An innovative tool for the quantification of road damages in alpine basins

Matteo Paternolli, MSc[1]; Corrado Lucarelli, MSc[1]; Simone Gambarotto, MSc[1]; Walter Gostner, Ph.D[1]; Nicola Marangoni, MSc[2]; Willigis Gallmetzer, MSc[2]

INTRODUCTION

Mountain zones are particularly subject to various types of natural hazards, such as debris flows, avalanches, and rock failures. Therefore, they require particular protection measures according to their specific orographic configuration. As a consequence of the increased anthropogenic development and exploitation, potential risks also increased over the past few decades. The protection of communities living in mountain zones is a very complex problem, and many different aspects must be taken into account, including hydrogeological, economic and social issues, by the means of a multidisciplinary and sustainable approach. Within this context, basin scale planning, also called basin management plan, represents an effective method. This approach is based on detailed analyses of the fluvial systems and allows to elaborate a sustainable and integrated management model. In this work, we present some results of the Solda River basin management plan.

METHODS

The Solda River basin is situated in South Tyrol, northern Italy, and is part of the Stelvio National Park. The main source of revenue for the study area is represented by tourism, both in summer and in winter. Infrastructures play an essential role, with two state highways constituting the main transport routes within the basin. In this strongly tourism-oriented area, roads therefore represent a key element for connection and fruition.
The results of the first phase of the project show that hydrological and avalanche hazards are substantial throughout the catchment, and significantly affect infrastructures, including roads (Figure 1).
In this work, we present a novel methodology to quantify direct and indirect damages to the road network caused by natural hazards and apply it to the Solda River basin. We define as direct losses the damages caused to the road infrastructure by avalanches or flood events. Indirect losses are a consequence of direct losses. For example, road closures during repair works could lead to significant economic losses for commercial and tourist facilities located upstream of the closed road section. For the quantification of direct damages we referred to the methodology developed by the Swiss Federal Roads Office (ASTRA, 2012).
In particular, this method distinguishes between two scenarios, namely road burial and erosion. The former focuses on the deposition of materials transported by the natural hazard event (wood, debris) on the road surface and takes into account the cost of debris removal and road repair. The latter focuses on erosion of road embankments caused by floods and related restoration costs.
In terms of risks to persons exposed to natural hazards, we distinguish between two cases: the natural event can directly impact on vehicles circulating on the road or vehicles could crash on sediments previously deposited on the road by the natural phenomenon. The quantification of economic damages depends on vulnerability, which represents losses extent (Totschnig et al., 2012), and probability, which is given by the chance of natural events occurrence. In the present project, vulnerability functions were developed for two different scenarios (erosion and road burial). The main parameters to take into account are the probability of the natural event, the value of the involved road and the economic damages caused by erosion or burying. The number of people potentially involved in direct impact or collision was estimated as a function of the recorded average daily traffic (ADT).
Beside direct damages, a fundamental aspect to take into account in the Solda River basin is given by indirect damages. The closure of a road section due to the occurrence of natural events can lead to substantial economic and social consequences, especially if the street constitutes the only way to

reach the inner parts of the basin. Economic losses mainly affect tourist facilities, while social impacts include, among the others, the impossibility to reach the workplace or, in case of emergency, adequate medical facilities. Since both touristic presence and the type of natural hazard (avalanche or flood) are directly linked to seasonality, in the present research two scenarios were considered, namely a winter and a summer scenario. As in the case of direct damages, the quantification of indirect damages depends on the probability of occurrence of a natural event and on vulnerability. In turn, the latter is a function of street closure duration, number of people present in the catchment upstream of the interruption and daily economic damage, that is the average cost per person per day.

RESULTS AND CONCLUSIONS

Firstly, the results of the present analysis show that the road network is of strategic importance in alpine catchments like the Solda River basin. Moreover, indirect damages are in some cases one order of magnitude higher than direct losses. These results are in agreement with previous studies (Pichler, 2011). Therefore, it is possible to conclude that commercial and tourist activities, as well as the enjoyment of the landscape by tourists and residents, is strictly linked to road network efficiency. The next steps are the definition of priorities for intervention and the planning of actions on the basis of the outcomes of this project, that highlighted the primary importance of roads in the Solda River basin. The methodology applied in the present study constitutes a tool of primary importance that can be widely applied. The Solda River basin is a classic example of an alpine tourist area where the interaction between natural hazards and mobility infrastructures is relevant and the efficiency of the road network has a fundamental role both from a social and an economical point of view.

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Figure 1. Floods of 1987 (links) and 2014 (right) on the Solda River, and consequent damages to the road network.

KEYWORDS

basin management plan; natural hazards; risk assessment; road efficiency

1 Patscheider & Partner Consulting Engineers Ltd, Bolzano, ITALY, m.paternolli@ipp.bz.it
2 Civil Protection Agency of the Autonomous Province of Bolzano – South Tyrol, ITALY