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Proposal for expeditious inspection sheets that can also be carried out with a drone for rockfall protection works

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A proposal for the management of rockfall protection works on complex infrastructure networks such as that of the Autonomous Province of Bolzano through planned inspections. A conscious management requires an adequate planning of inspections and the determination of economically sustainable 'thresholds' of intervention. Since it is not possible to predict the frequency of detachments that could cause deterioration of structural elements, it is necessary to plan different types of inspections: a more frequent visual inspection and a more detailed inspection leading to the planning of maintenance or monitoring projects.
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1. The Manager's functions on the heritage of rockfall mitigation works

The heritage of rockfall protection works along a complex infrastructure network is not fully known due to changes in management and the lack of habit of keeping records of the works, especially when emergency works are being carried out. The inspection of works involves an expenditure of funds that is often unsupportable by a public or private manager. Their maintenance is not provided for by national or European legislation, but there is a technical report UNI/TR UNI 11211-5 that defines the methods and the role of the manager.

The Autonomous Province of Bozen/Bolzano, following Legislative Decree No 112 of 31 March 1998, manages the state and provincial roads in its territory with more than 6,000 rockfall protection works. According to Article 14 of the Highway Code: 'The road-owning authorities, in order to ensure the safety and smooth flow of traffic, shall: a) maintain, manage and clean the roads, their appurtenances and furnishings, as well as equipment, installations and services…'

Rockfall protection works are to all intents and purposes to be considered as pertaining to the road itself.

The works are surveyed within the VISO database, which serves as a digital archive. Each work has been assigned a 'speaking name', the work code, indicating the road and the surveyor's code (e.g. SS042_SC_ 01) and an internal VISO database identification number. In some cases, such as rockfall barriers, the work code is applied to the work by means of an aluminium plaque.

VISO acts as a digital archive and for recently constructed works contains all information about the work (location, geometry, project documentation of the work, inspections and maintenance)

Operator's archive (VISO): for new works it is necessary to provide the operator with the works file and all the documents required by the regulations in force (NTC 2018, L.D. 9 April 2008 n 81) including information for the safety plan during maintenance operations.

For each work, the geometry, type, length, height and parameters defining its functionality are:

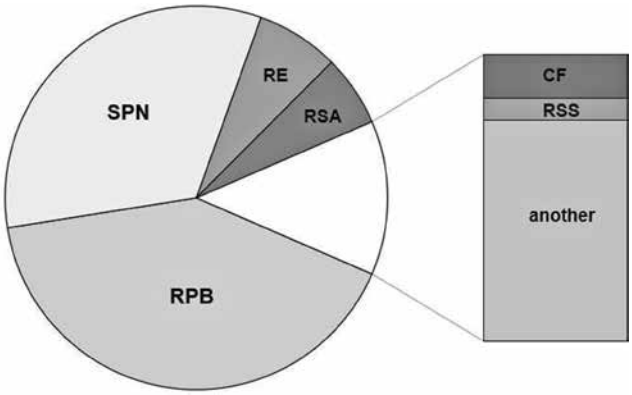

Fig. 1 – Percentage distribution of the main categories of works. RPB = rockfall protection barrier; SPN = slopes protection nets; RE= rockfall embankments (reinforced with geogrid or without); RSA = rock anchors or soil nailing anchors; CF = concrete foot (with or without anchors); RSS = rockfall sheltering structures.

a) recorded:Protection System Location (P.S.L.)
b) Protection System Design (PSD)
c) Preservation Protection System (P.P.S.)

These parameters also made it possible to classify all the works dated or inherited from Anas management, making it possible, by comparing them with the dangerousness of the slope and the expected damage, to give a parametric assessment (risk index) of the safety of the road section with regard to the rockfall hazard. On the basis of the risk index of the road sections, a list of intervention priorities is drawn up every 6 months Council Resolution 842 08/07/2014. The list is continuously updated with new designs, works realised, periodic inspections and events.

From this initial survey through the analysis of the state of the works, it was possible to define the works in need of maintenance and add them to the priority list.

The analysis of anomalies performed by the DICAM of University of Bologna made it possible to recognise the most frequent anomalies found on the works of the most important highways.

In order to manage the existing works in the best possible way with the human and financial resources available to the operator, the Province of Bolzano is developing a Management Plan, as a single coordination tool that harmonises the activities of the operator.

1.1. Viability Information Operating System

The main activities of the Manager on the existing assets, besides managing the data archive of the works (VISO) are inspection, maintenance and monitoring activities.

2. Inspections

There are 2 types of inspections, the first simpler and more frequent type A inspections based on visual observations determine a score. If the maximum score exceeds the threshold of 10 points, a second, more thorough inspection of type B is required.

2.1. Type A inspections

Type A inspections involve a series of checks by a Roads Service technician or operator that can be carried out by a simple inspection in the countryside without the need for monitoring or specific tests. They are carried out with on-site inspections from the ground, also with the aid of binoculars, and with the aid of drones for works that are not visible from the road and not easy to access. For inspections with drones, the winter months when the vegetation is free of fo-

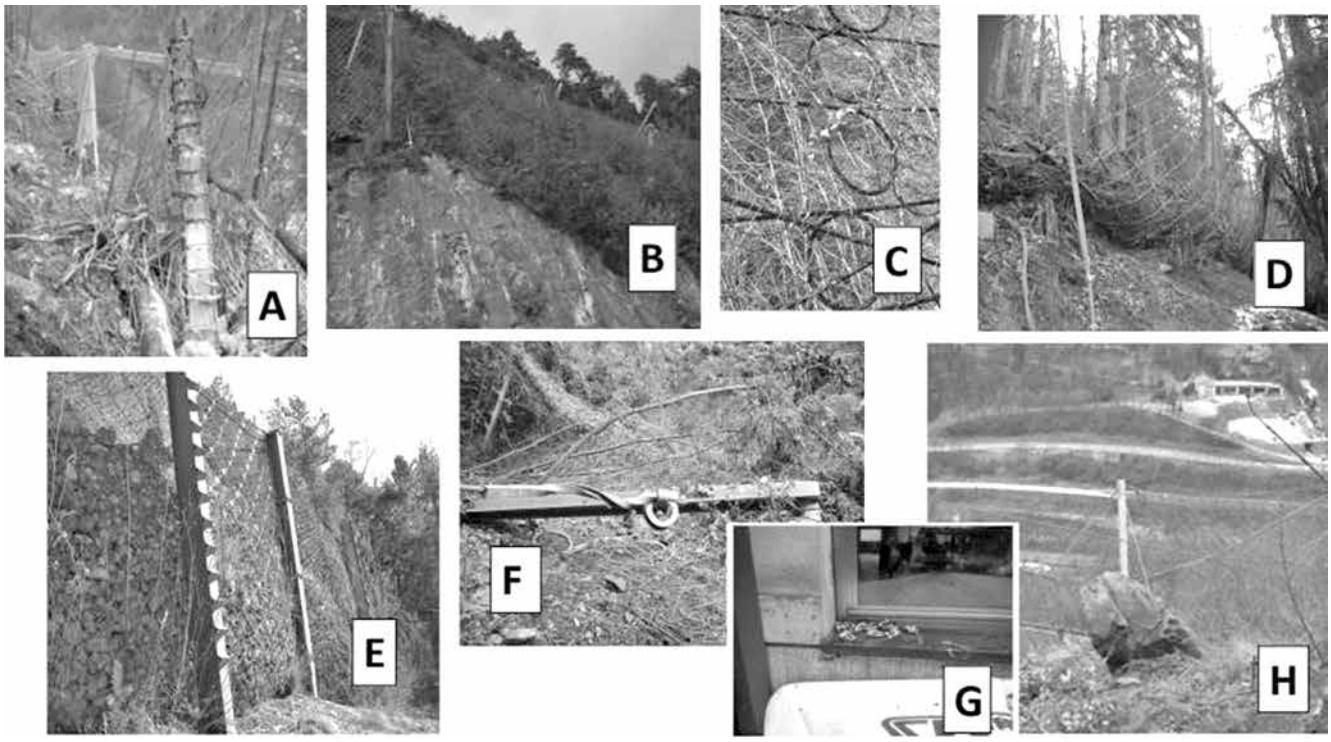

Fig. 2 – Examples of frequent anomalies found on rockfall barriers A) damage to the receiving structure, B) interference with vegetation, C) corrosion D) filling of plant material E) filling of stone material F) loosening or damage to brakes G) loosening of shackles and clamps H) damage to posts.

liage are preferred. The sheets include scores that are assigned to the various situations detected.

In addition to information on the anomalies, the sheets include the code of the work, the date of the inspection, the name and surname of the surveyor, photos and any considerations of the surveyor.

The sum of the anomalies detected determines the threshold for assignment in efficiency classes (P.P.S.) based on an index of conservation of the work (I.P.P.S.).

Tab. 1 – Split out into P.P.S. classes based on the I.P.P.S.

IPPS > 9	9 > IPPS > 3	3 > IPPS > 1	IPPS = 0
damage impairing the efficiency of the system; urgent maintenance or cleaning required insufficient P.P.S.; problematic	maintenance or clearance work is required but the efficiency of the system is not affected. P.P.S. sufficient	limited material clearing or cleaning/ cleaning work required discrete P.P.S.	requires no maintenance P.P.S. good

Type A ispectionsshets are provided for the following works: rockfall protection barrier; slopes protection nets; rockfall embankments (reinforced with geogrid or without); rock anchors or soil nailing anchors; concrete foot (with or without anchors); rockfall sheltering structures.

2.1.1. Rockfall protection barrier

Tab. 2 – Observations on rockfall protection barrier and scoring.

General state of the structure	Score
Abnormalities in the geometry and shape of the structure as a whole (gaps under the net, detensioning of ropes, obvious rotation of posts, displacement of foundation plinths and/or anchorages, etc.)	☐ [10]
General collapse of the structure or filling with material exceeding 30% of the initial height	☐ [10]
Impact damage to the rockfall barrier components (nets, ropes, posts, sliding energy dissipators, loose clamps)	☐ [10]
Presence of material and boulders in the interception structure for a height of less than 30% initial height	☐ [5]
Crash of trees on ropes / netting	☐ [5]
Presence of weed vegetation	☐ [1]
Abnormalities in the state of accesses to the work and/or complementary works to it	☐ [1]

2.1.2. Slopes protection nets

Tab. 3 – Slopes protection nets and scoring.

General state of the structure	Score
General structure collapse due to slope instability	☐ [10]
Abnormalities in the geometry and shape of the structure as a whole (gaps and/or deformations in the net, rope detensioning, displacement/deformation of anchorages, etc.)	☐ [10]
Presence of accumulations in the net (thickness over 20 cm)	☐ [5]
Presence of accumulations in the net (thickness up to 20 cm)	☐ [1]
Presence of weed vegetation	☐ [1]
Abnormalities in the state of accesses to the work and/or complementary works to it and/or surface water drainage works	☐ [1]

2.1.3. Rockfall embankments (reinforced with geogrid or without)

Tab. 4 – Observations on rockfall embankments (reinforced with geogrid or without)and scoring.

General state of the structure	Score
Anomalies in the geometry and shape of the structure as a whole (subsidence of the embankment foundation, lowering of the embankment crest, erosion of the structure that compromises its functionality)	☐ [10]
Stability of the slope-embankment system	☐ [10]
Penetration of the boulder into the embankment for more than half its width at the point of impact	☐ [10]
Check whether fires in the vicinity of the work have damaged reinforcing structures (geogrids, wire mesh, boulders)	☐ [10]
Presence of material and boulders upstream of the embankment (thickness more than 50 cm)	☐ [5]
Presence of material and boulders upstream of the embankment (thickness up to 50 cm)	☐ [1]
Crashing trees and presence of weeds	☐ [1]
Abnormal condition of accesses to the works and/or complementary works to the works (e.g. foundation kerbs, micropiles) and/or surface water drainage works	☐ [1]

2.1.4. Rock anchors or soil nailing anchors

Tab. 5 – Observations on rock anchors or soil nailing anchors and scoring.

General state of the structure	Score
General collapse of structure due to slope instability	☐ [10]
Deformation, displacement, slipping of anchors and/or anchor head (distribution plate, nut, etc.)	☐ [10]
Degradation (rust, etc.) anchor head (distribution plate, nut, etc.)	☐ [5]
Presence of weed vegetation	☐ [1]
Abnormal state of access to the work and/or complementary works to it and/or surface water drainage works	☐ [1]

2.1.5. Concrete foot (with or without anchors)

Tab. 6 – Observations on concrete foot (with or without anchors) and scoring.

General state of the structure	Score
General structure collapse due to slope instability	☐ [10]
Deformation, displacement, rotation of concrete structure	☐ [10]
Deformation, displacement, slipping of anchors and/or anchor head (distribution plate, nut, etc.)	☐ [10]
Degradation (rust, etc.) anchor head (distribution plate, nut, etc.)	☐ [5]
Presence of weeds	☐ [1]
Abnormal state of access to the work and/or complementary works to it and/or surface water drainage works	☐ [1]

2.1.6. Rockfall sheltering structures

Tab. 7 – Observations on rockfall sheltering structures and scoring.

General state of the structure	Score
General structure collapse due to slope instability	☐ [10]
Penetration of the boulder into the topsoil for more than half its thickness at the point of impact	☐ [10]
Presence of material and boulders on the ground cover (thickness more than 50 cm)	☐ [5]
Presence of material and boulders on topsoil (up to 50 cm thick)	☐ [3]
Presence of weeds on the ground covering the tunnel	☐ [1]
Defects in the condition of accesses to the works and/or complementary works to the works and/or surface water drainage works	☐ [1]

2.1.7. Type B inspections

Type B inspections involve a whole series of checks and monitoring to quantify the type of maintenance work required. They can only be carried out by experienced technicians.

The result of these inspections is a detailed picture of the anomalies and deteriorations with a graphic diagram of the work examined, advice on any ordinary or extraordinary maintenance operations or monitoring requirements, and an actual maintenance project in which the categories and quantities are indicated.

For the time being, the following works are envisaged: rockfall protection barrier; slopes protection nets; rockfall embankments (reinforced with geogrid or without); rock anchors or soil nailing anchors; concrete foot (with or without anchors); rockfall sheltering structures

3. Inspection times

The inspection times depend on the characteristics of the road section (TGM, strategic nature of the section, climatic conditions) and on the characteristics of the slope that underlies it (rockfall danger, vegetation) as well as on the technical characteristics of the existing rockfall mitigation works. The inspection times are defined by the area manager according to the indications in the following chapter, the peculiarities of the area and the availability of staff and funds to be allocated for maintenance.

Periodic intervention times indicate the time intervals in which type A inspections are repeated. For "exceptional" intervention times, the time intervals are indicated when the inspection and extraordinary maintenance activities are foreseen to extend the useful life of the work and depend on the requirements for that type of work (e.g. rockfall barriers certified by Etag 25 years)

The criteria identified to define the periodic intervention times derive from studies conducted on existing works, from the analysis of existing literature and from the experience and practical considerations of the Road Service of the Province of Bolzano. They are:

a) presence of Etag 2007 rockfall protection barriers for which inspections are scheduled after 1 year and every 5 years.
b) TGM: average daily traffic recorded by the Autonomous Province of Bolzano with fixed survey stations or mobile stations.
c) importance of the road section examined: if it is the only access to a valley or to important tourist areas, presence of detours, type of road.

Tab. 8 – Weights to be assigned to the various road sections according to these criteria for evaluating intervention times. (dark grey = very short times, grey = short times, light grey = intermediate times, white = possibility of intervention in longer times).

Presence of rockfall barriers Etag 2007	TGM	Strategic section	Area subject for long stretches to snow and ice	Frequency of rockfall events	Vegetation
Yes	< 15.000	Yes	Yes	very frequent	shrubland
No	< 5.000	No	No	frequent	coppice forest
	< 5.000				coniferous forest

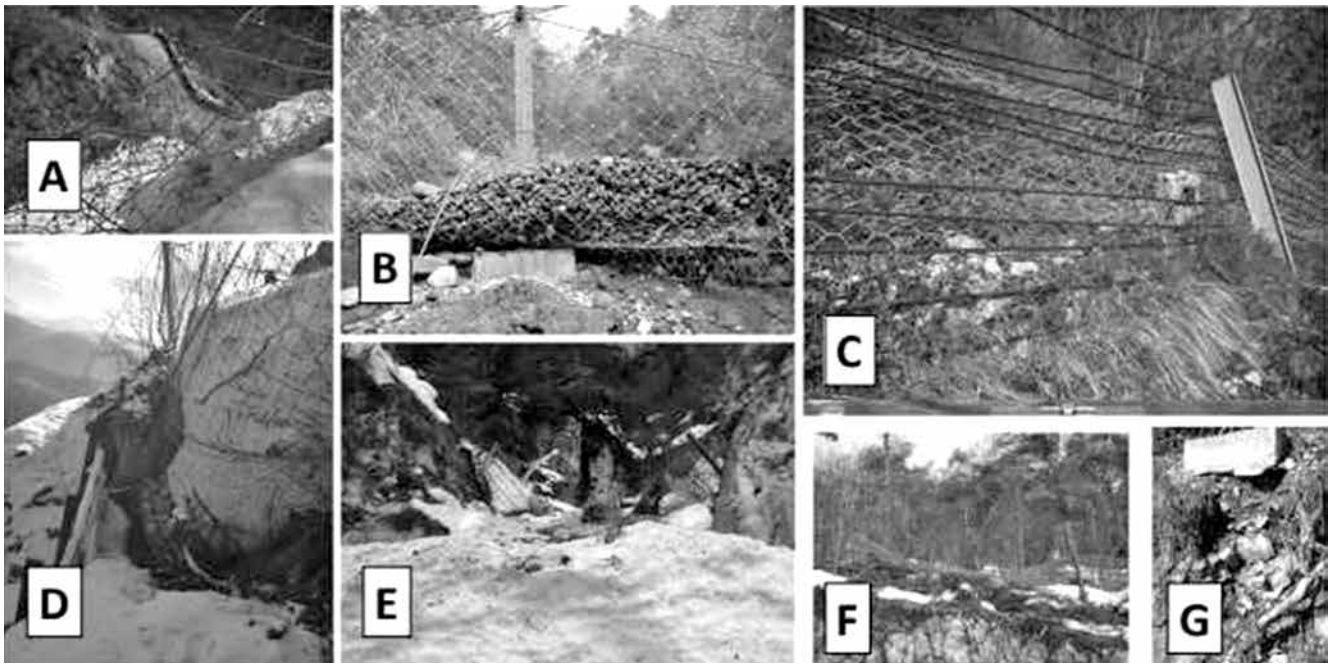

Fig. 3 – Damage after a very snowy winter season: A bending of uprights B filling with stone materials; C loosening of ropes; D breaking of netting E felling of uprights F filling with plant material; G under-excavation of foundations.

d) area subject for long stretches to snow and ice: generally, these are high altitude areas, alpine passes where it has been observed that the action of snow and ice produces frequent damage to structures;
e) the frequency of collapse events affects the possibility of damage to structures
f) type of vegetation: depending on the type of vegetation it has been noted that the access routes to the works and the works are greeted with different times.

Intervention times are defined according to the maximum weight given to the road or section examined.

Intervention times of less than one year are to be considered in exceptional circumstances (extreme weather events, earthquakes, fires, large-scale rockfall events resulting in damage to structures, etc.).

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