Part II
Rapid Runout Analysis

Introduction by Marina Pirulli and Claudio Scavia

Politecnico di Torino, Department of Structural, Geotechnical and Building Engineering, Torino, Italy

Landslides may damage any human structure and may even cause the loss of lives when they occur in a catastrophic way. In order to supply improved means of mitigation and planning to the Organisms working in land management for landslide prevention and hazard mitigation, the main goals of landslide runout analysis should be the assessment of future landslide activity with a range of potential scenarios. In particular, when a potential source of instability is identified, hazard mapping through runout analyses may contribute to define which areas could be threatened by landslide propagation.

Two main approaches to runout analysis can be identified: qualitative and quantitative. Numerical models are part of the latter approach and, in recent years, have particularly emerged as a useful tool for landslide runout analysis and risk assessment. With increasing attention and advances in computational capabilities, a large number of models have been developed or are currently in development. Several of these models have included innovations that have significantly advanced both the ability to simulate real events and the fundamental understanding of rapid landslide processes. Contributions have been made by a number of researchers with a wide variety of perspectives and goals, making this topic truly multidisciplinary. Still, some significant challenges remain as we move towards more accurate and objective runout prediction using numerical models. Accordingly to this scenario, a large number of the contributions that are part of this Chapter focus on numerical modeling.

The simplest qualitative method, which mainly consists in estimating the distal limit of motion, the distribution of intensity within the impact area and the potential direction of motion on a topographic map by following the direction of steepest descent from the source area (subjectively accounting for spreading, superelevation and possible avulsion in channel bends), is here proposed only by Lima who describes a methodology called "Relative Rapid Landslides Analysis" for rapid evaluation of risk. This methodology is based on five different indicators of risk. Each of these indicators is estimated based on experience, judgment and the observation of similar landslides. The sum of these values results in an index of relative landslide risk of the area.

Quantitative runout analysis methods are less subjective and can be broadly classified as either empirical or analytical. In regard to the analytical class, discontinuum and continuum methods have advanced incrementally over the past three decades to the point where, when used in combination with careful engineering and geological judgment, first-order runout prediction appears to be possible. However, there is still room considerable for improvement.

In defining the characteristics of mathematical and numerical models for the simulation of rapid landslides, it is important that all the key aspects that control the dynamics of a moving mass are taken into account. As to this, Crosta et al. investigate the important role of processes as entrainment of material located along the landslide path in changing the runout configuration. Before moving to the application to real site problems, they interpret this phenomenon referring to laboratory experiments. Similarly, Pisani et al. evidence that the rheological parameter calibration can result altered, even in simulating laboratory experiments, if some important factors as the centripetal acceleration are neglected in the numerical implementation. In this regard, it is proved that the consequence of including the centripetal effect in the set of governing equations is a significant lowering of the dynamic basal friction angle necessary to back-calculate some simulated experiments, this makes the value of the friction angle much closer to the real one than if the centripetal acceleration term is neglected.

A major problem in applying numerical modeling to the study of real events is the definition of constitutive laws and the calibration of their rheological parameters, which cannot be measured directly and which are crucial for a realistic simulation of a landslide behavior. Both Deangeli et al. and Quan Luna et al. focus their papers on this aspect. In particular, Deangeli et al. analyze debris-flows and propose that the constitutive law is selected as a function of the lithology existing in the investigated basin. They evidence that, among others, the content of fine fraction in the flowing mass contributes in the distinction from collisional to viscoplastic regimes. Validation of the approach is made through the application of a Cellular Automata Model to cases of debris-flows at basins having different lithological characteristics in North-western Alps. Quan Luna et al. aim to quantify the uncertainties in resistance parameters and release volumes through the definition of probability distributions to be used as input for runout modeling probabilistic methodologies.

With regard to rheological problems, laboratory experiments can give an interesting contribution in investigating landslide dynamics from a physical point of view, in validating a numerical model and in identifying the more appropriate rheology for an analysed event. In particular, Cola et al. perform laboratory experiments to study the interrelations between the grain-size composition of mud-flows and the rheological properties at different solid concentrations. Guilhem et al. analyse in laboratory a single-particle impacts to assess parameters to be used in the contact law adopted in a numerical model based on the discrete element method. Once calibrated, the model allows the study of the influence of several parameters on the propagation of a granular mass.

On the other side, Manzella et al. and Sauthier and Labiouse use laboratory experiments specifically to study the influence of different parameters (e.g. volume, falling height, slope angle) on the characteristics of the final deposit (e.g. runout and extension). In particular, Manzella et al. investigate the motion of large masses with the aim of determine the reasons of the mass high mobility, which results much greater than could be predicted using frictional models. The same aspect is treated by Sosio et al. who replicate the motion of historical rock/debris avalanches using a Frictional and a Voellmy models and define a range of values for the parameters of each rheology, which best replicate the propagation.

With reference to site analysis, Marsella et al. discuss the implication of parameter choice on maximum runout and invasion of inhabited areas in case of some pyroclastic debris-avalanches. Similarly, Mortara et al. calibrate the input parameters for the rheological model assumed to numerically simulate a well-documented case of ice-rock avalanche. In site applications, Tobler et al. and Filipello and Mandrone propose the approach to runout modeling with GIS-based models with reference to shallow landslides and rockfall, respectively.

An interesting discussion on the possible advantages of using a two-phase model respect to the above mono-phase model, to simulate debris-flow propagation, is open by Stancanelli et al. They underline that the calibration of a two-phase model could be easier, since parameters have a more specific physical meaning respect to the empirical tuning of the parameters used in a mono-phase model.

From a detailed analysis of the all the here described contributions, it emerges that numerical models for landslide runout simulations are of wide interest given the high importance of the results they can give in respect to the territory management, however the major problem that concerns all the approaches is the difficulty in calibrating the parameters necessary to reproduce the real behavior of the complex type of investigated phenomena.

A consensus on the best method of determining the input resistance parameter values for predictive runs has not yet emerged.