

## **Landslide hazard assessment of the Black sea coastline (Caucasus, Russia) via drones**

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Landslide hazard assessment of slopes of Sochi was performed along the railway between the cities Tuapse and Adler (total length 103 km).

The railway passes through the territory with active development of hazardous geological processes such as landslides, rock falls and debris-flows.

By the beginning of 2016, 36 landslide sites were discovered along the railway (total length 34 km), 48 rock-fall sites (length 31 km), and 5 debris-flow sites (length 0.14 km).

In recent years the intensification of deformations was observed. For instance, during previous 10 years (1996–2005) 28 sudden deformations occurred due to slope processes, which caused interruptions in traffic. And in the present decade (2006-2015), 72 deformations were recorded.

High landslide activity and economic loss determined the necessity of complex investigations of engineering geological conditions of landslides development and causes of its intensification. The protection strategy development was needed to minimize negative consequences.

Thus, the investigations of landslide situation along the railway “Tuapse – Adler” included the categorization of landslide sites by level of hazard, with risk assessment based on numerical criteria.

Preliminary evaluation of landslide hazard for the railway was conducted via the analysis of archived engineering-geological documents.

13 of 36 landslide sites (total length 13 km) were selected, reflecting the variety and peculiarities of landslide displacements on slopes (both active and inactive sites).

Visual field observations of landslide slopes using drone “DJI Phantom 4” were completed during the second stage of this investigation. High-resolution photographs of landslide cirques, cracks, scarp walls, vegetation features were obtained via drone, which would have been impossible to obtain from the ground in conditions of dense subtropical vegetation cover.

Possible approaches to the landslide activity and hazard assessment were evaluated: slope stability analysis, geophysical monitoring methods, analysis of critical deformations and critical velocities of displacement, the analysis of changes of conditions of landslide development during its displacement, as well as scoring approaches to landslide hazard and risk assessment. As the result, the method of probabilistic estimation of landslide activity and hazard has been proposed, based on selection and analysis of main factors, influencing landslide displacements.

Slope steepness, landslide thickness, slope length, bedrock dip, slope relief, cracks, vegetation patterns and other factors were used for assessment of activity of landslide sites.

The investigation was based on the proposed probabilistic method of assessment of landslide activity and hazard.

The considered landslide sites were ranked by the rate of activity as inactive, potentially active and active.

The most active sites were used to identify potentially the most hazardous sites.

Furthermore, the following factors were additionally considered: the damage of railroad facilities due to landslide, landslide activity, thickness of landslide at the toe of the slope, bedrock stratification, the conditions for the cirque development, the position of the sliding surface relatively to the railway, the involvement of bedrock into displaced mass.

As the result, the investigated railroad sites were divided into three categories: non-hazardous, potentially hazardous and hazardous.

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