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Vulnerability Assessment and Damage Analysis as Planning Imperatives

credits:
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Dr. Ing. PhD Silvia Simoni
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Dr. Ing. Bernhard Gems
Dipl. Ing. Thomas Hofer

Contents:

1. A quick tour: the processes of interest

2. Process and impact patterns for a “residential building“

3. A formal Cost-Benefit Analysis Framework Based on Dynamic Risk Assessment – State of the Art of Vulnerability and Risk Assessment

4. A discursive presentation of a case study

5. Design Principles to mitigate Flood Risk

A quick tour: the processes of interest

1

1981 - Salurn - Salorno

A quick tour: the processes of interest

1

A quick tour: the processes of interest

1

1966 - Innichen – San Candido

A quick tour: the processes of interest

1

1966 - Welsberg - Monguelfo

A quick tour: the processes of interest

1987 – Martell – Val Martello

2008 – Tisenserbach – Rio Tisana

1987 – S. Leonhard i.P. – S. Leonardo in P.

A quick tour: the processes of interest

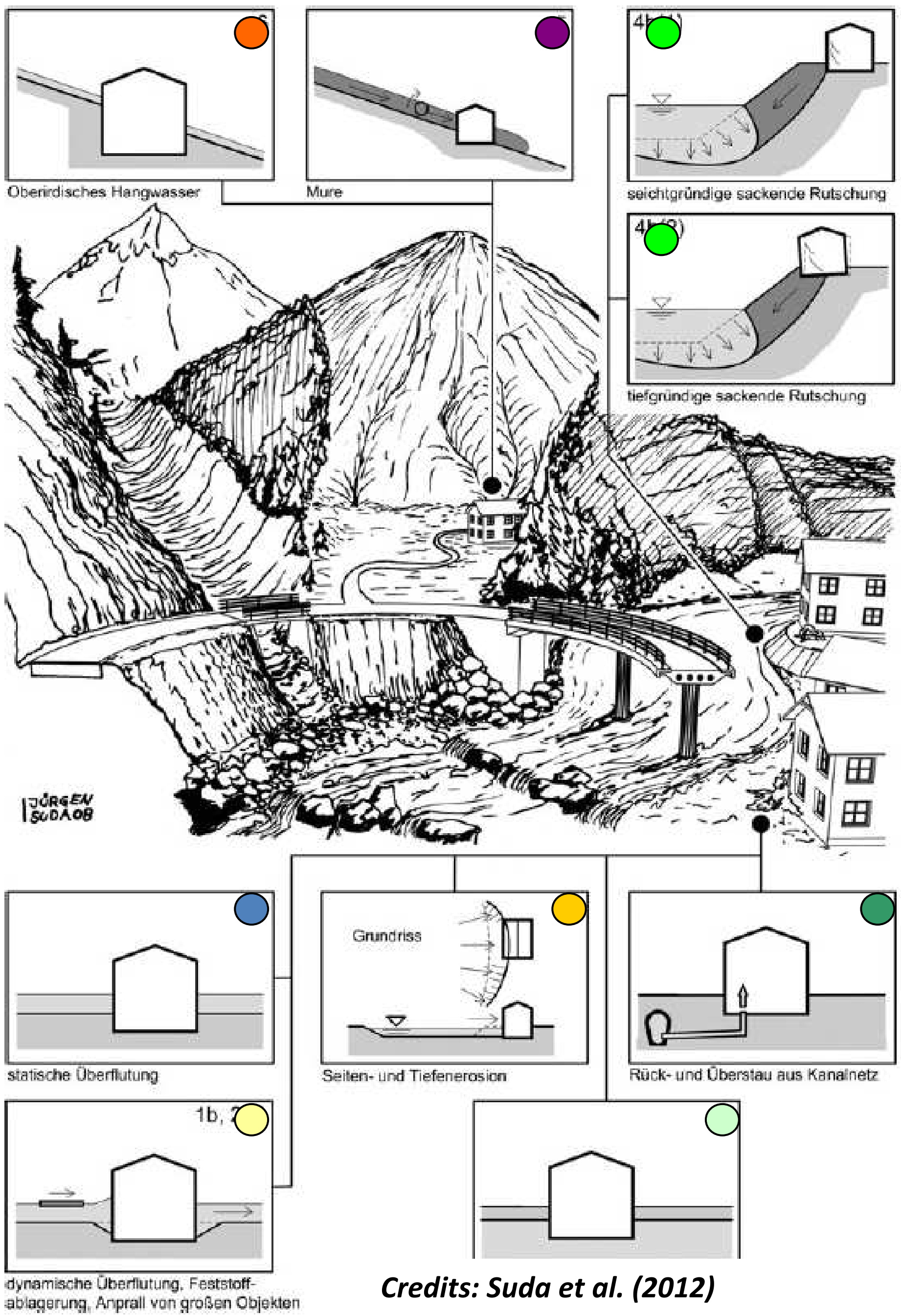
1

2002 – Ulten – Val d‘Ultimo

A quick tour: the processes of interest

1

1986 – Tramin – Termeno



Credits: Suda et al. (2012)

2

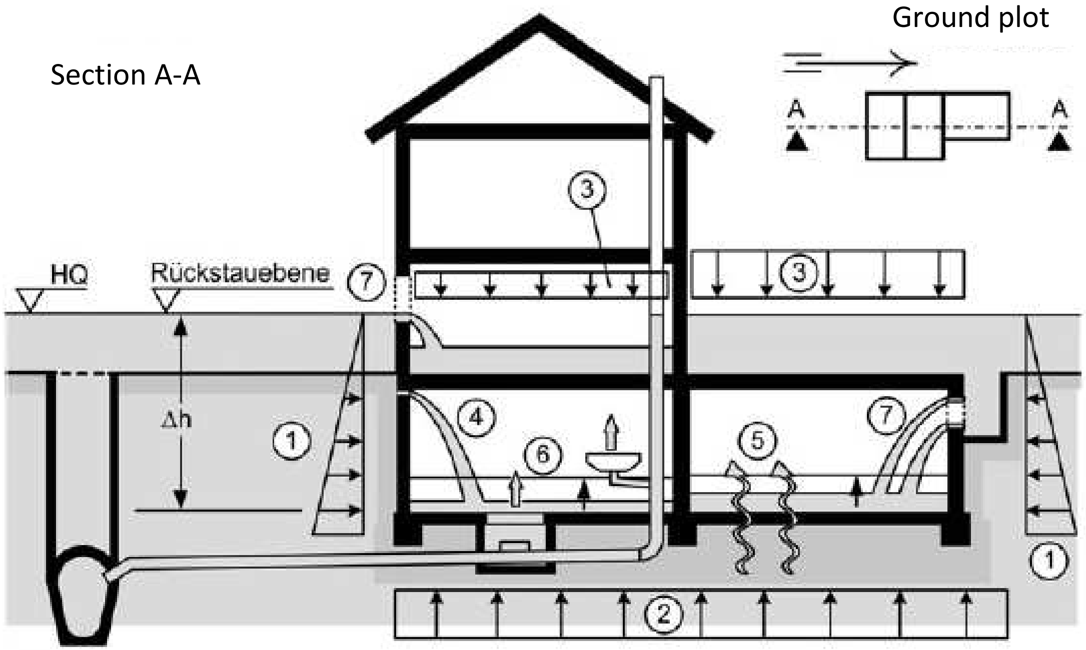
Process patterns for a “residential building“

- „static“ flooding
- „dynamic“ flooding
- groundwater upsurge
- lateral erosion and incision
- “pluvial” flooding
- “overland” flow
- debris flow
- Flow – soil mechanics interaction

Exemplified process patterns

Impact patterns for a “residential building“

2

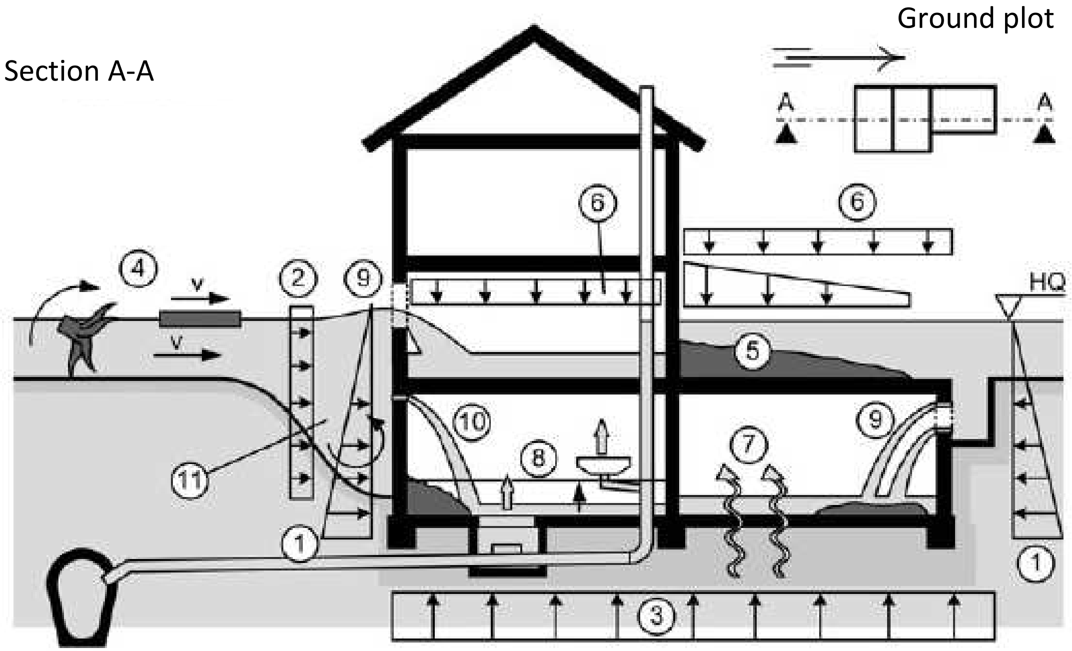


1. Hydrostatic pressure
2. Buoyancy
3. Vertical loading
4. Water intrusion through structural discontinuities
5.
6. Water intrusion through backwater effects in the sewage system
7. Water intrusion through openings in the building envelope

Impact pattern „static“ flooding

Credits: Suda et al. (2012)

Impact patterns for a “residential building“

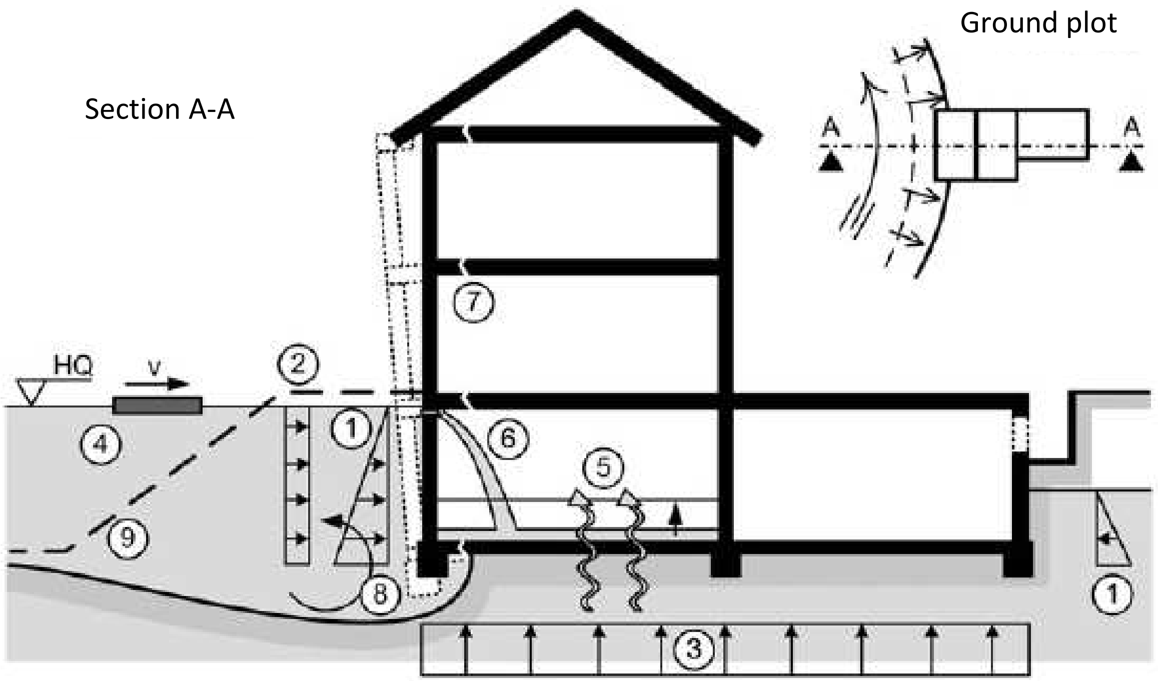


1. Hydrostatic pressure
2. Dynamic pressure
3. Buoyancy
4. Impact of wood stems and roots
5. Deposition
6. Vertical loading
7. Water intrusion through structural discontinuities
8. Water intrusion through backwater effects in the sewage system
9. Water intrusion through openings in the building envelope
10.
11. Erosion

Impact pattern „dynamic“ flooding

Credits: Suda et al. (2012)

Impact patterns for a “residential building“



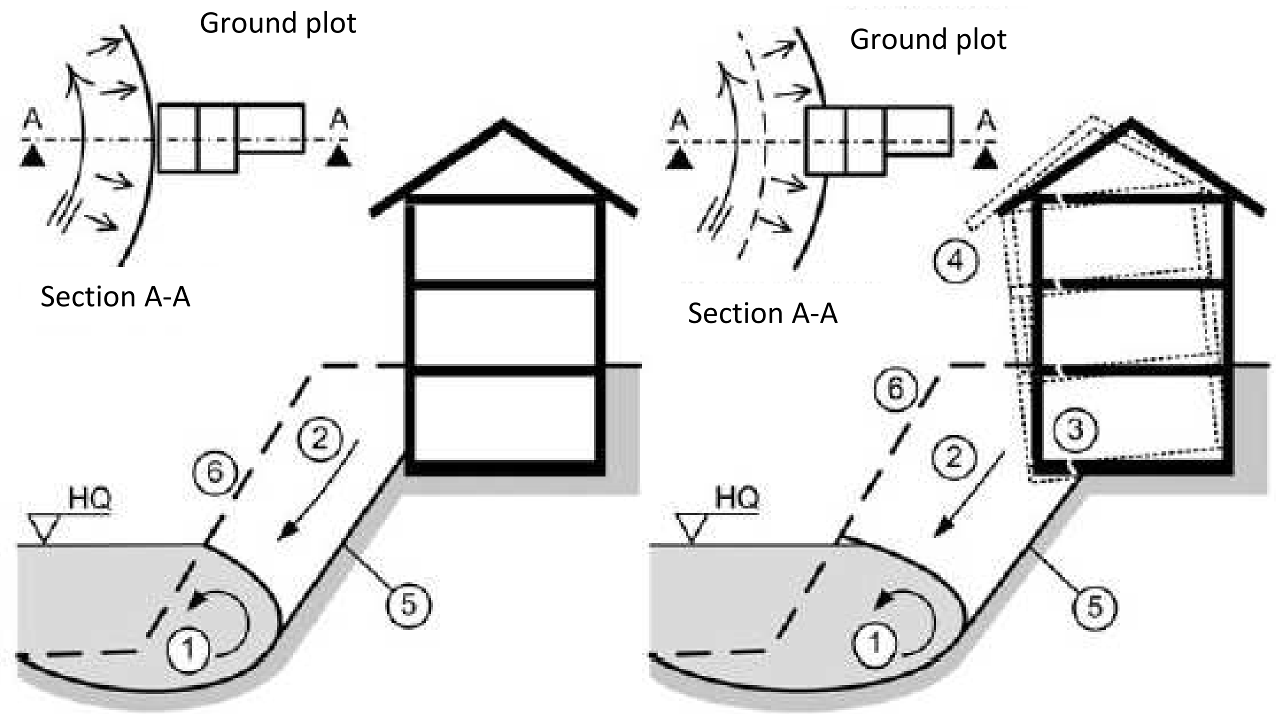
1. Hydrostatic pressure
2. Dynamic pressure
3. Buoyancy
4. Impact of wood stems and roots
5. Water intrusion through openings in the building envelope
6.
7. Deformations and failures in the static system [response?]
8. Erosion
9. Topography before the event

Impact pattern lateral erosion and incision

Credits: Suda et al. (2012)

2

Impact patterns for a "residential building"



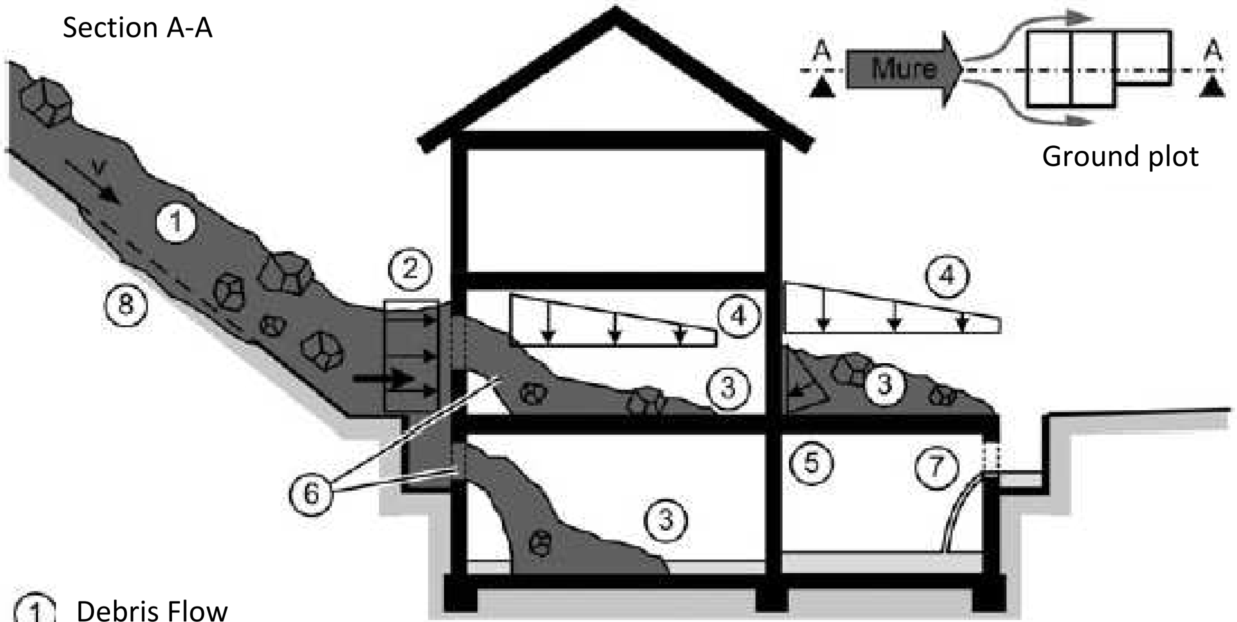
(1) Lateral erosion
(2) Slope failure
(3) Deformations and failures in the static system
(4) Settlement and rotational movements
(5) Sliding surface
(6) Topography before the event

Impact pattern flow – soil mechanics interaction

Credits: Suda et al. (2012)

Impact patterns for a “residential building“

2



(1) Debris Flow
(2) Debris Flow impact on the building envelope
(3) Debris Flow deposited volumes – vertical loading
(4)
(5) Earth pressure
(6) Intrusion of debris flow material through openings in the building envelope
(7) Intrusion of percolating water through openings
(8) Erosion

Impact pattern Debris flow

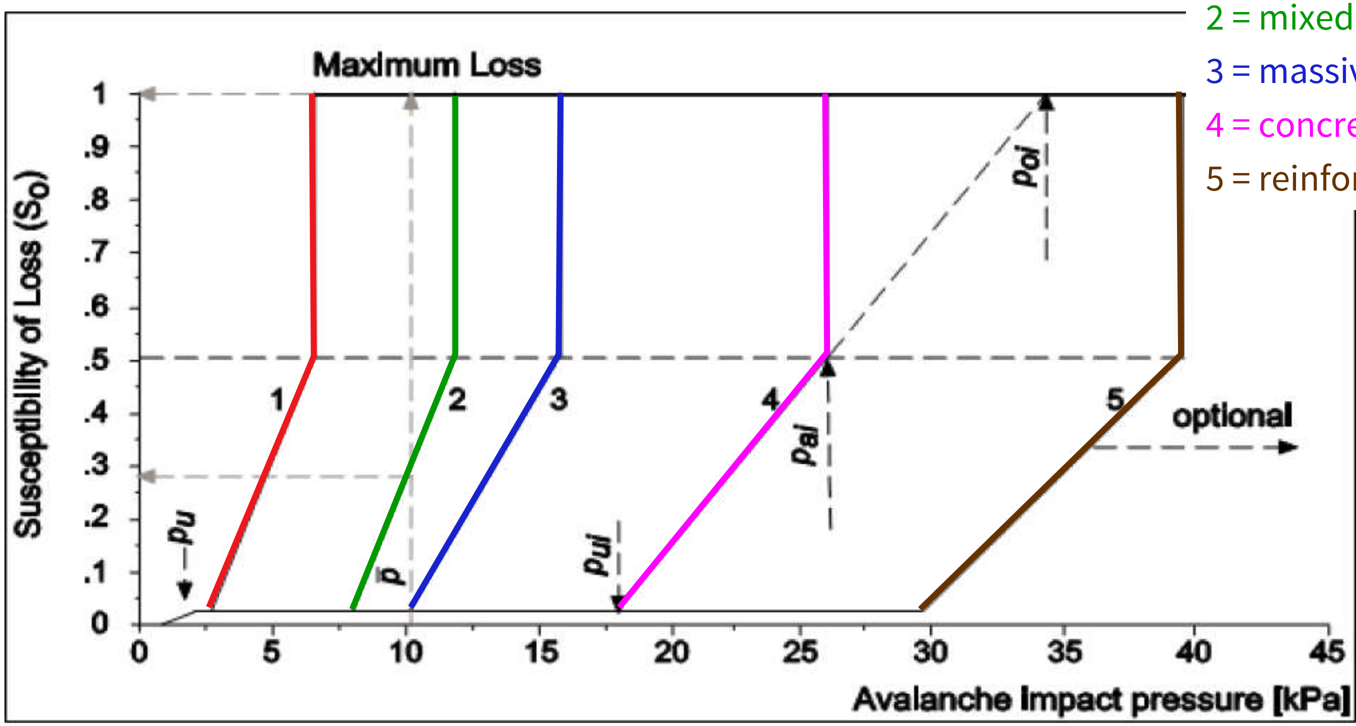
Credits: Suda et al. (2012)

CLOSURE PROBLEM: IMPACT –LOSS NEXUS
Vulnerability Curves (Functions)

2

- Vulnerability Model considering from building material

1 = lightweight construction
2 = mixed construction
3 = massive construction
4 = concrete reinforced construction
5 = reinforced construction

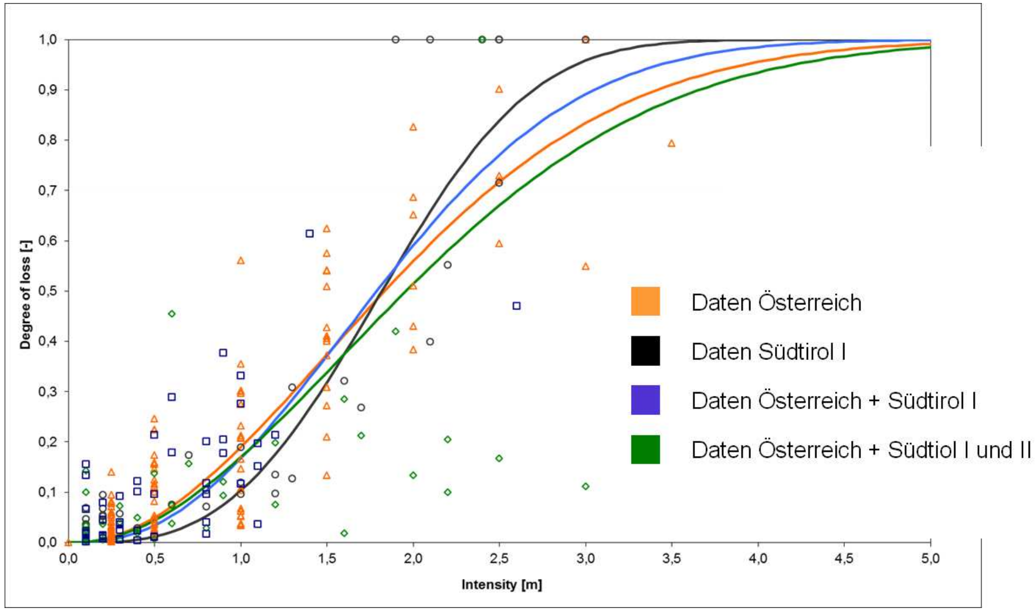


Wilhelm (1997)

Keiler, Sailer, Jörg, Weber, Fuchs, Zischg, Sauermoser (2006): Avalanche risk assessment – a multi-temporal approach, results from Galtür, Austria. *Natural Hazards and Earth System Sciences* 6: 637-651

CLOSURE PROBLEM: IMPACT –LOSS NEXUS Vulnerability Curves (Functions)

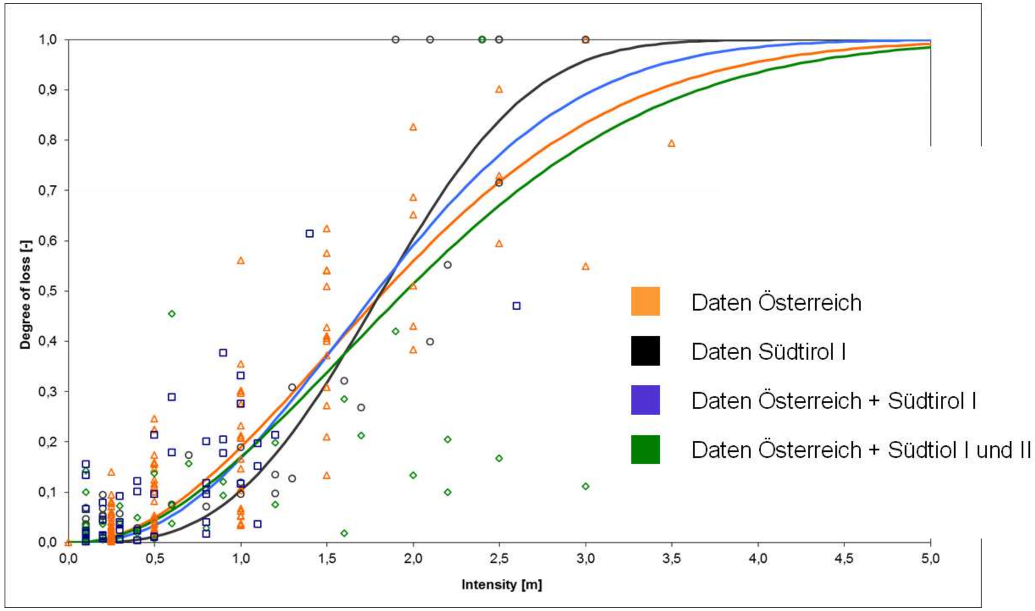
- Large deviations from best-fit functions (for deposition depths >1m)

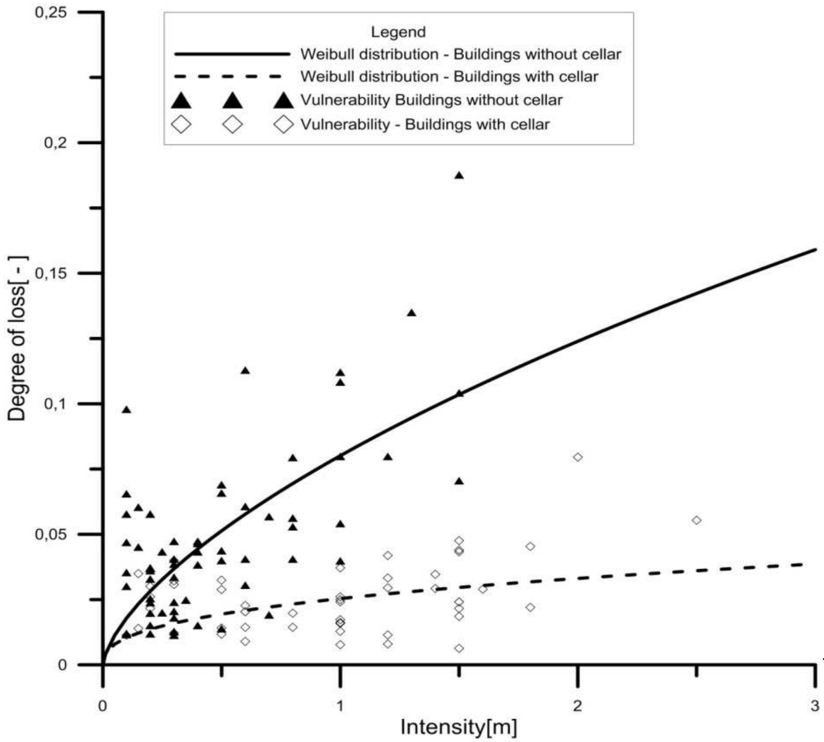


Holub, Suda, Fuchs (2013): Mountain hazards: reducing vulnerability by adapted building design. *Environmental Earth Sciences* 66: 1853-1870

Empirical vulnerability functions

- Empirical vulnerability functions (comparison Alps – Greece)



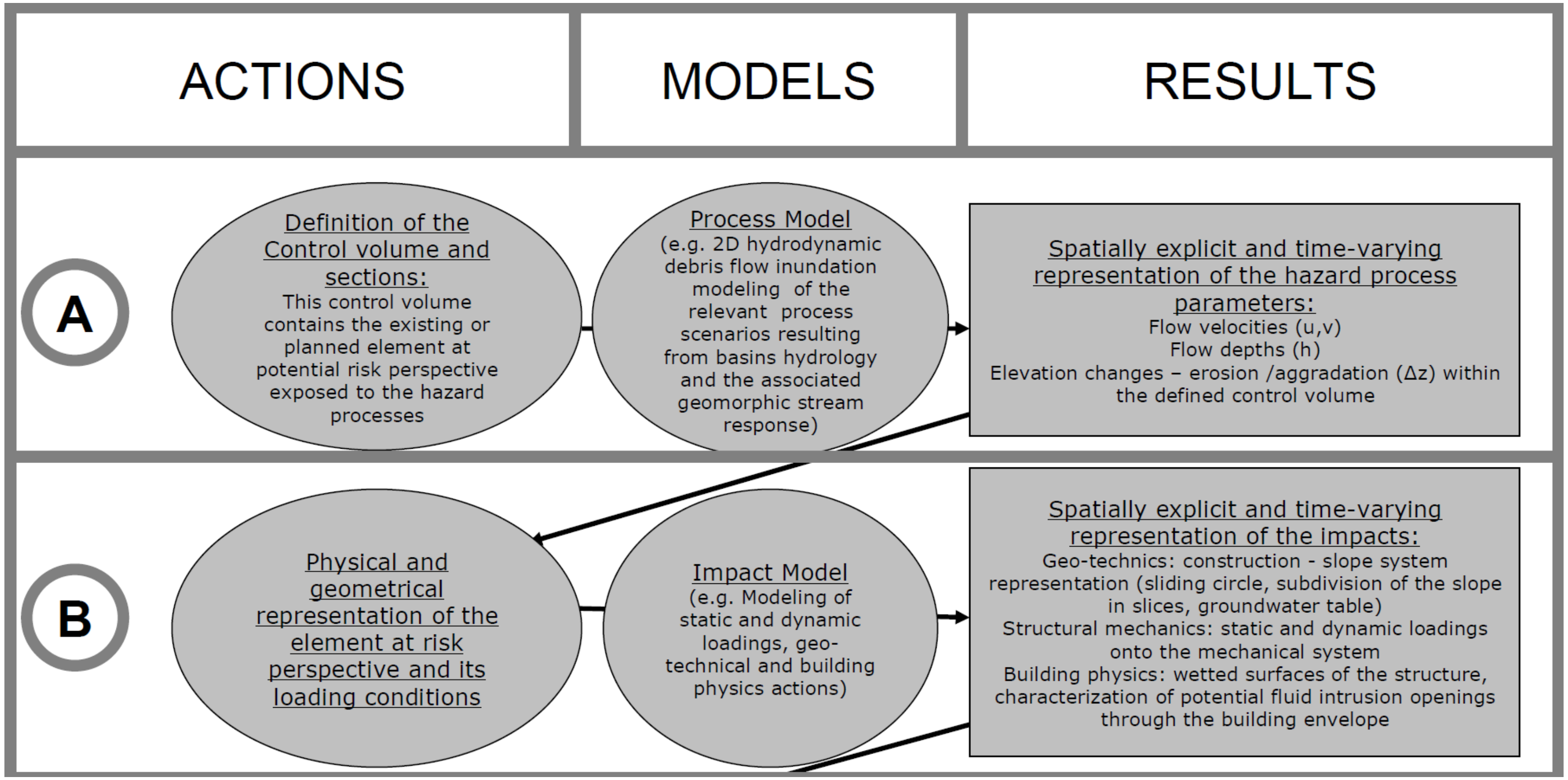


Karagiorgos et al. (in press)

Holub, Suda, Fuchs (2013): Mountain hazards: reducing vulnerability by adapted building design. *Environmental Earth Sciences* 66: 1853-1870

Physically based vulnerability assessment

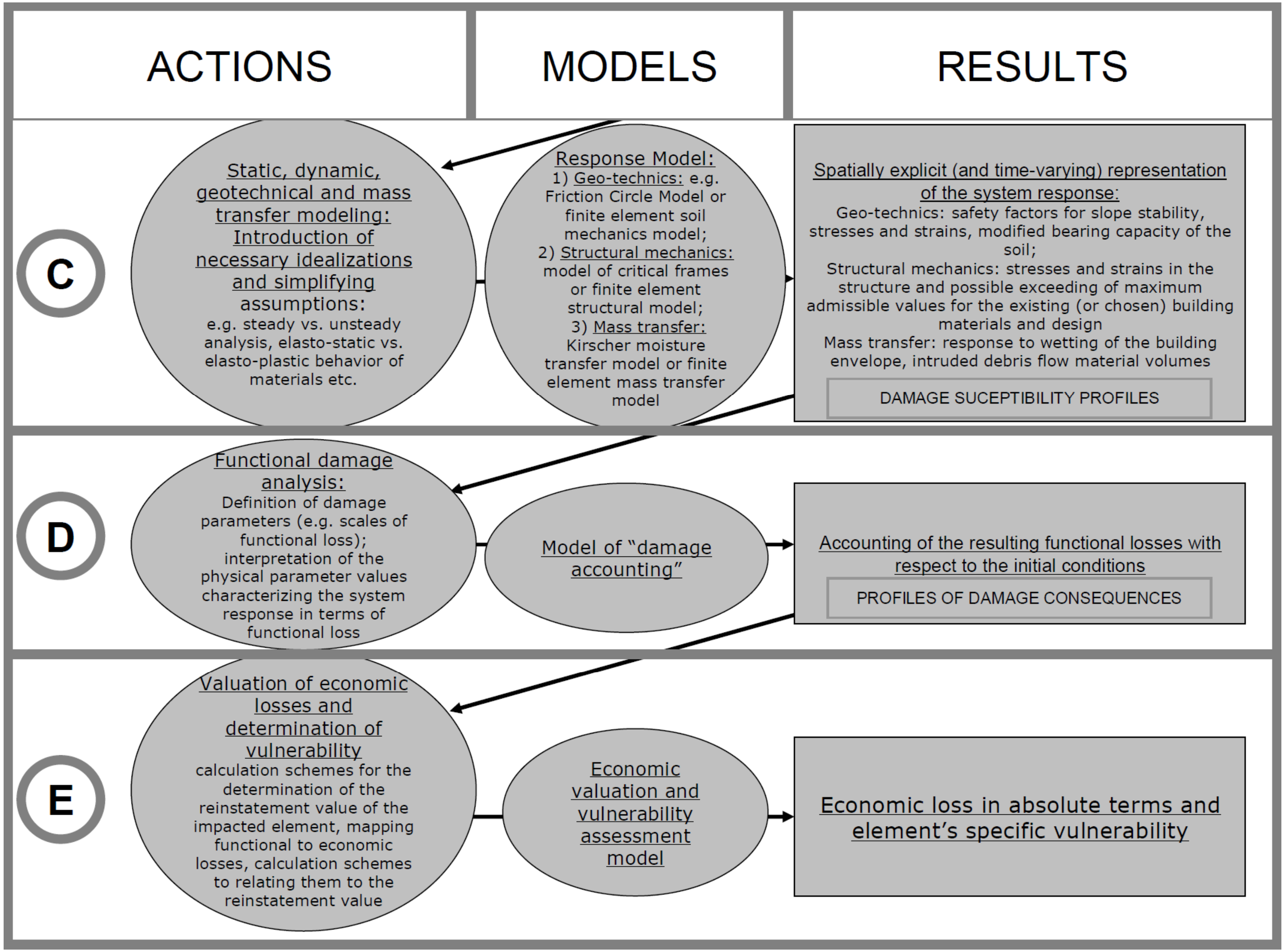
- Methodological concept 1



Mazzorana, B., Simoni, S., Scherer, C., Gems, B., Fuchs, S., Keiler, M.: A physical approach on flood risk vulnerability of buildings. Hydrol. Earth Syst. Sci. Discuss. (2014)

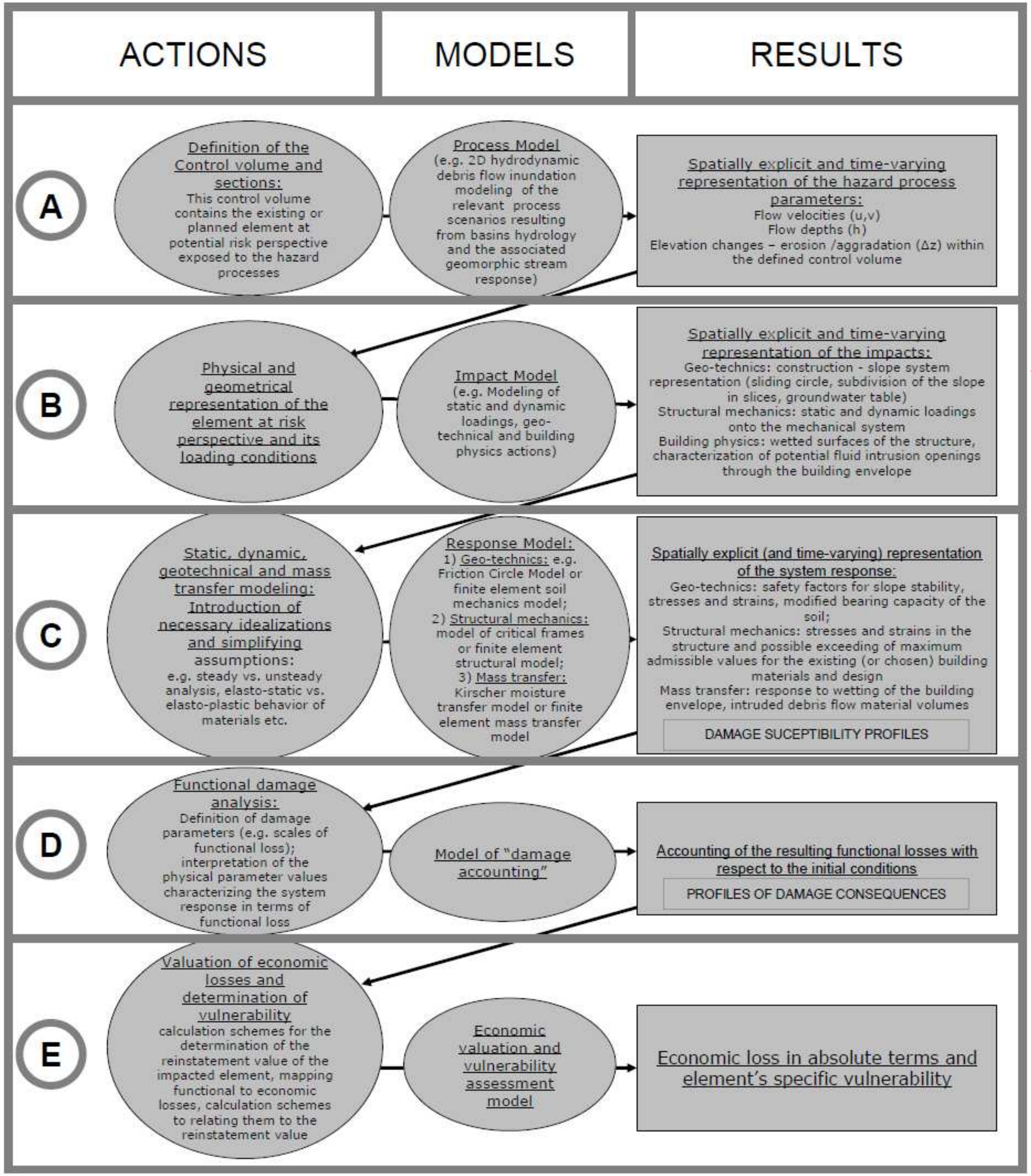
Physically based vulnerability assessment

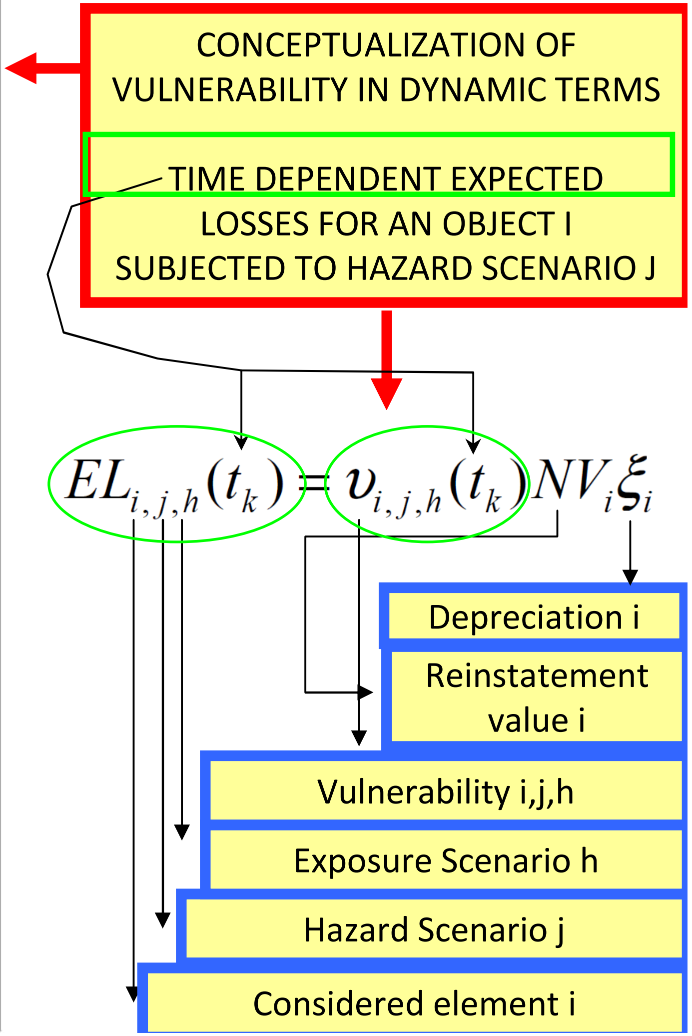
2



Mazzorana, B., Simoni, S., Scherer, C., Gems, B., Fuchs, S., Keiler, M.: A physical approach on flood risk vulnerability of buildings. Hydrol. Earth Syst. Sci. Discuss. (2014)

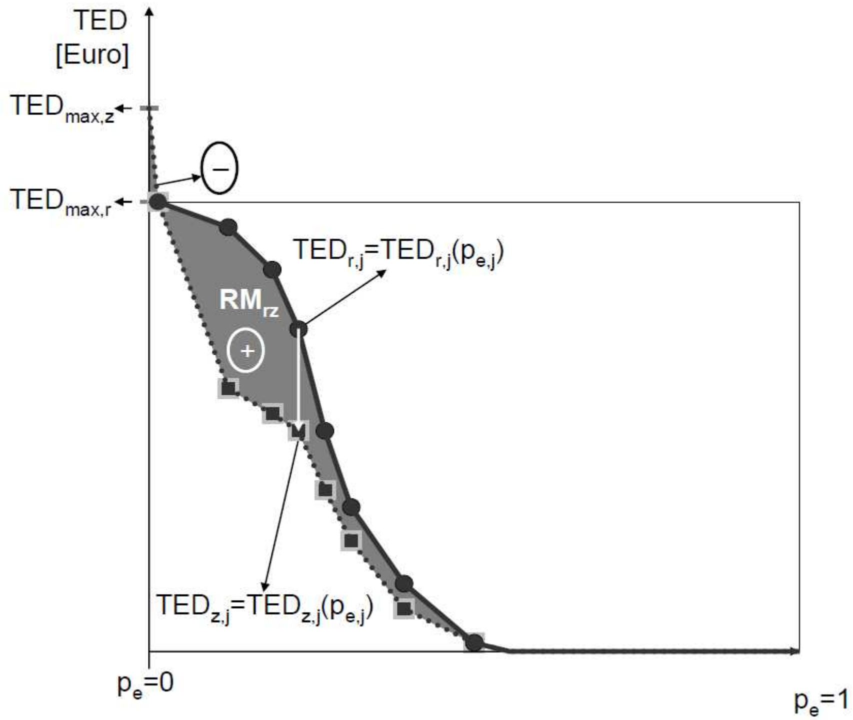
A formal Cost-Benefit Analysis Framework Based on Dynamic Risk Assessment





A formal Cost-Benefit Analysis Framework Based on Dynamic Risk Assessment

2



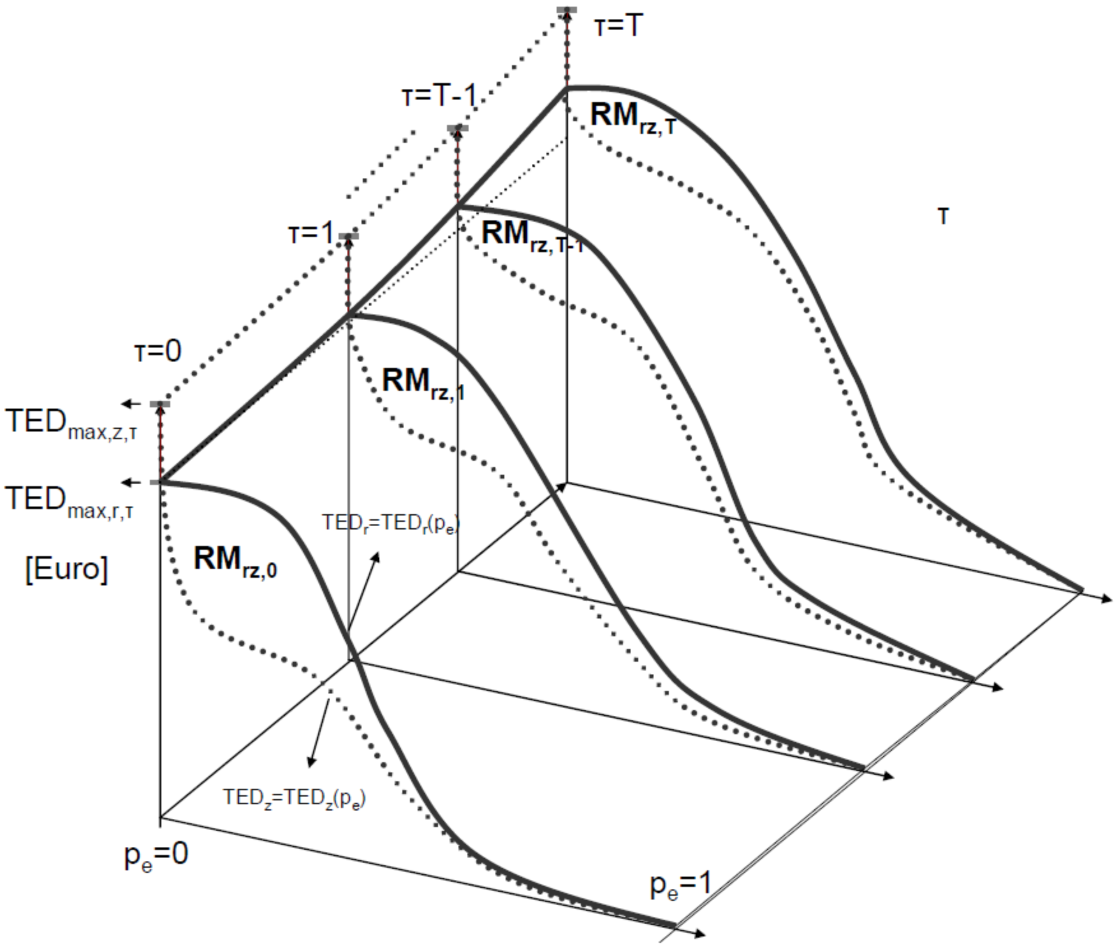
Risk Mitigation Performance of a Strategy z
Finite number of scenarios

$$R_r = \sum_{j=1}^{j=J-1} \frac{1}{2}\left[TED_{r,j}\left(p_{e,j}\right) + TED_{r,j+1}\left(p_{e,j+1}\right)\right]\left(p_{e,j+1} - p_{e,j}\right)$$

$$R_z = \sum_{j=1}^{j=J-1} \frac{1}{2}\left[TED_{z,j}\left(p_{e,j}\right) + TED_{z,j+1}\left(p_{e,j+1}\right)\right]\left(p_{e,j+1} - p_{e,j}\right)$$

$$RM_z = \sum_{j=1}^{j=J-1} \frac{1}{2}\left[\left(TED_{r,j}\left(p_{e,j}\right) - TED_{z,j}\left(p_{e,j}\right)\right) + \left(TED_{r,j+1}\left(p_{e,j+1}\right) - TED_{z,j+1}\left(p_{e,j+1}\right)\right)\right]\left(p_{e,j+1} - p_{e,j}\right)$$

Filtering out: A formal Cost-Benefit Analysis Framework Based on Dynamic Risk Assessment



Risk Mitigation Performance (variable in time) of a Strategy z

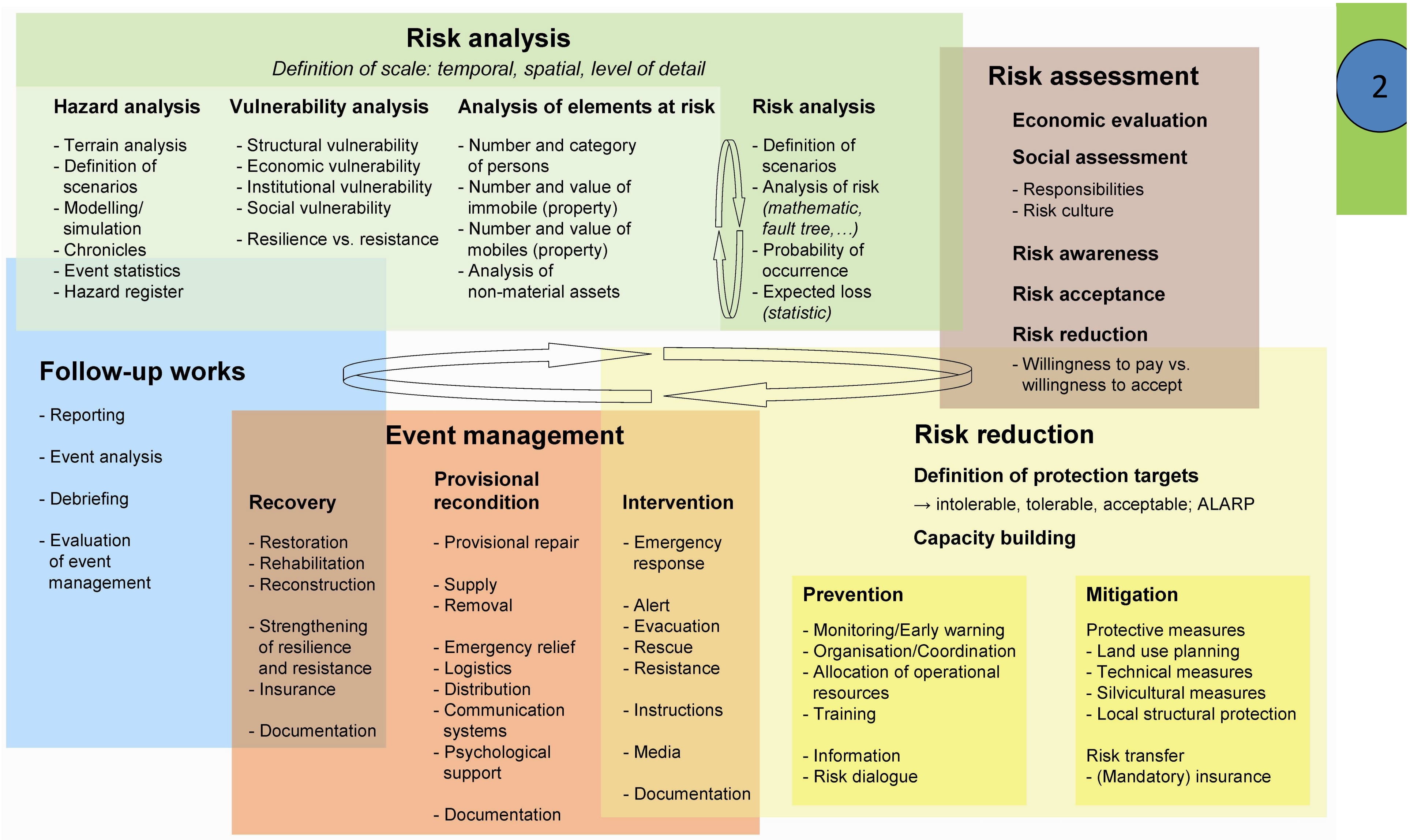
$$NPV_z = \sum_{\tau=1}^{T} \frac{(RM_{z,\tau} - e_{z,\tau})}{(1+r)^{\tau}}$$

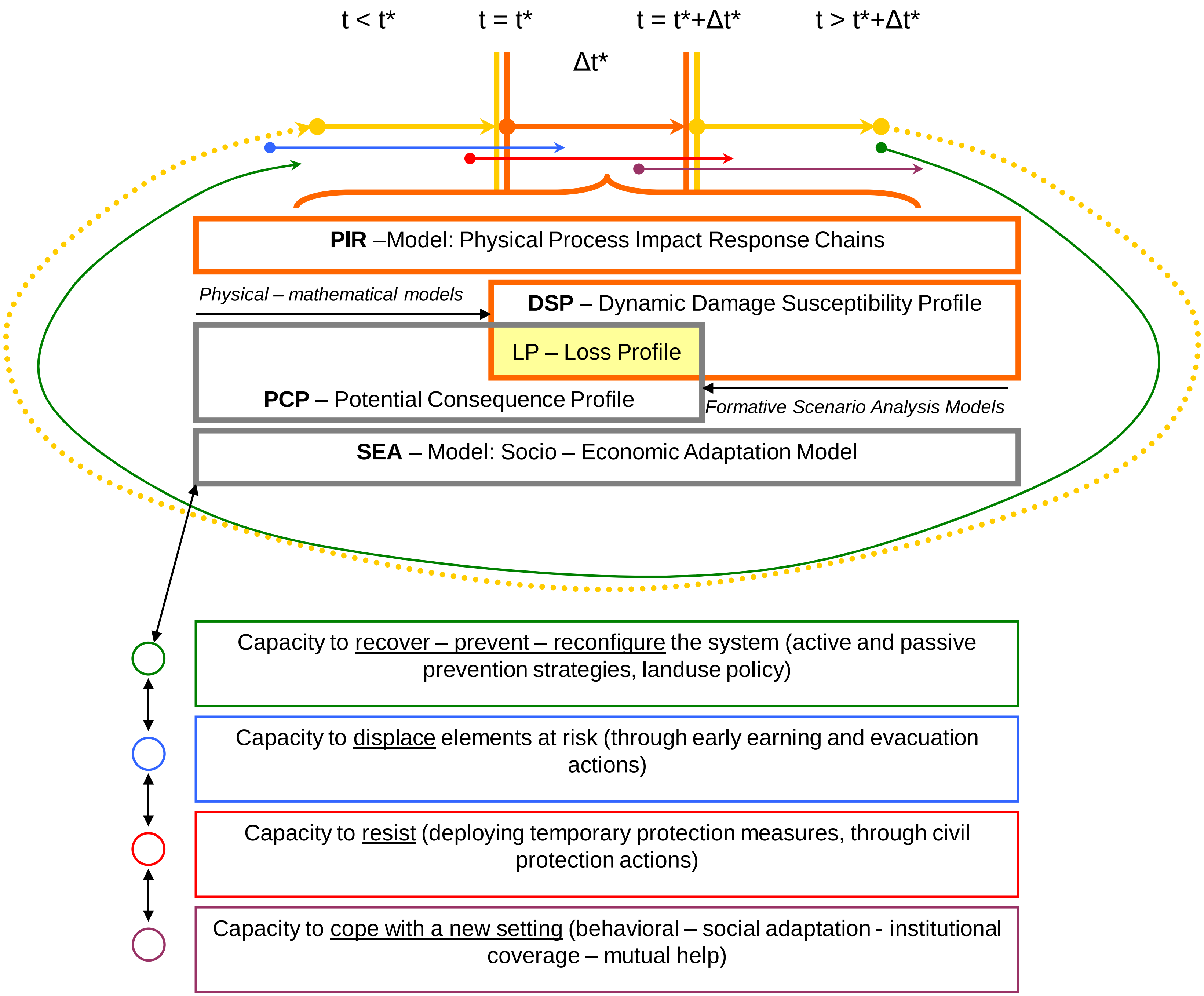
Discount rate

Cost Vector describing the expected costs over the entire life cycle

Risk mitigation performance through time of management alternative z

Net present value of management alternative z


Risk analysis
Definition of scale: temporal, spatial, level of detail
Hazard analysis
- Terrain analysis
- Definition of scenarios
- Modelling/ simulation
- Chronicles
- Event statistics
- Hazard register
Vulnerability analysis
- Structural vulnerability
- Economic vulnerability
- Institutional vulnerability
- Social vulnerability
- Resilience vs. resistance
Analysis of elements at risk
- Number and category of persons
- Number and value of immobile (property)
- Number and value of mobiles (property)
- Analysis of non-material assets
Risk analysis
- Definition of scenarios
- Analysis of risk (mathematic, fault tree, …)
- Probability of occurrence
- Expected loss (statistic)
Risk assessment
Economic evaluation
Social assessment
- Responsibilities
- Risk culture
Risk awareness
Risk acceptance
Risk reduction
- Willingness to pay vs. willingness to accept
2
Follow-up works
- Reporting
- Event analysis
- Debriefing
- Evaluation of event management
Event management
Recovery
- Restoration
- Rehabilitation
- Reconstruction
- Strengthening of resilience and resistance
- Insurance
- Documentation
Provisional recondition
- Provisional repair
- Supply
- Removal
- Emergency relief
- Logistics
- Distribution
- Communication systems
- Psychological support
- Documentation
Intervention
- Emergency response
- Alert
- Evacuation
- Rescue
- Resistance
- Instructions
- Media
- Documentation
Risk reduction
Definition of protection targets
→ intolerable, tolerable, acceptable; ALARP
Capacity building
Prevention
- Monitoring/Early warning
- Organisation/Coordination
- Allocation of operational resources
- Training
- Information
- Risk dialogue
Mitigation
Protective measures
- Land use planning
- Technical measures
- Silvicultural measures
- Local structural protection
Risk transfer
- (Mandatory) insurance



t < t*
t = t*
t = t*+Δt*
t > t*+Δt*
Δt*
PIR –Model: Physical Process Impact Response Chains
Physical – mathematical models
DSP – Dynamic Damage Susceptibility Profile
LP – Loss Profile
PCP – Potential Consequence Profile
Formative Scenario Analysis Models
SEA – Model: Socio – Economic Adaptation Model
Capacity to recover – prevent – reconfigure the system (active and passive prevention strategies, landuse policy)
Capacity to displace elements at risk (through early earning and evacuation actions)
Capacity to resist (deploying temporary protection measures, through civil protection actions)
Capacity to cope with a new setting (behavioral – social adaptation - institutional coverage – mutual help)

2

The challenge of deploying quality from a sustainability perspective

The meaning of quality of engineering and management practices in a sustainability context

On a very general und "almost undisputable" level:

Do the right thing and do things right all the time!

Perceived quality:

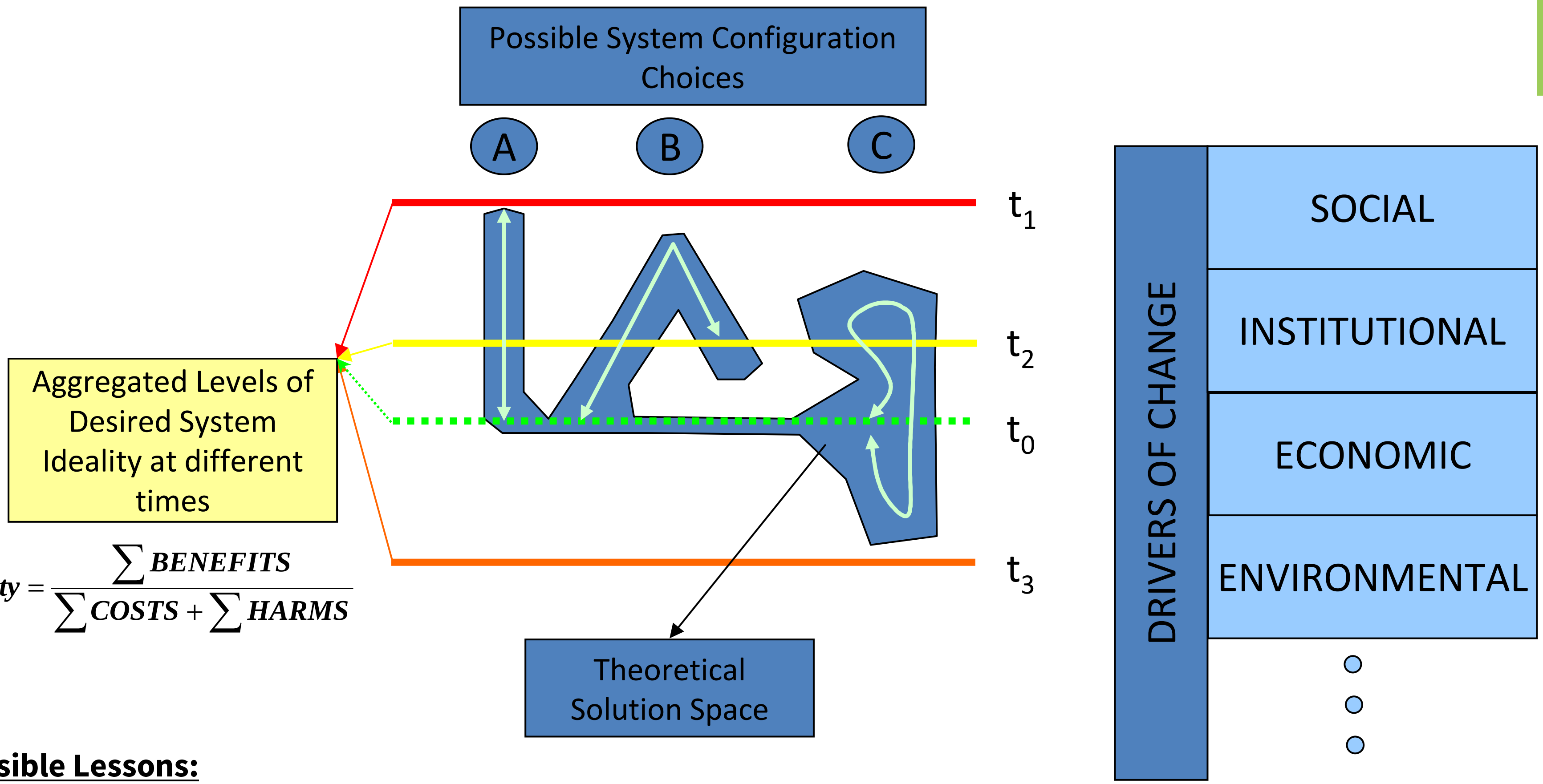
Quality is a perception of how well the balanced needs of all stakeholders have been met or exceeded!

Quality in participatory engineering design:

A superior system requires not only a good engineering. Teamwork, open-mindedness, communications, broad perspectives, diversity of input, cost effectiveness, environmental consciousness are also essential.

Quality in planning, design, operations, maintenance, and service requires the continuous application of creative problem solving tools.

The challenge of deploying quality from a sustainability perspective



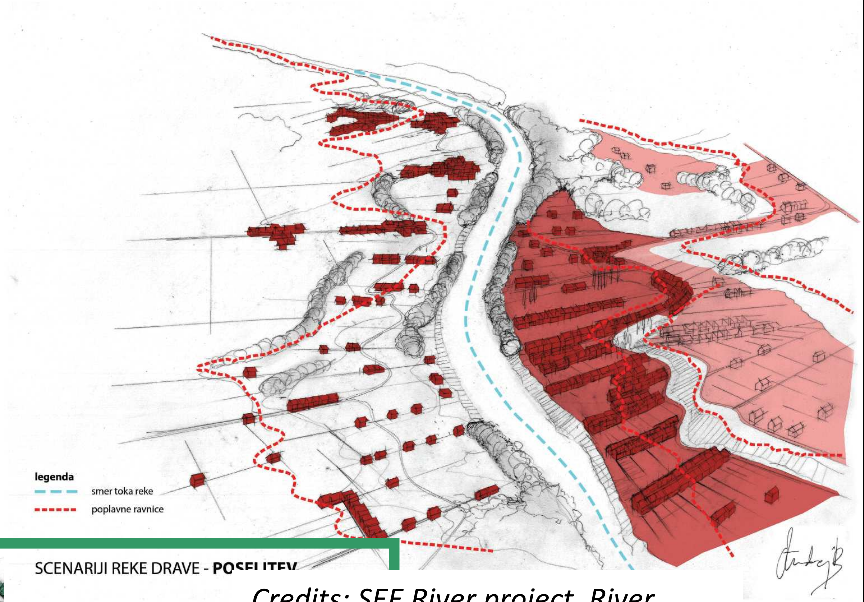
$$Ideality = \frac{\sum BENEFITS}{\sum COSTS + \sum HARMS}$$

Possible Lessons:

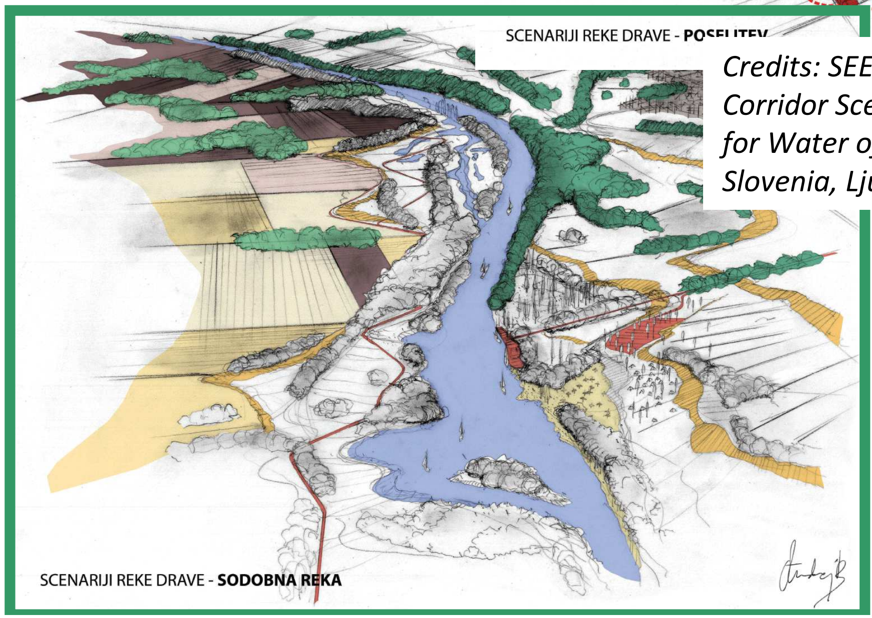
1) **Investing in understanding the drivers of change**
2) **Investing in understanding the SYNERGIES [or APPARENT CONFLICTS] among the factors generating benefits, costs and harm –quality of the Leitbild and related Target System**

The challenge of deploying quality from a sustainability perspective

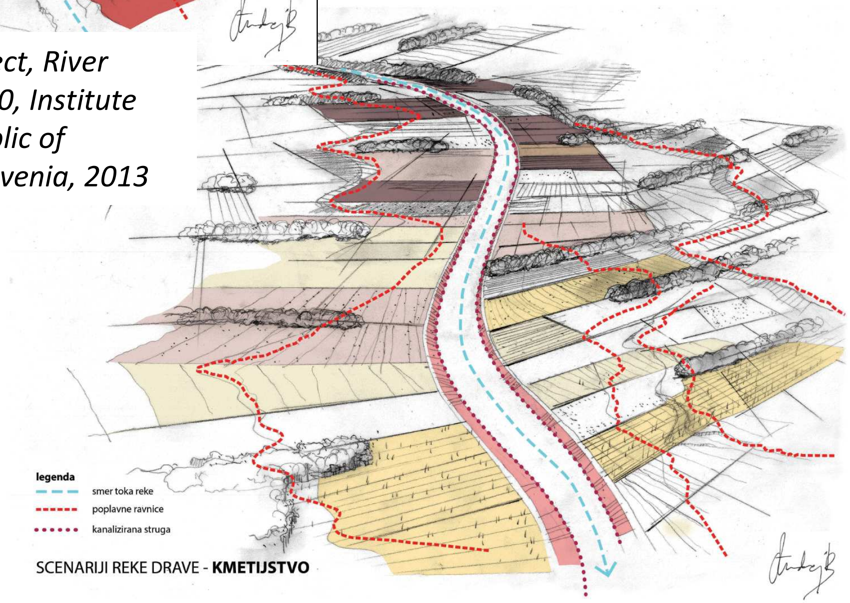
Visualized Leitbild:

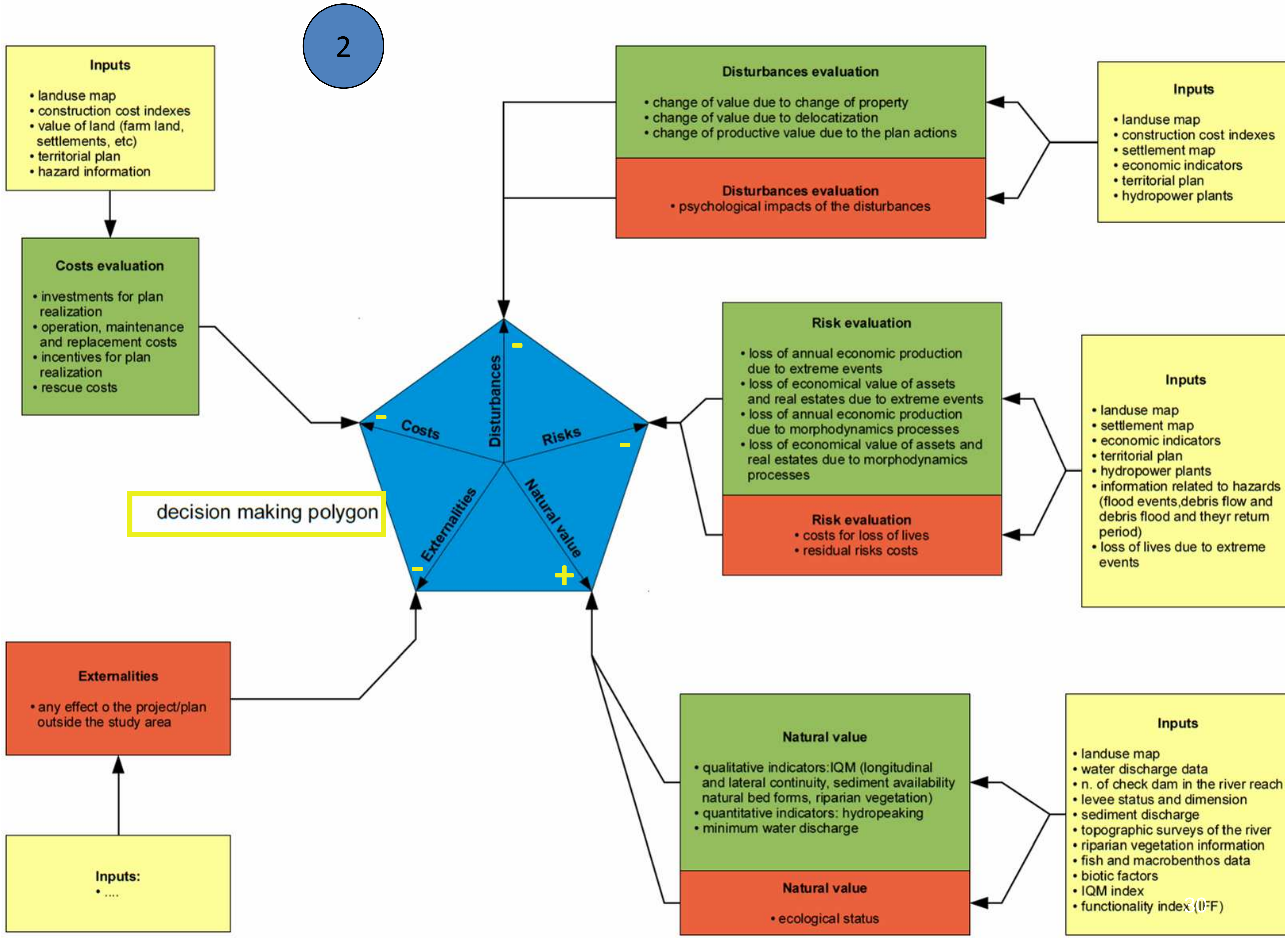


1. **MODULARITY!**
2. **REVERSIBILITY!**
3. **MAINATINING DEGREES OF FREEDOM!**
4. **NOT PREJUDGING!**



Credits: SEE River project, River Corridor Scenarios 2030, Institute for Water of the Republic of Slovenia, Ljubljana, Slovenia, 2013




2
Inputs
• landuse map
• construction cost indexes
• value of land (farm land, settlements, etc)
• territorial plan
• hazard information
Costs evaluation
• investments for plan realization
• operation, maintenance and replacement costs
• incentives for plan realization
• rescue costs
Disturbances evaluation
• change of value due to change of property
• change of value due to delocatization
• change of productive value due to the plan actions
Disturbances evaluation
• psychological impacts of the disturbances
Inputs
• landuse map
• construction cost indexes
• settlement map
• economic indicators
• territorial plan
• hydropower plants
Costs
Disturbances
Risks
Externalities
Natural value
-
-
-
-
+
decision making polygon
Risk evaluation
• loss of annual economic production due to extreme events
• loss of economical value of assets and real estates due to extreme events
• loss of annual economic production due to morphodynamics processes
• loss of economical value of assets and real estates due to morphodynamics processes
Risk evaluation
• costs for loss of lives
• residual risks costs
Inputs
• landuse map
• settlement map
• economic indicators
• territorial plan
• hydropower plants
• information related to hazards (flood events,debris flow and debris flood and theyr return period)
• loss of lives due to extreme events
Externalities
• any effect o the project/plan outside the study area
Inputs:
• ....
Natural value
• qualitative indicators:IQM (longitudinal and lateral continuity, sediment availability natural bed forms, riparian vegetation)
• quantitative indicators: hydropeaking
• minimum water discharge
Natural value
• ecological status
Inputs
• landuse map
• water discharge data
• n. of check dam in the river reach
• levee status and dimension
• sediment discharge
• topographic surveys of the river
• riparian vegetation information
• fish and macrobenthos data
• biotic factors
• IQM index
• functionality index (IFF)

Making the performance of management actions verifiable: a computational architecture with multiple objectives

THE SINERGY TABLE

R	C	D	E	N	
↑	↑	↑	↑	↑	MAX
↑	↑	↑	↑	=	
↑	↑	↑	=	↑	
↑	↑	=	↑	↑	
↑	=	↑	↑	↑	
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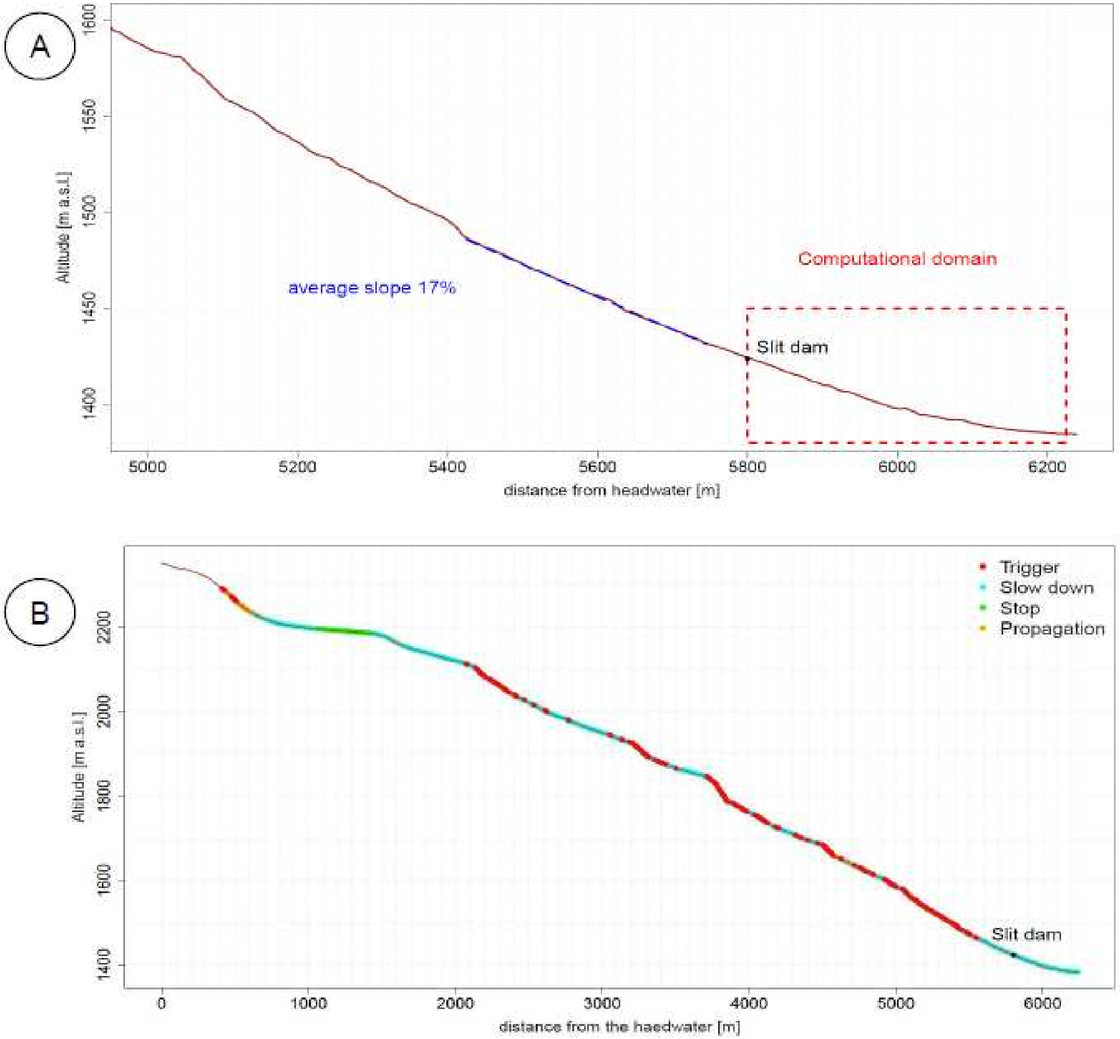
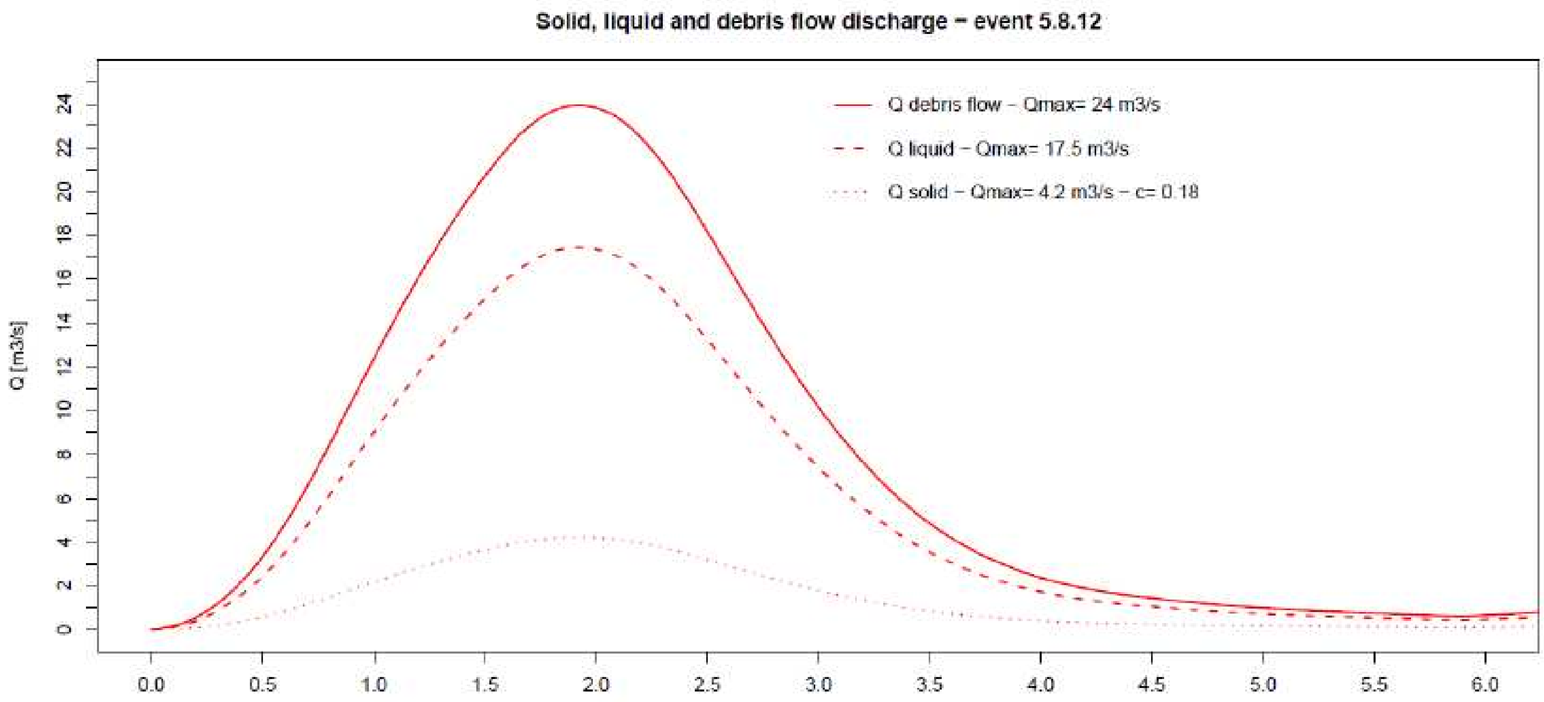
=	=	=	↑	=	
=	=	=	=	↑	MIN

Case study: discursive presentation

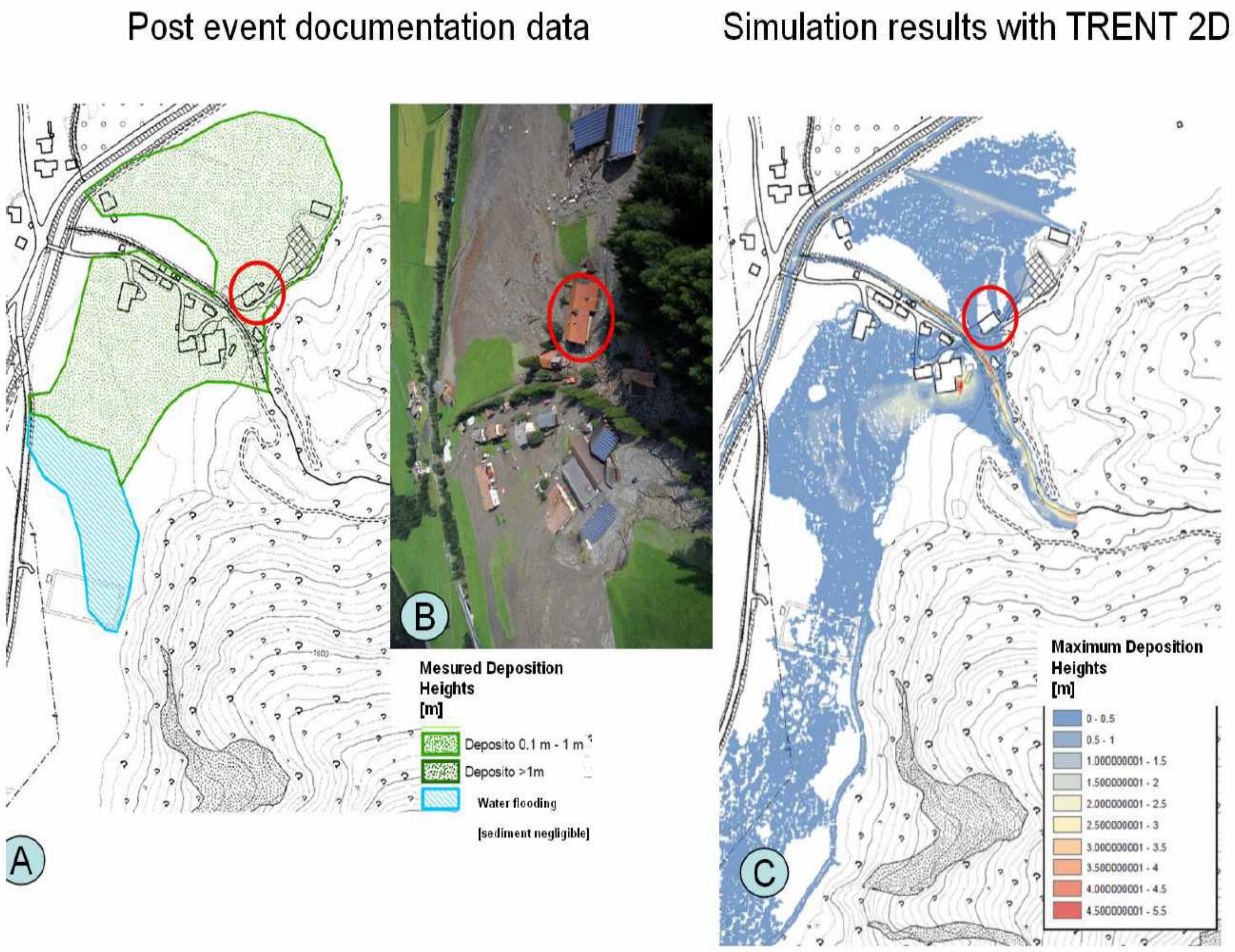
Case study: discursive presentation



Case study: discursive presentation



Case study: discursive presentation



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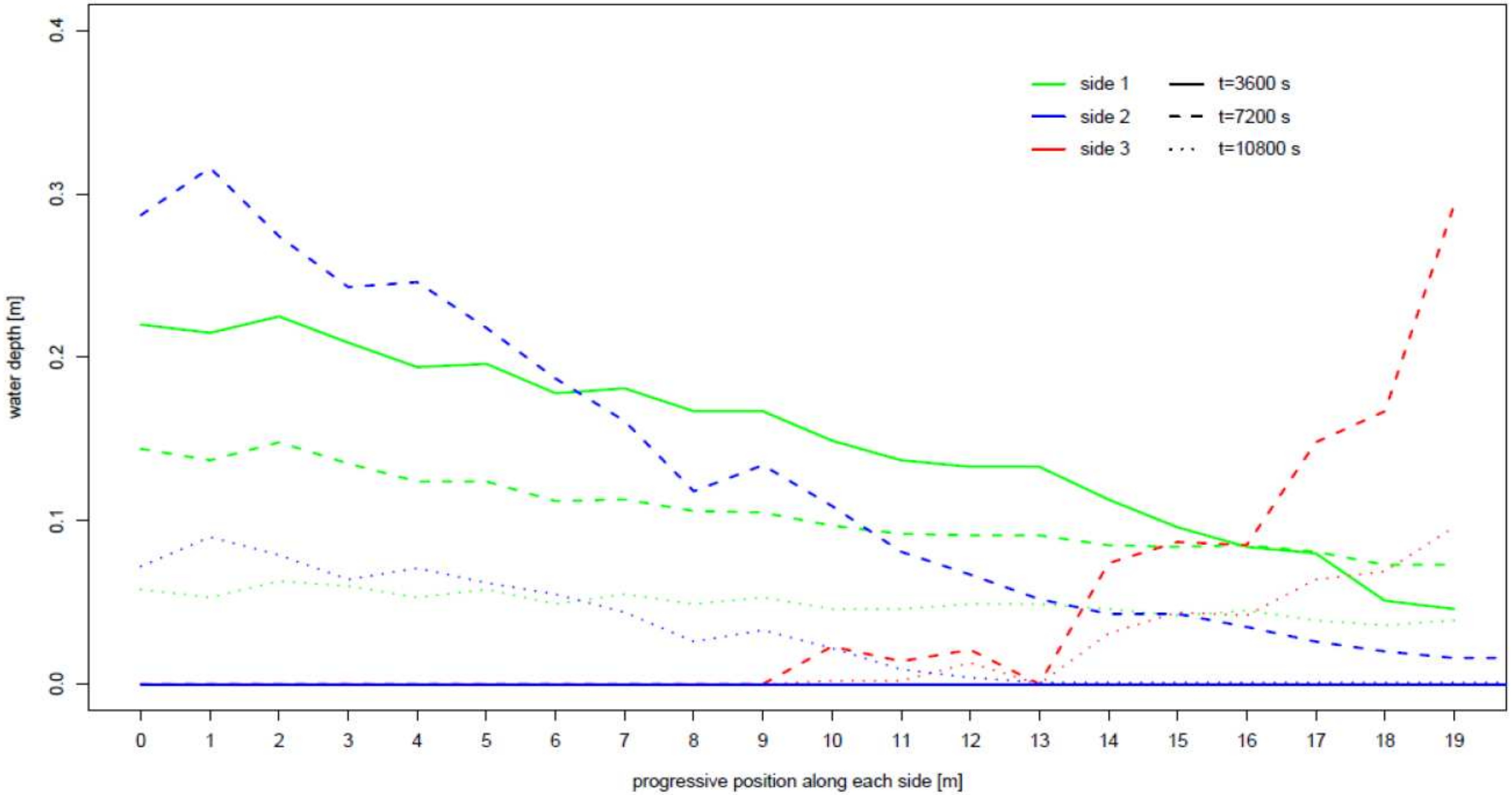
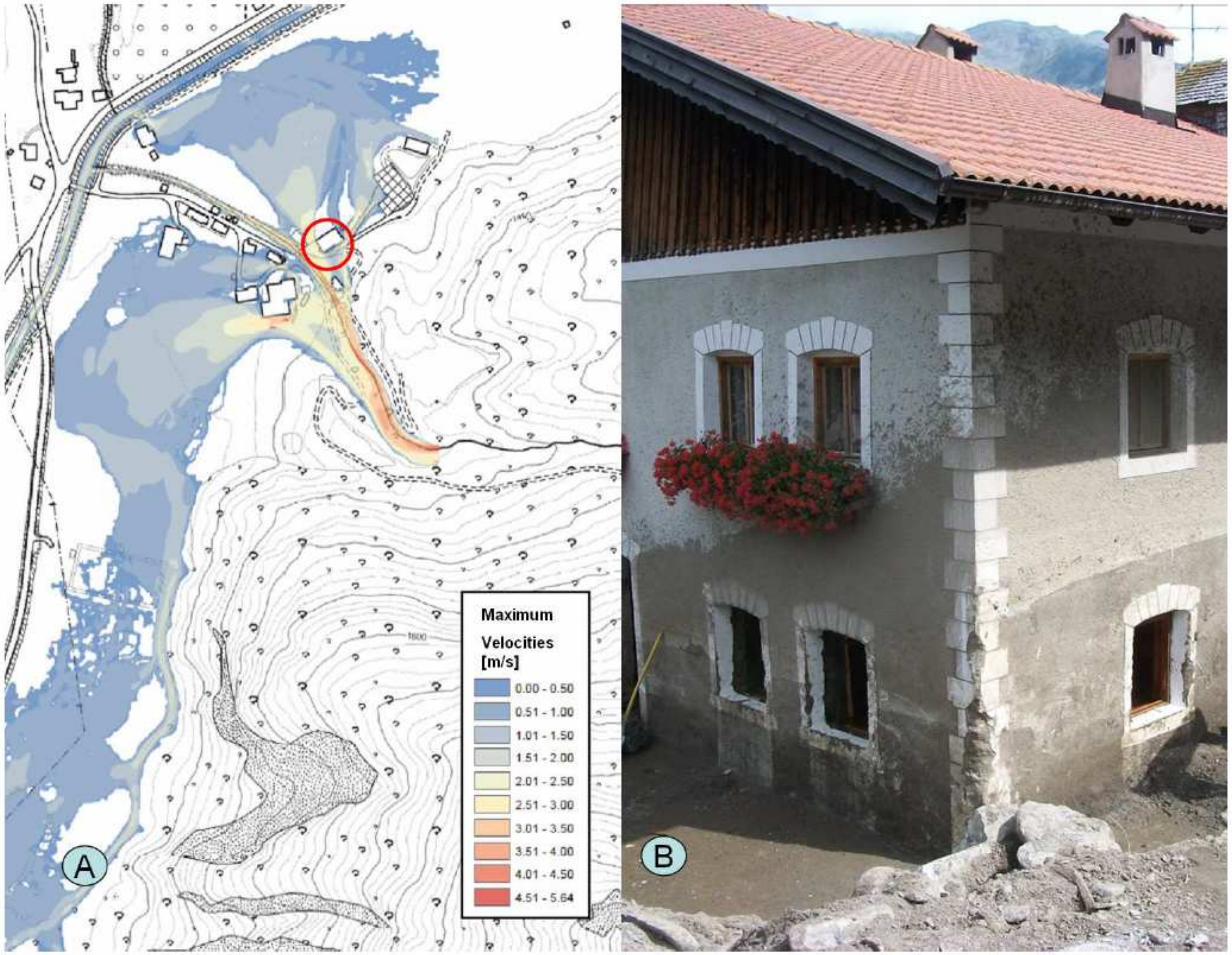
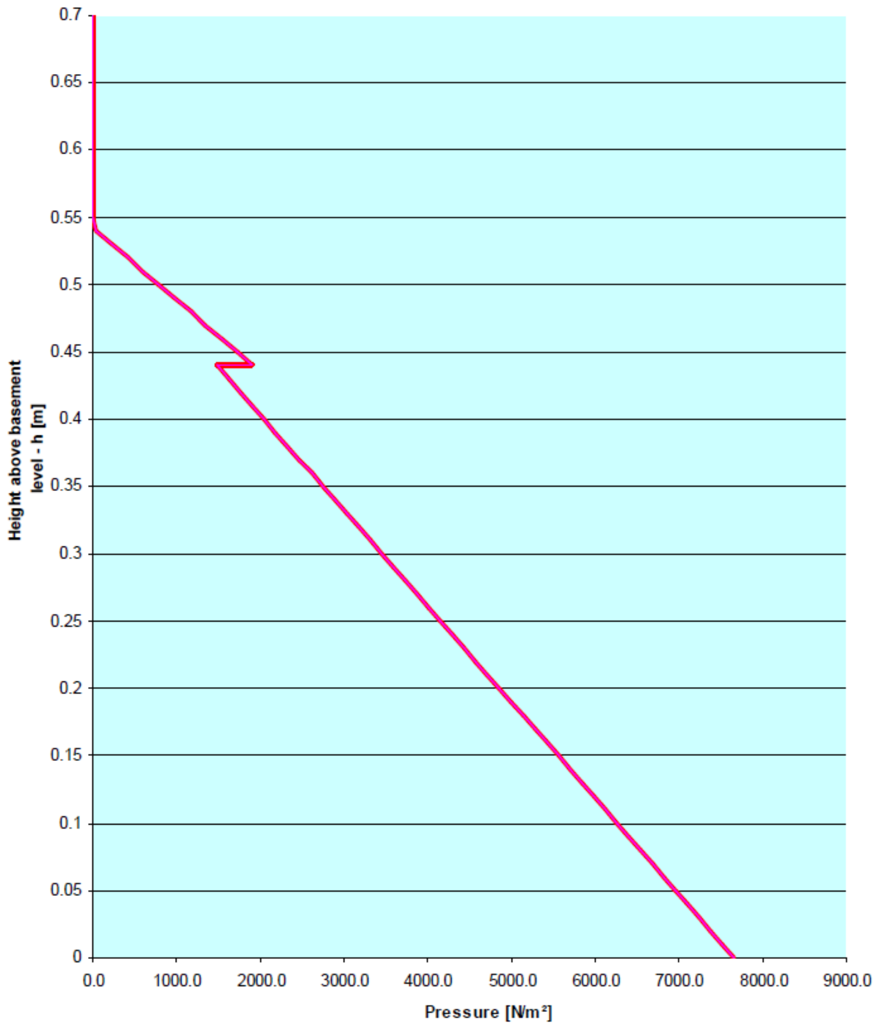


Case study: discursive presentation



Case study: discursive presentation

4



Case study: discursive presentation

Table 2. Overall exposure to wetting and potential permeability for the selected time steps.

Time step k	Overall exposure to wetting $-WE(t_k)$ – in m^2 where	Overall potential permeability $-TO_H(t_k)$ – in m^2 where
$k = 1 \rightarrow t_k = 3600\,\text{s}$	3.63	1.45
$k = 2 \rightarrow t_k = 7200\,\text{s}$	10.00	4.36
$k = 3 \rightarrow t_k = 10\,800\,\text{s}$	7.79	3.58

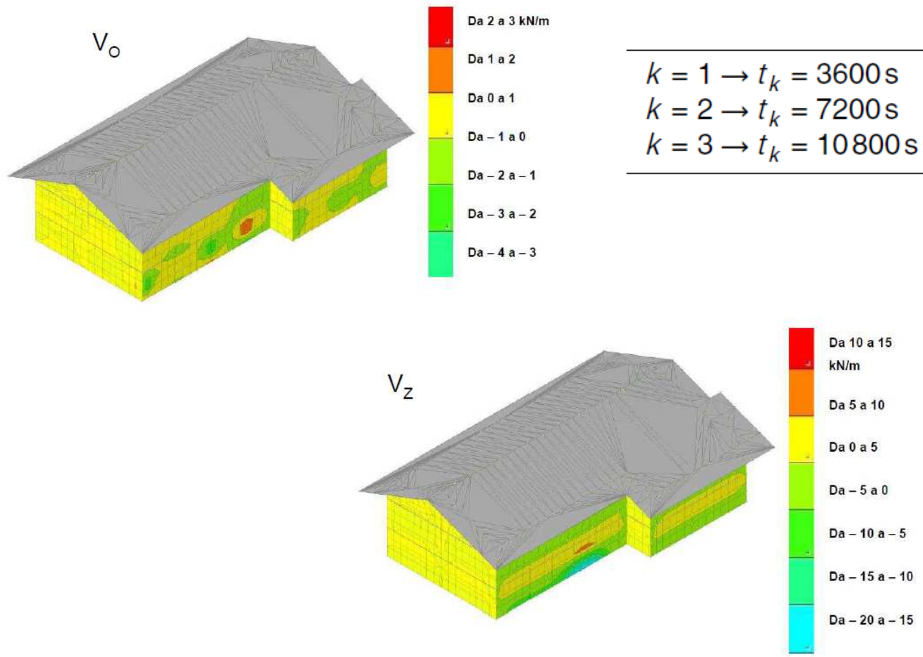
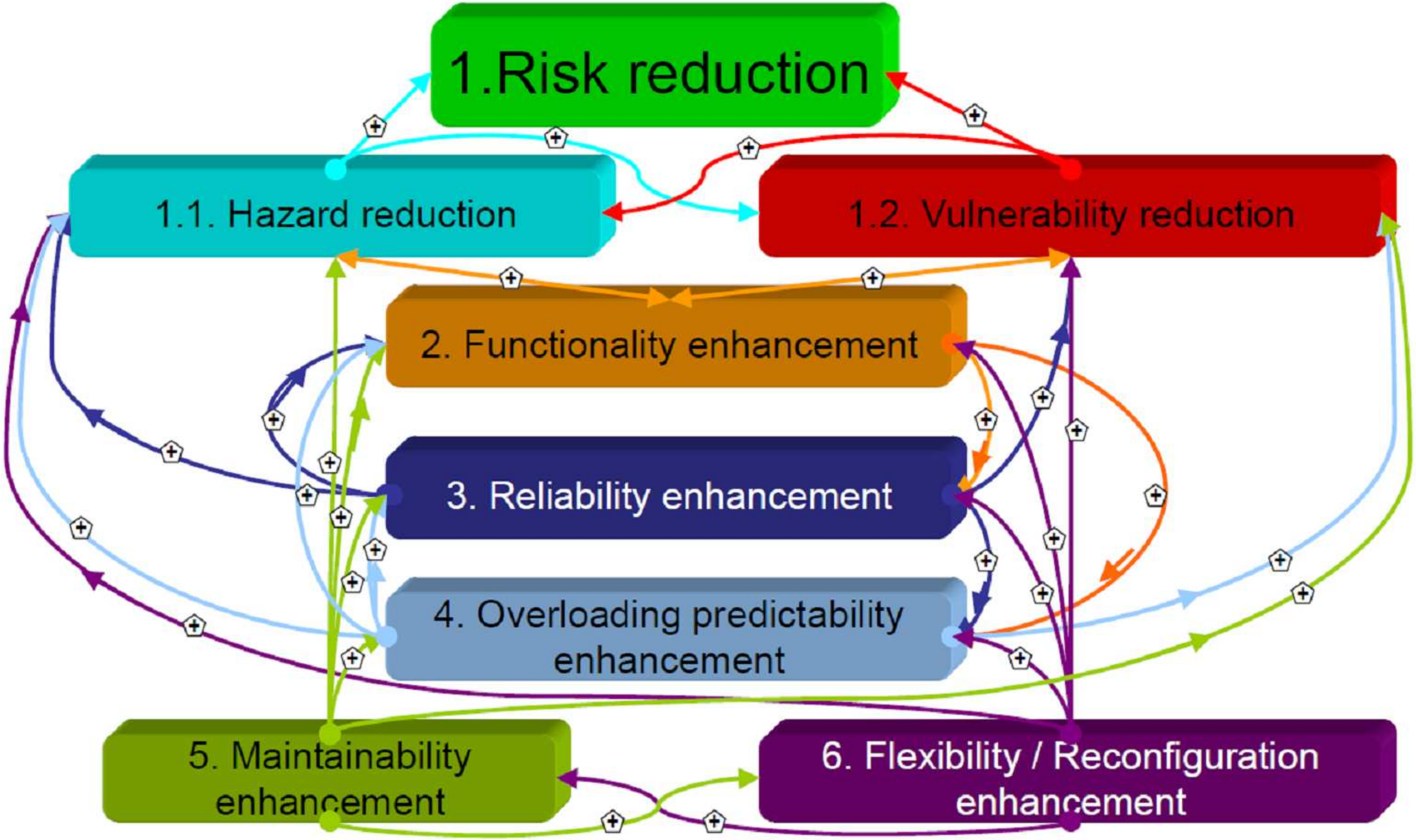


Fig. 18. Shear forces (V_O and V_Z).

Design Principles to mitigate Flood Risk



Pathways toward Risk Mitigation

Design Principles to mitigate Flood Risk

Root Principles	Derived Principles
(i) Separation Principles	a) Spatial separation: The overall aim is to separate areas characterized by relevant process intensities from areas at risk perspective, i.e. with a relevant accumulation of values at risk. Corollary: Concentrate adverse effect in low vulnerable areas. b) Temporal Separation: The overall aim is to decouple in time the intensity maxima of liquid discharge and sediment transport on the process side, and to displace movable objects at risk from endangered areas during the critical timeframes within the extreme event duration (e.g. by evaluating people at risk). c) Separation by change of status: The aim is to achieve a reconfiguration of critical system configurations during the critical timeframes within the event duration (e.g. by avoiding bridge clogging). d) Separation within the system and its parts: It may be possible to create subsystems with a lower degree of susceptibility while the residual parts of the system remain unaffected (e.g. local structural protection for individual buildings).

Design Principles to mitigate Flood Risk

5

Root Principles	Derived Principles
(ii) Dynamisation Principles	a) Dynamisation of the sediment transport process: The overall aim is to control the sediment transport process (e.g. by dosing it through open check dams) and the wood transport process (e.g. by preventive entrapment through retention structures). b) Ecosystem dynamisation: The overall aim is to enhance ecosystem functionality. c) Dynamisation of mitigation – Modularization of the protection system: The overall aim is to create a flexible modular mitigation concept taking into account the entire range of possible alternatives. This principle allows for adaptation if the parameterization will change in the future.

Design Principles to mitigate Flood Risk

Root Principles	Derived Principles
(iii) Combination Principles	a) Combination of mitigation: The overall aim is to efficiently reduce effects with respect to hazard and vulnerability, and to increase the system reliability and maintainability. b) Multipurpose combination: The overall aim is to design parts of the mitigation concept with respect to alternative uses (e.g. modeling the landscape in order to achieve flow deflection without compromising the agricultural use of the area).
(iv) Redundancy Principles	a) Redundancy of the worst case:
	b) Redundancy in intervention planning: In particular for a worst-case scenario, certain elements of the mitigation concept should be redundant in order to avoid system failures.

THANKS