ID 196: Climate-Informed Geotechnical Assessment of Rainfall-Induced Landslide Hazards for Road Network Resilience in Turin, Italy

9:30 AM – 9:50 AM

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Climate change is intensifying the frequency and magnitude of rainfall events, both extreme and regular ones, leading to more severe hazard conditions over the long run. In this regard, rural road infrastructure in hilly and mountainous regions is particularly vulnerable to rainfall-induced landslides (RILs), as evolving precipitation regimes interact with heterogeneous soil properties and complex terrain morphology, affecting slope stability and the resilience of road networks (RNs). Thus, higher-intensity hazards result in greater risks, even without accounting for the ever-growing vulnerability of ageing construction materials.

This study presents preliminary results from a GIS-based, physically informed framework for assessing rainfall-driven landslide hazards along road infrastructure, to support climate-adaptive risk assessment and resilience-oriented planning.

The methodology is applied to a representative hilly and forested area in the Piedmont Region (northwestern Italy), between the large metropolitan area of Turin and the small town of Pino Torinese, along a high-traffic road (Strada Statale Padana Inferiore – SS10), and smaller alternative routes. High-resolution topographic data, spatially distributed geotechnical parameters, and regional rainfall statistics are integrated within a unified modelling environment.

Rainfall infiltration is explicitly modelled using a steady-state hydrological formulation, enabling estimation of the saturated soil depth as a function of rainfall intensity, soil porosity, hydraulic conductivity, and other geotechnical parameters. This infiltration depth is incorporated into a physically based slope stability model to compute the Factor of Safety (FS) under rainfall-induced conditions. A viewshed-based terrain classification is employed to distinguish uphill and downhill slope sectors relative to road alignments, allowing targeted assessment of slope failures most likely to disrupt infrastructure through debris accumulation or loss of ground support. Results identify several zones prone to instability, some of which intersect critical road segments.

To account for climate nonstationarity, the framework is applied not only to historical and design rainfall events but also to projected rainfall intensities derived from climate change forecasts for the same spatial domain. This enables assessment of how anticipated increases in rainfall magnitude may alter stability conditions and expand zones susceptible to failure; the results indicate a systematic reduction in stability margins and a widening of hazardous areas, underscoring the sensitivity of geotechnical systems to climate-driven changes in precipitation. Quantitative metrics to evaluate shifts in landslide-triggering thresholds under future climate scenarios are also estimated.

In conclusion, the proposed framework supports nonstationary risk assessment and informs adaptation strategies such as updated early-warning thresholds, prioritised slope stabilisation, and resilience-based infrastructure management. The approach is transferable to other landslide-prone regions and contributes to the development of climate-resilient transportation networks.

Speaker

Marco Civera

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ID 41: Using an Informational Design Approach for Civil Engineering Project Planning under Climate Change

9:50 AM – 10:10 AM

Author(s): Richard Koehler, Visual Data Analytics, LLC

Climate change affects multiple types of engineered infrastructure. Engineers are encouraged to engage in cooperative research involving scientists from multiple disciplines to gain an understanding of the magnitudes of future extremes and their consequences [1]. Beyond this guidance, it is important that with increasingly sophisticated risk analysis of engineering projects, an assessment of environmental input data with similarly advanced techniques should be included to identify relevant patterns.

Specifically, the research presented here demonstrates novel ways to increase the understanding of the hydrologic regime, critical when designing and monitoring engineering projects. By using informational design concepts and a geo-temporal information system (GtIS) , the following three data visualization and analysis techniques are possible.

1 - The raster hydrograph. This dual time scale graph simultaneously displays daily, weekly, monthly, seasonal, annual and inter-annual flow patterns on a single plot, helping to identify climate change signatures.

2 - The enhanced flow duration curve (eFDC). The traditional FDC has no chronological order information, limiting the ability to identify climate change within the streamflow record. The eFDC solves this problem by plotting a dQ/dt point cloud around the traditional FDC [2]. This results in new ways to visualize and identify changes in flow patterns between comparison periods.

3 - The dQ/dt matrix. An extension of the eFDC, this matrix displays and quantifies all hydrologic conditions within the daily flow record. Data self-sorts within the matrix, showing regions of increasing flow ($dQ/dt > 0$), steady flow ($dQ/dt = 0$), and decreasing flow ($dQ/dt < 0$). The number and degree of discharge conditions are detailed, allowing for a Markov transition matrix approach to summarize streamflow changes and to facilitate future Markov chain simulations.

Other benefits include more efficient, higher resolution model calibrations and sensitivity analyses, greater plot customization, and improved communication of results to a wider audience.

[1] Committee on Adaptation to a Changing Climate, June 2015. Adapting infrastructure and civil engineering practice to a changing climate. American Society of Civil Engineers.

[2] Koehler, R., March 2025, How to modernize the flow duration curve, Staying Sharp, CE Magazine, American Society of Civil Engineering.

Speaker

Richard Koehler

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