Selection of appropriate landslide risk mitigation measures - LaRiMiT

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KLIMA2050

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)

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

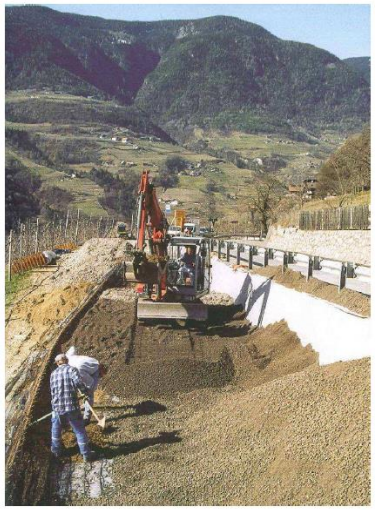
D 5.1 Compendium of tested and innovative structural, non-structural and risk-transfer mitigation measures for different landslide types

MITIGATION THROUGH REDUCTION OF HAZARD

2 MODIFYING THE SLOPE GEOMETRY/MASS DISTRIBUTION

2.4 SUBSTITUTION OF MATERIAL IN DRIVING AREA WITH LIGHTWEIGTH FILL

Picture 2: Installation of expanded clay for lanslide remediation (source: Di Prisco, 2007)



Picture 3: Installation of expanded clay for lanslide remediation (sour

Picture 4: Use of shredde tyres for lanslide remediation (source: Dub

MITIGATION THROUGH REDUCTION OF HAZARD

2 MODIFYING THE SLOPE GEOMETRY/MASS DISTRIBUTION

2.4 SUBSTITUTION OF MATERIAL IN DRIVING AREA WITH LIGHTWEIGTH FILL

APPLICABILITY

Class	Descriptor	Rating	Notes
Type of movement (Cruden & Varnes, 1996)	Falls	0	Only suited to rotational or pseudo-rotational slides.
	Topples	0	
	Slides	6	
	Spreads	0	
	Flows	0	
Material	Earth	8	Mainly applicable to landsliding involving earth and debris. Applicability in rock limited by difficulty of excavation.
	Debris	6	
	Rock	2	
Depth of movement	Superficial (< 0.5 m)	6	Typically applicable to relatively small and/or shallow landslides. It is generally impractical and not necessary to carry out large scale substitution as would be necessary on large landslides.
	Shallow (0.5 to 3 m)	6	
	Medium (3 to 8 m)	6	
	Deep (8 to 15 m)	4	
	Very deep (> 15 m)	0	
Rate of movement (Varnes, 1978)	Moderately to fast	0	While excavation can be carried out without special difficulty when the rate of movement is slow (5 cm/day) or less, backfilling with lightweight fill presupposes that the slide is stable or moving at most very slowly.
	Slow	2	
	Very slow	6	
	Extremely slow	8	
Groundwater	Artesian	4	High or artesian groundwater conditions pose special problems both to the excavation and to the stability of the slope after backfilling with lightweight fill, limiting the applicability of this technique when these conditions occur.
	High	6	
	Low	8	
	Absent	8	
Surface water	Rain	6	Surface flows must be diverted to prevent them from accumulating in the lightweight fill and/or infiltrating the portion of the landslide mass left in place. Drainage to be provided both on surface and at interface between fill and natural soil.
	Snowmelt	6	
	Localized	6	
	Stream	2	
	Torrent	0	
	River	0	
Maturity		6	Concept is well developed but knowledge of mechanical properties and applicability of different lightweight fills still not fully established.
Reliability		6	The reliability of the technique depends on the evaluation of the stability of the treated slope and on the homogeneity and durability of the fill used.
Implementation		6	Can be implemented with widely available equipment. Possible difficulties with excavation in rock and with the disposal of arisings. Construction control.
Typical Cost		6	Moderate to high, depending on the material used.

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"

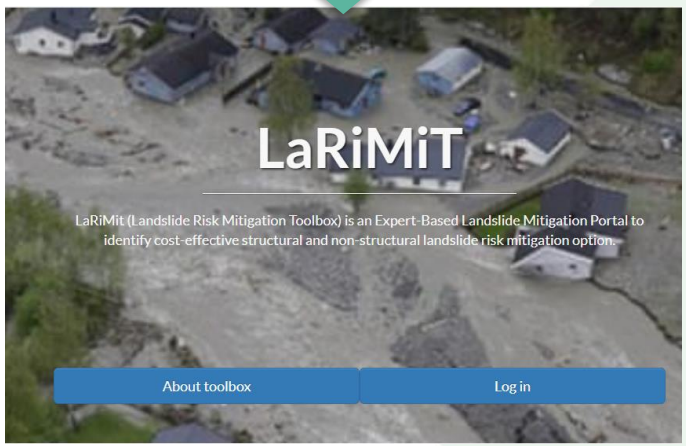
Fact sheet

KLIMA2050

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)



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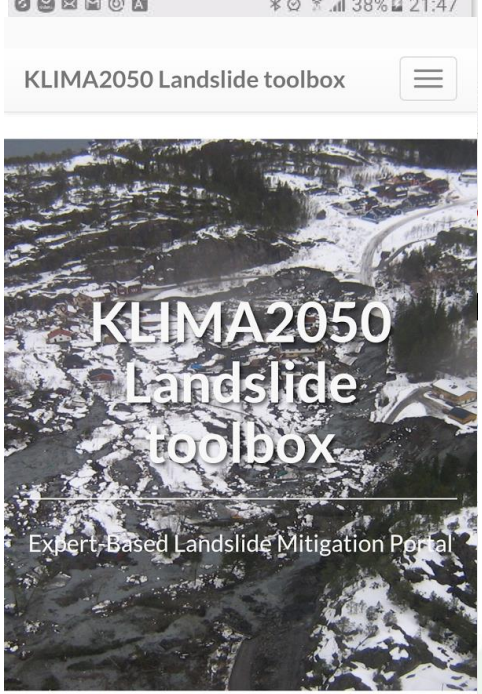
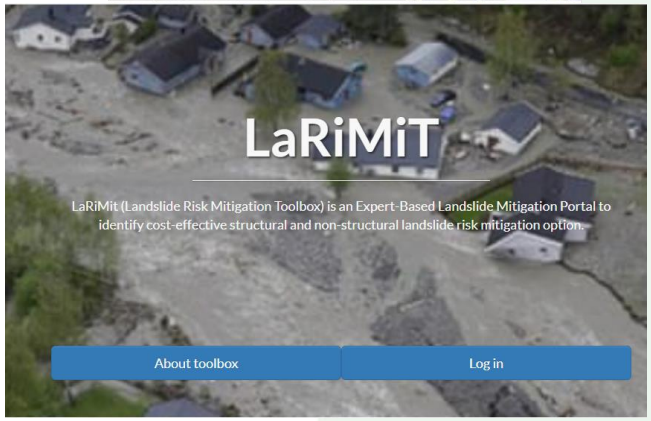
Decision makers/Users point of view

- 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





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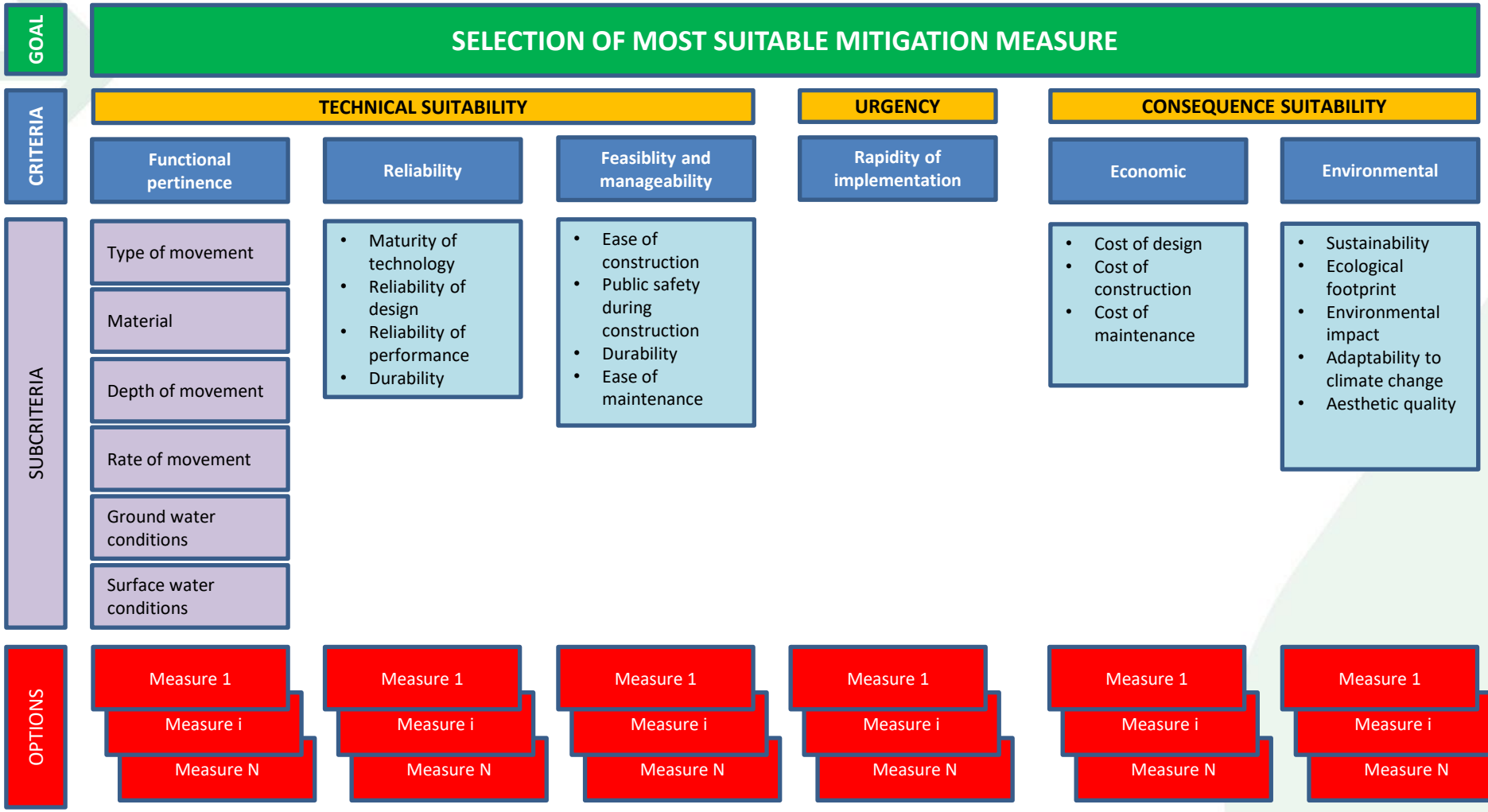
Goal, criteria and options



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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

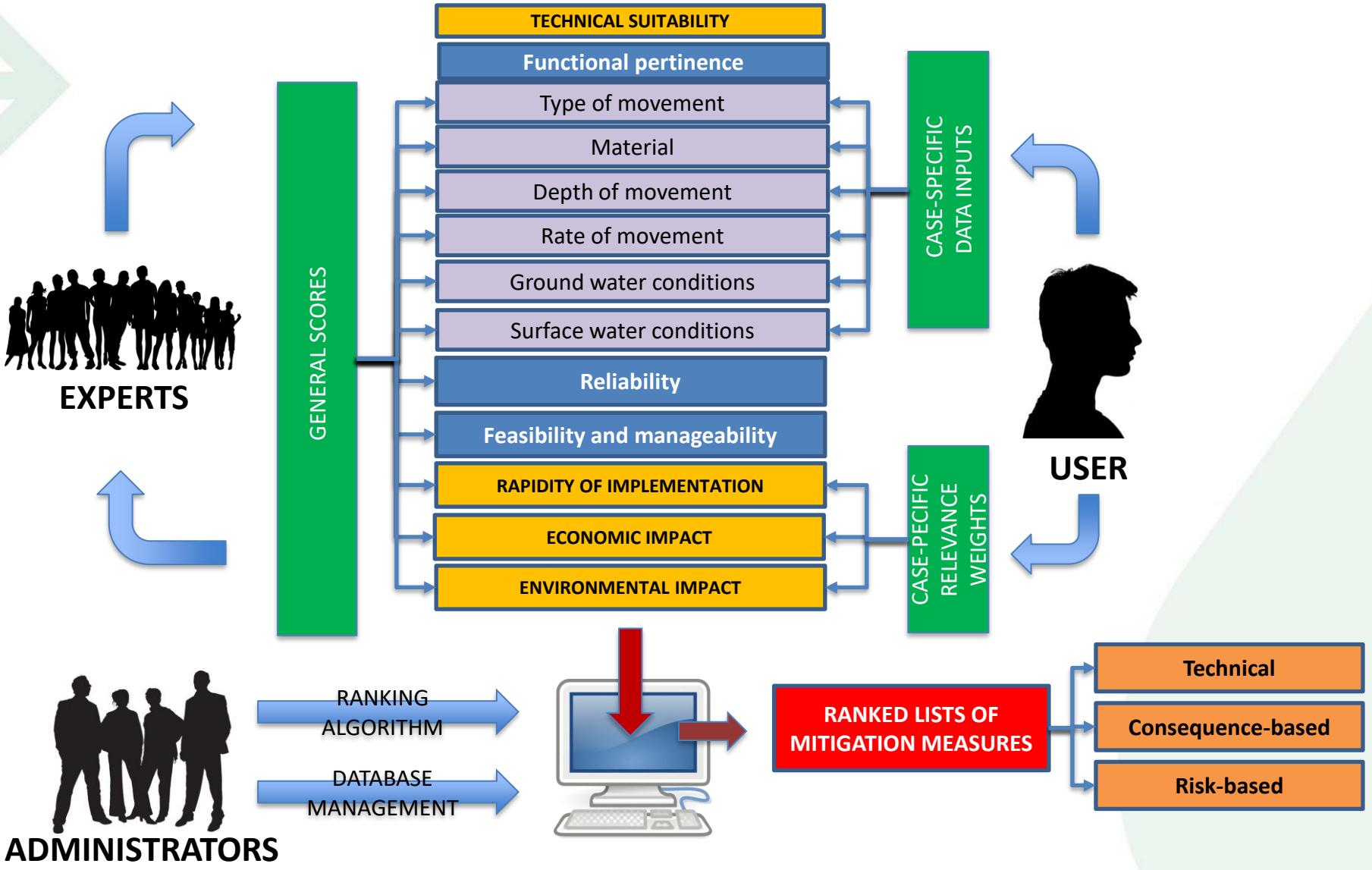
Expert inputs ARE NOT case- and site-specific and are resident in the toolbox server in the form of database

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

Risk = Hazard x Vulnerability x Elements at risk

Risk = Hazard x 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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