# Spatial multi-scale approach to manage hydrogeological hazard along linear infrastructures

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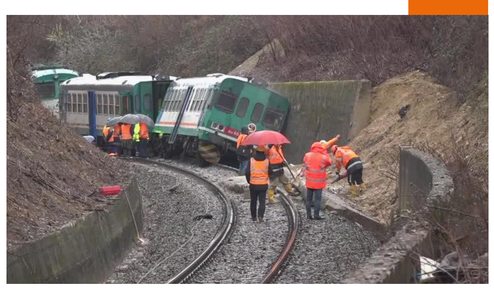
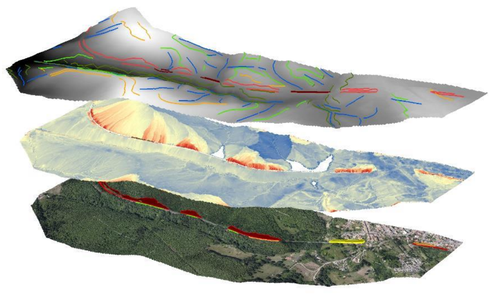
## INTRODUCTION AND MOTIVATION

**Long linear corridors** often cross areas that are highly susceptible to **landslides** and even low volume landslips can cause serious problems and may compromise safety. In order to assess the landslides hazard, detailed data such as slope geometry, geotechnical and geomechanical properties of materials, drainage system pattern etc. are needed. Even though thematic datasets are available and easily downloadable for the majority of the Italian territory, their scale is not adequate and ad-hoc input data must be gathered. An original procedure based on **geomatics and geomorphometric approach to assess landslide hazard** and support remedial works planning along linear infrastructures has been developed by IMAGEO. Ground and remotely sensed data are processed in order to obtain a wide range of parameters along the corridor, from slope geometry to rock mass classification. A Spatial Multi-Criteria Analysis (SMCA) is then used to create a composed and spatially distributed index of landslide hazard, based on normalized values of triggering factors Such index is used to identify and classify the morphological unstable element along the infrastructure corridor, supporting decision-makers in defining the most appropriate mitigation measures and planning their implementation. This method has been successfully applied to hundreds km of railway lines and highways in Italy, so far.





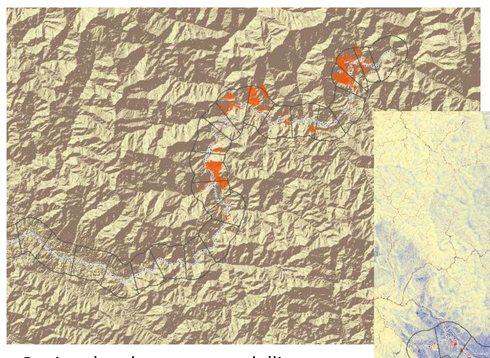
## MULTISCALE AND SPATIAL MULTICRITERIA APPROACH

A **downscale approach** allows the infrastructure manager to identify the potentially more instable areas with a Multi-Scale approach based on progressively more detailed levels of analysis: the most detailed in-depth investigations are applied only to the sections that have been highlighted as critical in lower-resolution analysis.

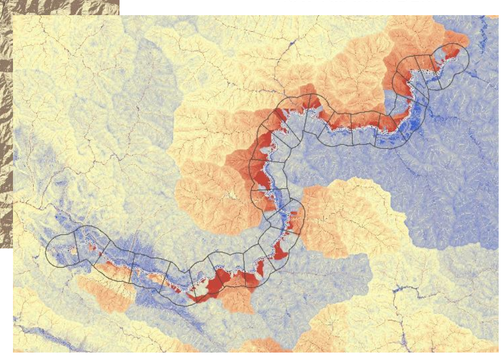
Data collection is organized into different levels in order to produce a synoptic state-of-the-art view of the infrastructure, which depends on the actual knowledge along the infrastructure. This approach allows to integrate ground surveys data, historical data, analysis of remote sensing data (e.g.: radar interferometry), geomorphometric analysis (e.g.: curvature, connectivity index, etc…), geomorphological maps, real-time or post-processed monitoring instruments data (inclinometers, piezometers, gnss stations, etc…) and results of landslide runout modelling at different scales; it can even be integrated with predictive results of triggering factors as precipitations.

## REGIONAL ZONING– Scale 1:50000 -1:100000

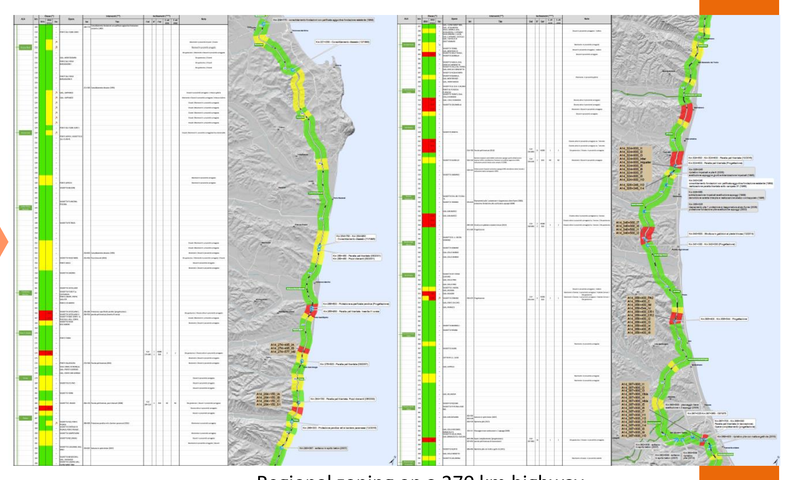
The first and lower-scale level is based on the collection of existing data on the area, like National Landslides Inventory, geomorphometric analysis on available DEM in the area (integrated in most cases with an ad-hoc Airborne LIDAR products), elaboration of available satellite images (Sentinel data can be very useful at this level of analysis) and integration of all the previously collected data along the infrastructure. The result is a Hazard or Susceptibility map (usually based on a kilometric division) which highlights those sections that need more in-depth investigations.



Regional scale runout modelling based on low resolution satellite interferometric data and 30m DEM



Geomorphometric analysis (Connectivity Index) based on low-res 30m DEM



Regional zoning on a 270 km highway

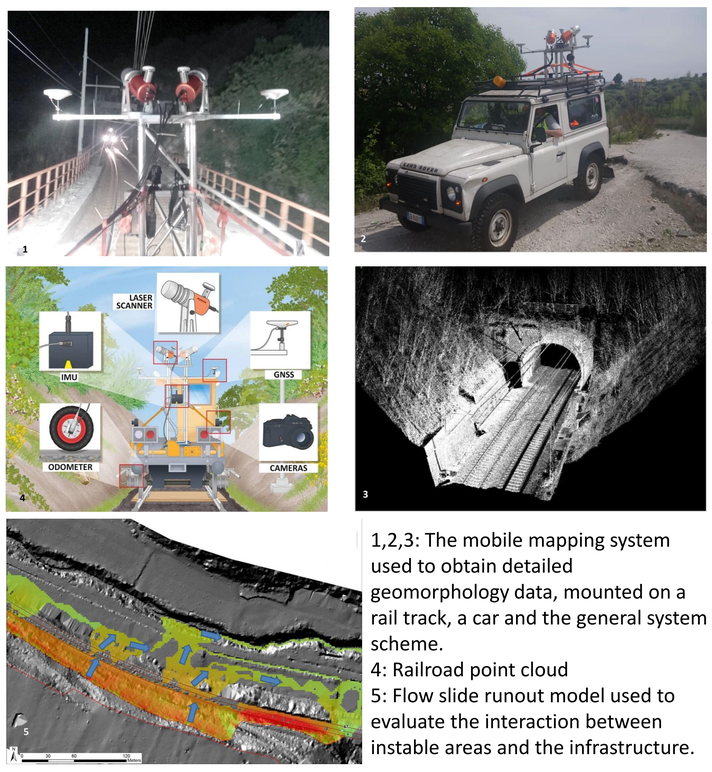
## LOCAL ZONING – Scale 1:10000

A second level of analysis exploits detailed cartographic products (DEMs, orthoimages, point clouds) obtained from **LIDAR flights** taken along all the infrastructure corridor, needed to produce a detailed and updated geomophological map. Depending on the morphological framework of the area, an integration with **mobile mapping** surveys can provide information on sub-vertical rock walls, which area typically not well described by a Lidar flight. Our modular and versatile mobile mapping system is shown in the picture aside.

At this scale, a mid-level geomechanical charachterization of rock walls and stability analysis on landslides are performed, as well as the evaluation of the possibile interaction between the instabilities and the infrastructure.

The analysis procedure depends mainly on two factors: the landslides dynamics in the area and the type of infrastructure. Problem related to railways, road or flowlines are, to some extent, different. The accessibility of the area, in order to perform measures and surveys are strongly different too.

The output is a morphological based hazard or susceptibility map, as shown in the picture.




1,2,3: The mobile mapping system used to obtain detailed geomorphology data, mounted on a rail track, a car and the general system scheme.
4: Railroad point cloud
5: Flow slide runout model used to evaluate the interaction between instable areas and the infrastructure.

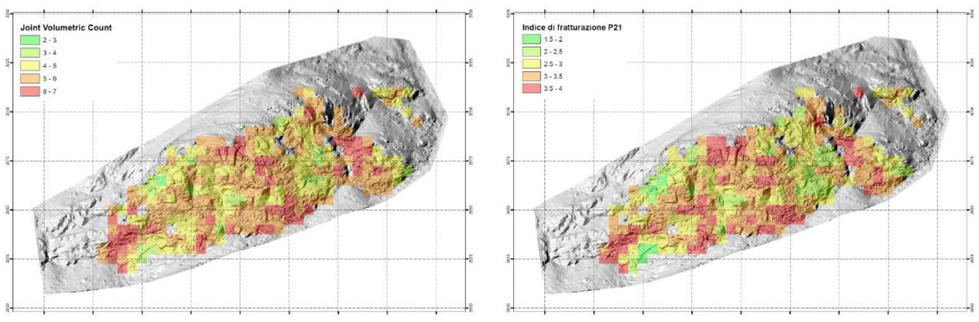

Output map of the potentially unstable elements (natural and man-made slopes), characterized and classified in four classes (from green to red). This is a detailed global view on the infrastructure that can be used to plan mitigation measures.

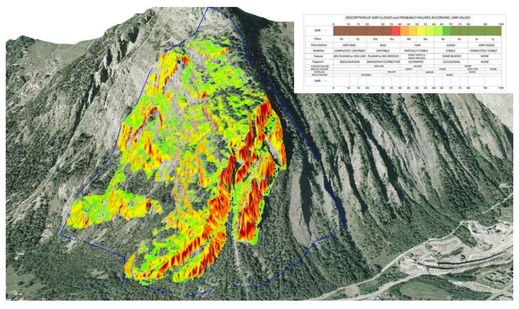
## SITE SPECIFIC ZONING – Scale 1:1000

At this scale, a mid-level geomechanical charachterization of rock walls and stability analysis on landslides are performed, as well as the evaluation of the possibile interaction between the instabilities and the infrastructure.

Terrestrial Laser Scanner and UAV/helicopter photogramemetric surveys are used to produce detailed point clouds on which automatic and iterative procedures, properly developed by IMAGEO, are applied to obtain spatially distributed values of the main geomechanical parameters as VRU, JV, P21, SMR, etc…

At this scale, the monographic study of the area is strongly customized, depending on the instability issues to be investigated.

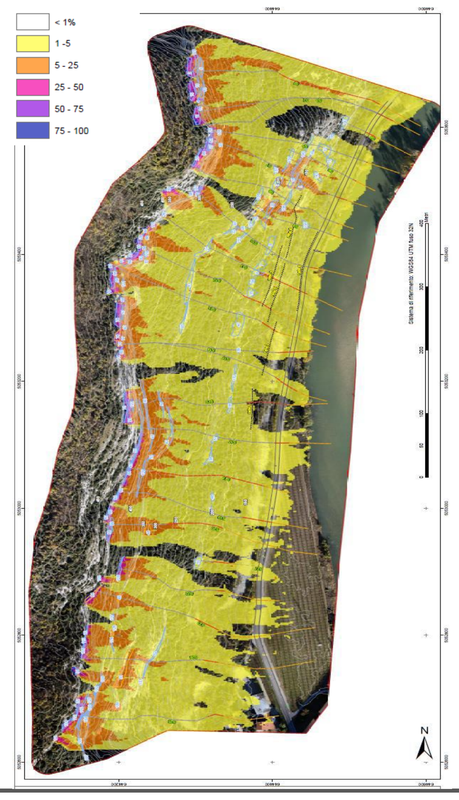


Above: example of spatialized geomechanical parameters on a rock wall.

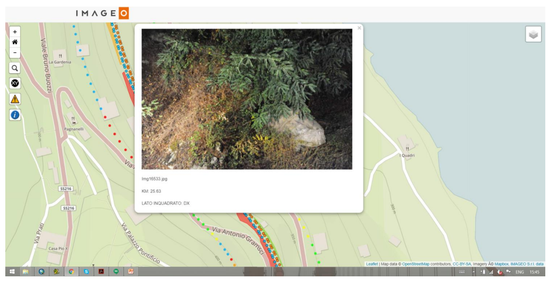
Left: spatialized SMR value on a wide potentiially unstable rock slope

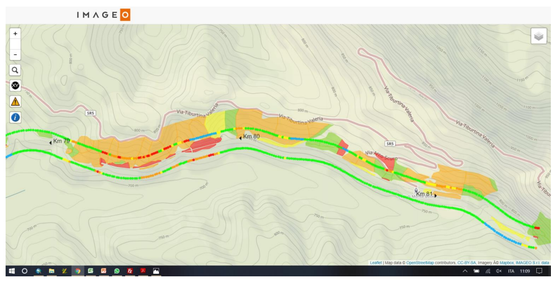
Right: rockfall transit probability map obtained from 3D trajectographic analysis




## DATA ACCESS AND USABILITY

Since the final user's need is to have an operational tool to manage the hydrogeological risk along the infrastructure, a WebGIS service have been implemented to allow the visualization of the surveyed data, the results and the interpretation also to non geospatial-expert users. Customized geo oriented services allow the user to update the system, insert pictures, notes, and what can be useful to maintain the system alive and updated.





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