision problem

- Start problem driven
- Find out missing data
- Assess value of data
- Use proxy indicators. (correlation)

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SMCE process

- Identification of the main goal.
- Identification of a hierarchy of sub goals.
- Identification of criteria or effects, which measure the performance of the sub goals.
- Creating and filling a criteria tree, which represents the hierarchy of the main goal, any sub goals, and the criteria.
- Identification of alternatives to be evaluated.
- Assignment of input maps to criteria for each alternative.
- Determination of a standardization method per criterion.
- Weighing of criteria in the criteria tree.
- Calculation of the Composite Index maps and visualization.
- Classifying or slicing the Composite Index maps and visualization.
- Calculation of Shape Index and/or Connectivity Index.

Formulate (sub-)objectives well – the criteria tree should be self-explanatory

Poor formulation

- Environmental (criteria)
- Economic (criteria)
- Social (criteria)

Data driven

Good formulation

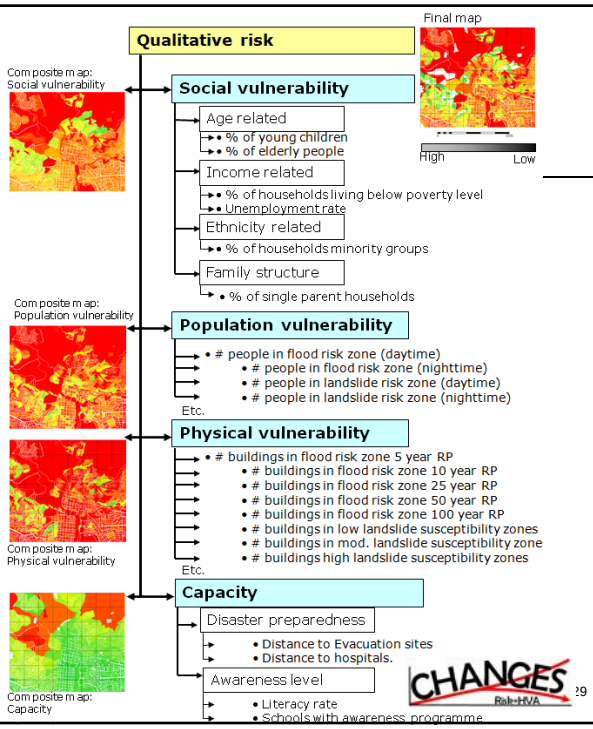
- (we want) to minimize environmental impact
- (we want) to minimize economic risk
- (we want) to create stable social networks

Problem driven

Tip: use verbs!

& “so what does it mean?”

Procedure



Indicators

1. Generic social vulnerability indicators:

- Percentage of young children
- Percentage of elderly people
- Percentage of minority groups
- Percentage of single parent households
- Percentage of households living below poverty level.
- Literacy rate

Indicators

2. Hazard specific social vulnerability indicators

- people located in flood risk zones, both a daytime and nighttime scenario
- people located in landslide risk zones, both a daytime and nighttime scenario
- people located in technological risk zones, both a daytime and nighttime scenario
- people located in seismic risk zones, both a daytime and nighttime scenario

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Indicators

3. Hazard specific physical vulnerability indicators

- buildings located in flood risk zones, with different return periods
- buildings located in landslide risk zones, with different degree of susceptibility to landslides
- buildings located in technological risk zones, with different degree of susceptibility to landslides
- buildings located in seismic risk zones, with different intensities and return periods

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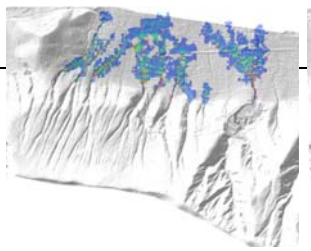
Indicators

4. Capacity indicators

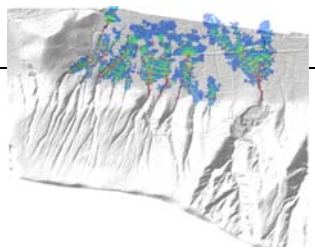
- Distance to Evacuation sites
- Distance to hospitals.
- Awareness

Flood hazard indicators:

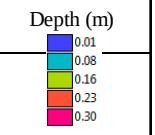
Flood depth:



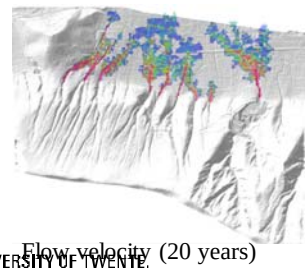
Flood Depth (20 years)



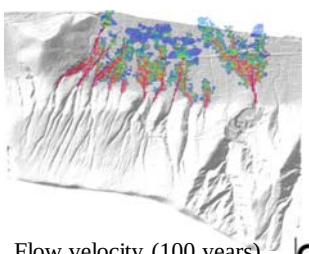
Flood Depth (100 years)



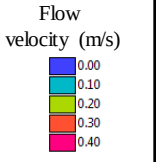
Flow velocity:



Flow velocity (20 years)

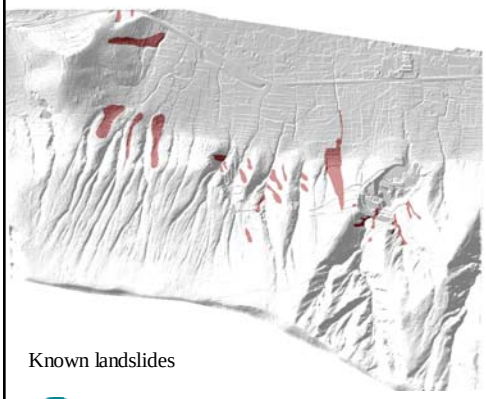


Flow velocity (100 years)

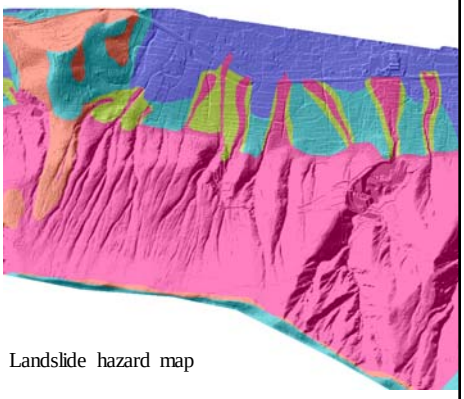


Landslide hazard indicators:

Landslides:



Known landslides



Landslide hazard map

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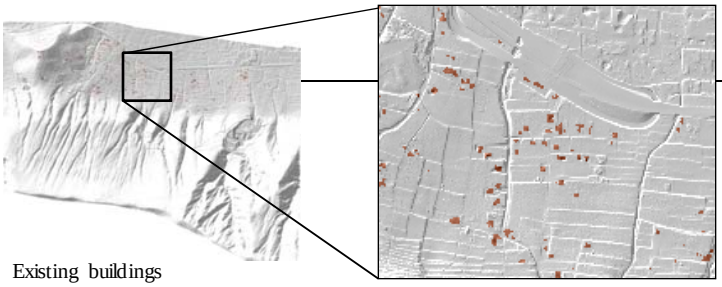
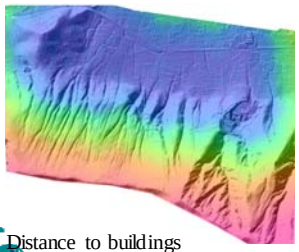
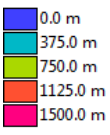
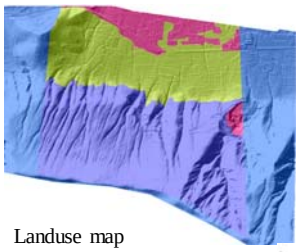
Vulnerability indicators:



Existing buildings







Distance to buildings

Landuse map

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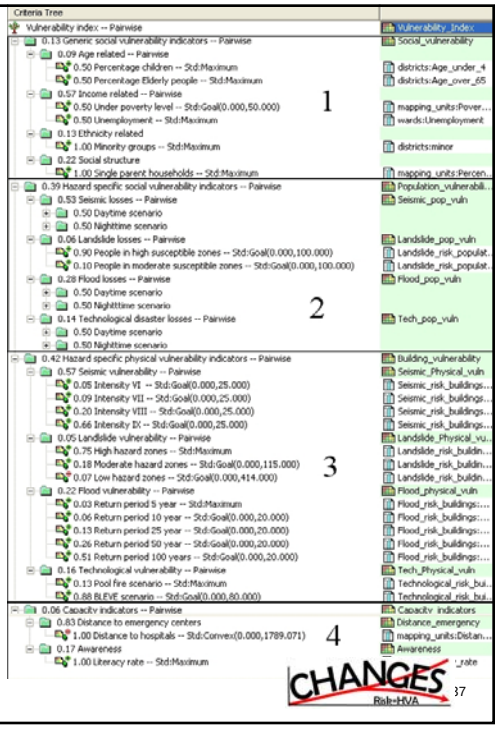
Spatial multi-criteria analysis

A criteria tree contains all criteria

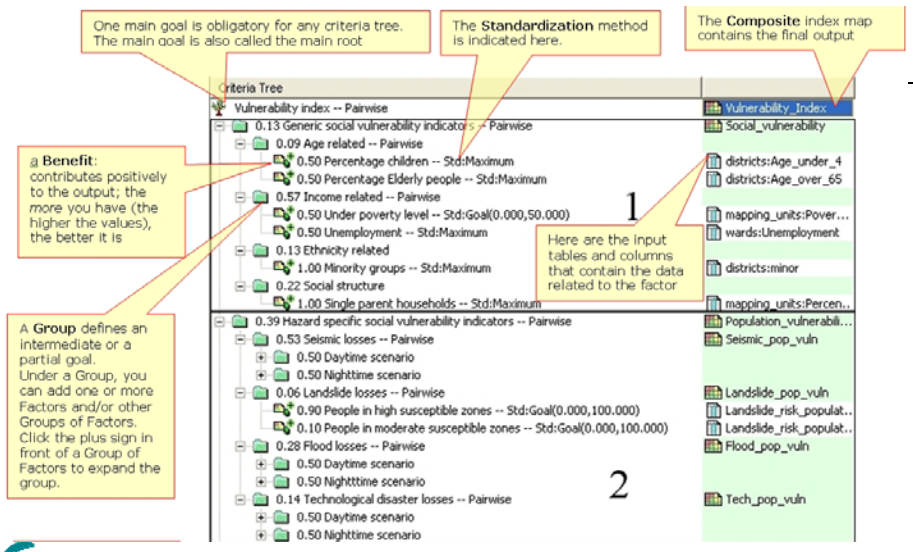
Factors: a criterion that contributes to a certain degree to the output

- Benefits
  - **contributes positively to the output; the *more* you have (the higher the values), the better it is**
- Costs
  - **contributes negatively to the output; the *less* you have (the lower the values), the better it is**

Constraints: criterion that determines in the calculation of the main goal
.Mask out area



The criteria tree



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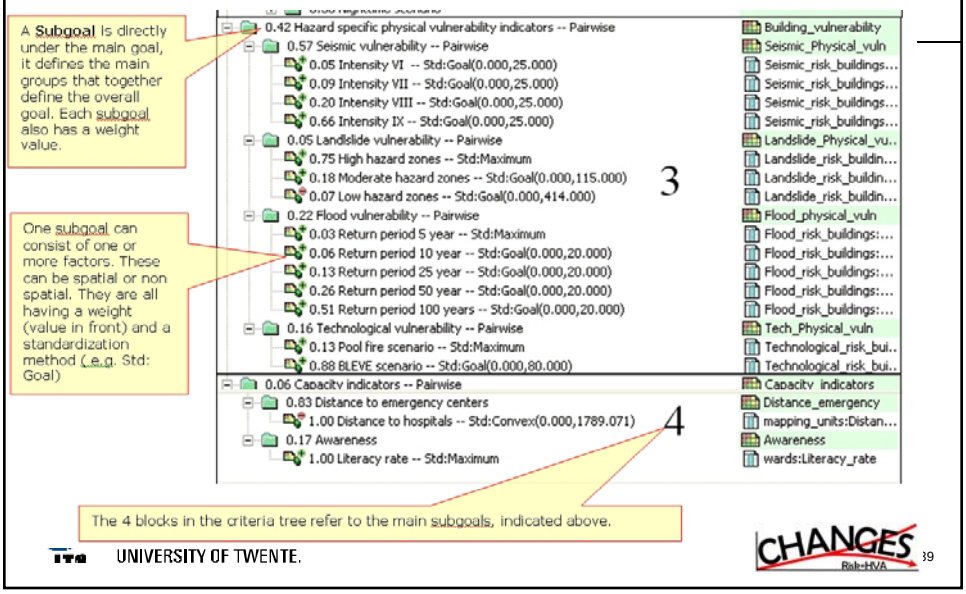
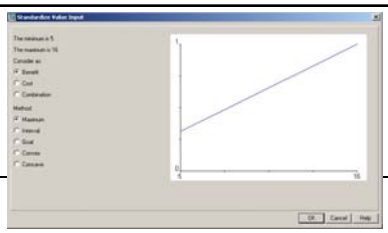
The criteria tree



Good features of family of criteria

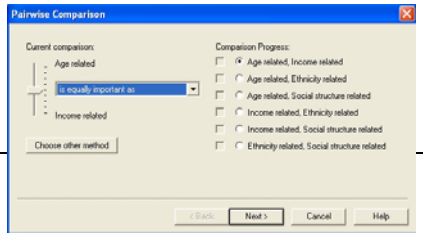
- Measurable
  (explain effects in terms of the fundamental interest in the situation)
- Understandable
  (facilitate communication and understanding)
- Completeness: the main categories have to represent all the relevant aspect
- Comprehensibility: each category has to be as homogenous as possible and has to represent a recognizable type of differences
- Balance: main categories have to be equal in relation to the level they express
- Double counting: each category must be as distinguishable as possible

Standardization of criteria



- Maximum: The input values are divided by the maximum value of the map
- Interval: Linear function with the maximum and minimum values of the map
- Goal: Linear function with a specified maximum and minimum values
- Piecewise linear: Linear function with two breaking points located between the extremes
- Convex: Convex function with one user defined value to re-shape the curve
- Concave: Concave function with one user defined value to re-shape the curve
- U-Shape: U-shape curve with one user defined value to stretch or shrink the curve GaussianBell-shape curve with one user defined value to stretch or shrink the curve

How to select weights?



- Direct estimation by expert
  - The user has to specify weight values him/herself. These user-defined weights are automatically normalized
- Pair-wise comparison
  - With a pairwise comparison matrix, each variable (or criterion) is compared to all others in pairs in order to evaluate whether they are equally significant, or whether one of them is somewhat more significant / better than the other for the goal concerned
- Ranking method
  - the criteria and variables are simply ranked according to their importance as landslide controlling factors
- Source: ILWIS Multi Criteria Evaluation

SMCE in this study: