



Selection of appropriate landslide risk mitigation measures - LaRiMiT

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Aim



LARIMIT

1. Database of available landslide mitigation measures
2. Assistance for decision makers for selection of appropriate mitigation measure for a given case
3. Sharing a platform for scientists, decision makers, policy actors and other stakeholders

Background:

EU FP7 project – ‘SafeLand’, 2009-2012


- Coordinated by NGI, with 27 partners from 12 countries
- Total budget of 8.6 mill Euro (6.6 mill Euro from EU).
- Landslide mitigation toolbox (NGI, SGI)

SafeLand

[Introduction](#) | [Reasons for research](#) | [Objectives](#) | [Consortium](#) | [Achievements](#)



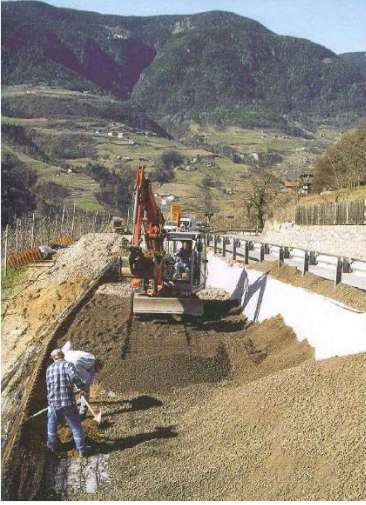

 **Work Area 1**
Improving knowledge
on landslide hazard

 **Work Area 2**
Quantitative risk
assessment

 **Work Area 3**
Quantifying global
change scenarios

Toolbox for landslide hazard and risk mitigation measures (NGI, SGI)

D 5.1 Compendium of tested and innovative structural, non-structural and risk-transfer mitigation measures for different landslide types

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<p><small>Note: Ratings are given on a scale of 1 to 10; the higher the grade, the most suitable is the specific method under consideration to use in landslides of the given characteristics, evaluated individually. Overall suitability to specific case under consideration may be obtained by a weighted average of these ratings, with user defined weights. Zero rating means "not applicable"</small></p>																																																																																													

Fact sheet

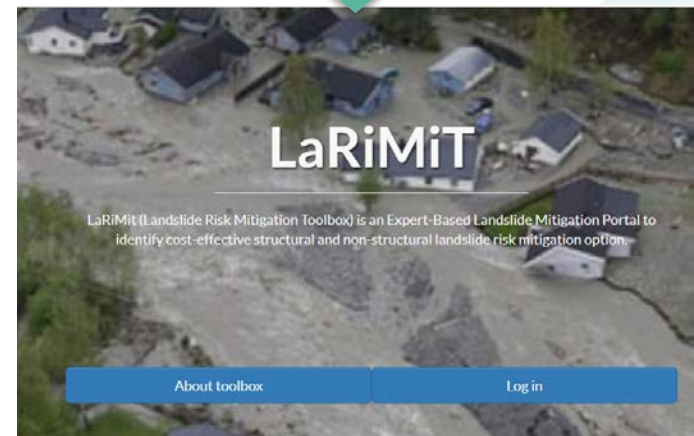
Research Council of Norway; Center for Research Based Innovation: 'Klima 2050'



- 5 scientific partners, 15 industry partners. Lead by SINTEF
- 8 years; 2015-2023
- Total budget >20 mill Euro

- Risk reduction through climate adaptation of buildings and infrastructure

• WP3 – landslide risk mitigation (NGI)



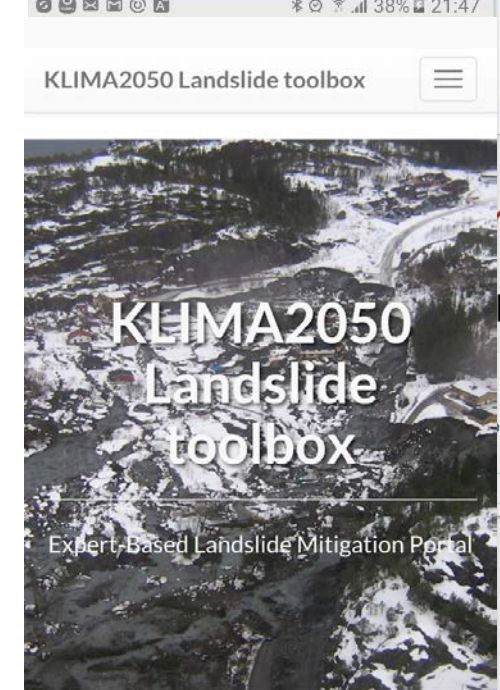
Decision makers/Users point of view

- Decision makers/users want to know, which is reflected in LaRiMiT
 - What are the options available?
 - How expensive and effective are they?
 - Are they feasible?
 - Do they require maintenance?
 - What are the environmental impact of the measure?

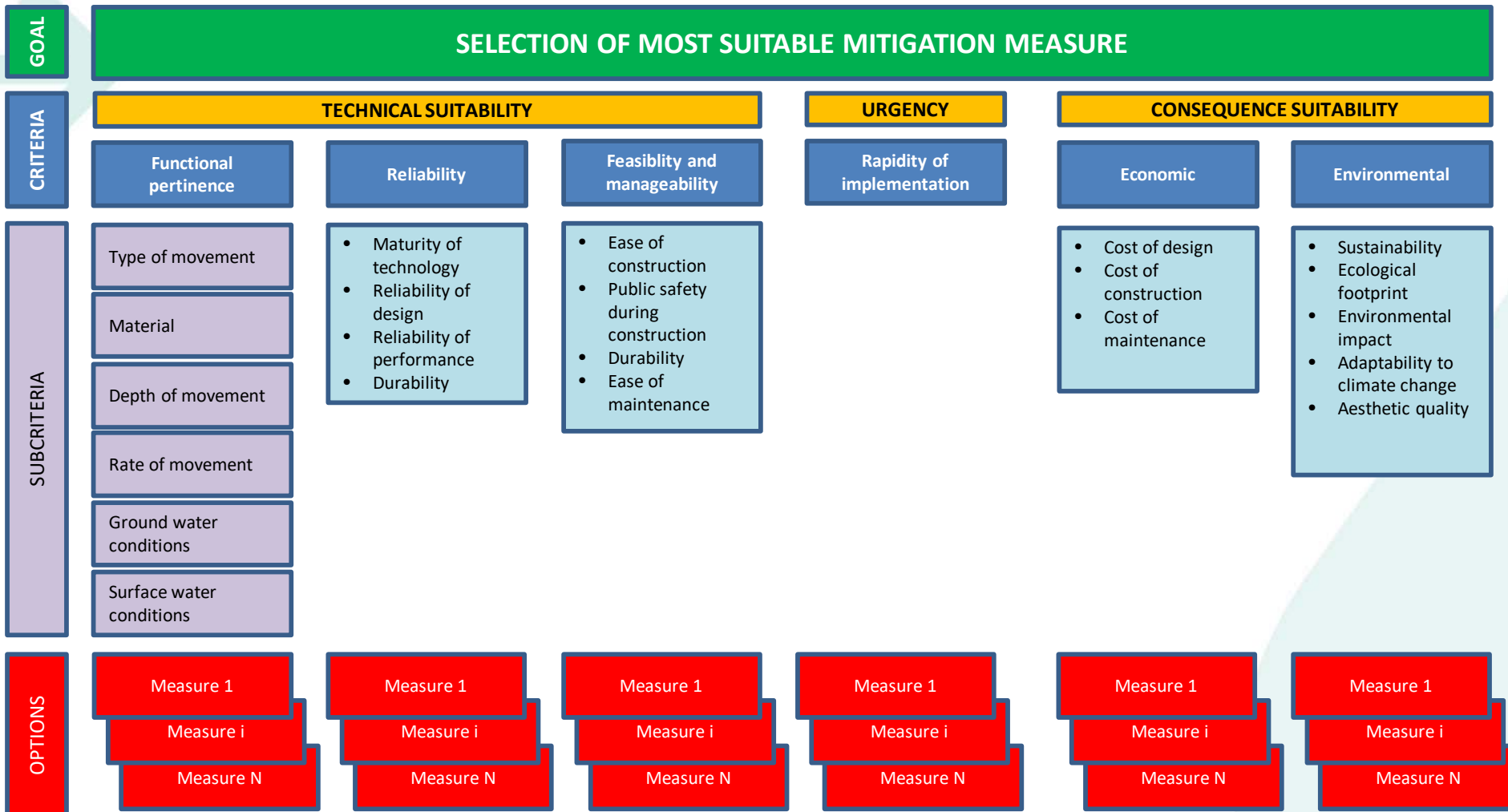


Web portal LaRiMiT

- Allows extensive database of alternatives for mitigation measures
- Provides an expert-assisted tool for the case- and site-specific ranking and best-practice selection of landslide risk mitigation measures.
- Allows the synergy between portal administrators, users and landslide risk experts in pursuing the optimization of risk reduction measures through the merging of user-input case- and site-specific information with expert-input knowledge



Goal, criteria and options



Expert and user actions

Experts

- Compile and update database of candidate mitigation measures
- Assign and update scores to each candidate mitigation measure in terms of:
 - Functional and technical suitability
 - reliability
 - feasibility and manageability
 - rapidity of implementation
 - Typical cost
 - environmental impact

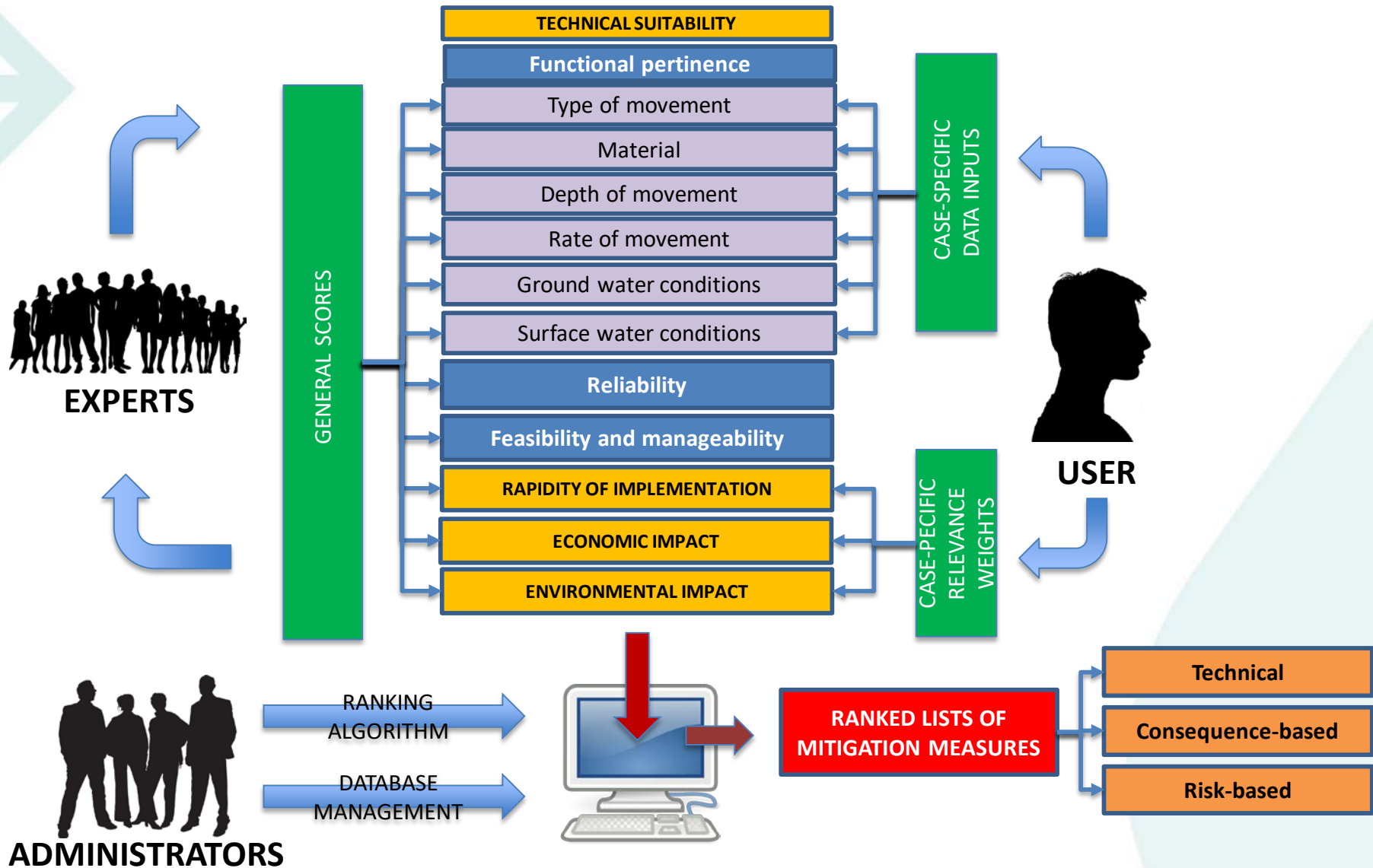
Expert inputs ARE NOT case- and site-specific and are resident in the toolbox server in the form of database

Users

- Check out the database of measures
- Provide information about site-specific conditions:
 - type of movement
 - material
 - depth of movement
 - rate of movement
 - groundwater conditions
 - surface water conditions
- Input give a weight to relevant factors in decision making:
 - Timeliness of implementation
 - Environmental suitability
 - Economic suitability

User inputs ARE case- and site-specific

Data flowchart



Structural measures in LaRiMiT


$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \times \text{Elements at risk}$$



$$\text{Risk} = \text{Hazard} \times \text{Consequences}$$

Measures reducing Hazard

Triggering

- 1 NBS for erosion control – living approach
- 2 NBS for erosion control – living/not living approach
- 3 Modifying slope geometry or mass distribution
- 4 Modifying surface water regime – drainage
- 5 Modifying groundwater regime – deep drainage
- 6 Modifying mechanical charact. of the unstable mass
- 7 Transfer of loads to more competent strata
- 8 Retaining structures to improve the slope stability

Measures reducing Consequences

Runout

- 9 Deviating the paths of landslides
- 10 Dissipating the energy of landslides
- 11 Arresting and containing landslides

11 Categories: each category addresses a specific physical process

Structural measures in LaRiMiT

Measures reducing hazard

1 NBS for erosion control – living approach

- 1.1 Hydroseeding
- 1.2 Turfing
- 1.3 Tree bushes direct/pit planting
- 1.4 Live/inert fascines and straw wattles
- 1.5 Brush mattresses
- 1.6 Brush layering
- 1.7 Live stakes (live poles)
- 1.8 Live smiles

2 NBS for erosion control – living/not living approach

- 2.1 Geotextiles (Rolled Erosion Control Products)
- 2.2 Drainage Blankets
- 2.3 Beach replenishment/nourishment
- 2.4 Rip-rap
- 2.5 Rock dentition

3 Modifying slope geometry or mass distribution

- 3.1 Removal of unstable soil/rock mass
- 3.2 Removal of loose/unstable blocks/boulders
- 3.3 Removal of material from driving area
- 3.4 Substitution of material with lightweight fill
- 3.5 Addition of material to the area maintaining stability
- 3.6 Terracing (NBS)

4 Modifying surface water regime - drainage

- 4.1 Surface drainage works (ditches, channels, pipes)
- 4.2 Local regrading to facilitate run-off
- 4.3 Sealing tension cracks
- 4.4 Impermeabilization (geomembranes, imperv.facing)
- 4.5 Vegetation -hydrological effects (NBS)
- 4.6 Hydraulic control work (channel lining /check dams)
- 4.7 Diversion channels

5 Modifying groundwater regime - deep drainage

- 5.1 Shallow trenches filled with free-draining material
- 5.2 Deep trenches filled with free-draining material
- 5.3 Sub-horizontal drains (conventional drilling)
- 5.4 Sub-horizontal drains (directional drilling)
- 5.5 Wells

6 Modifying mechanical characteristics of the unstable mass

- 6.1 Vegetation - mechanical effects (NBS)
- 6.2 Substitution
- 6.3 Compaction from surface
- 6.4 Deep compaction
- 6.5 Mechanical deep mixing with lime and/or cement
- 6.6 Low pressure grouting with cements/chemical s
- 6.7 Jet grouting
- 6.8 Modification of ground water chemistry (lime piles)

7 Transfer of loads to more competent strata

- 7.1 Counterfort drains (intersecting trench drains)
- 7.2 Piles
- 7.3 Barrettes (diaphragm walls)
- 7.4 Caissons - mechanical effects
- 7.5 Soil nailing
- 7.6 Dowels and harnessing
- 7.7 Rock bolting
- 7.8 Strand anchors
- 7.9 Soil nail and root technology – SNART (Hybrid)

8 Retaining structures to improve the slope stability

- 8.1 Reinforced soil structure
- 8.2 Gabion walls
- 8.3 Crib walls
- 8.4 Drystack masonry walls
- 8.5 Mass concrete or masonry walls
- 8.6 Reinforced concrete stem walls
- 8.7 Vegetated gabions (Hybrid)
- 8.8 Live crib walls (NBS)
- 8.9 Vegetated slope gratings (Hybrid)

NEW MEASURES
- 12 NBS
- 3 Hybrid

Structural measures in LaRiMiT

Measures reducing Consequences

9 Deviating the path of landslides

- 9.1 Deflection structures (berms)
- 9.2 Rock sheds
- 9.3 Channelisation structures (lateral walls)

10 Dissipating the energy of landslides

- 10.1 Debris racks
- 10.2 Baffles (Impediments)
- 10.3 Check dams
- 10.4 Attenuator system
- 10.5 Afforestation (NBS)
- 10.5 Live gully breaks (NBS)

11 Arresting/containing landslides

- 11.2 Rigid barriers
- 11.3 Flexible barriers
- 11.4 Ditch and embankment
- 11.4 Debris retention basin



Technological aspects

- The portal is designed as a web-based application
- The risk mitigation algorithm based on the AHP is developed using the Python-based Django web framework
 - Easy remote access by the experts' panel and users
 - Accessibility through mobile devices
 - No software installation required
 - Online availability of the most recent version
 - Integration with geospatial databases, landslide inventories, etc.
 - Integration with mathematical software for the statistical processing of the expert scores database.
 - Automated generation of output reports for users

Summary and Conclusion

- This study introduce the web-based toolbox for landslide mitigation measures.
- The tool can provide more knowledge about alternatives for mitigation measures to stakeholders, decision makers, and public
- The toolbox provides preliminary strategy of the risk mitigation. The suggestions involves not only technical suitability but also environmental and economic constraints
- Experts acting alone cannot choose the “most appropriate” treatment method. Better way to implement a multi-disciplinary approach should be considered in the further development.

On-going and future works (developments and *extensions*)

On-going

- **Validation of the program**
NBS (20 cases, worldwide - on going)
Passive control works (30 cases, Italy)
- **Expert scores for the individual measures** - Involving practitioners, researchers, decision makers...

Future

- **Help the users while adding inputs of site-specific case**
pop-up message
classification type of landslide etc..
- **Case studies** – extensive literature review
- **Statistical management of expert inputs**
- **Integration with geospatial database**
(e.g., Skrednett, National Road Databank, among others)
- **Improve the aesthetic of the webpage**



Thank you for your attention!

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