

### Technical Solutions to Risk Mitigation

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### **Contents - Technical Solutions**

- 1. What Critical Infrastructure do we consider
- 2. What type of failures (hazards) occur due to weather effects
- 3. What solutions are available
- 4. How do we decide which approach (at a technical level)
- 5. How in reality do we assess hazard
- 6. What is the future?



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Analysis of Practical Remediation Strategies for discrete Infrastructure systems is a report that focuses on the potential failure impacts (in respect to weather hazards) for critical infrastructure elements such as:

Bridges (ROD) Pavements (TCD) Cuttings and Embankments (GDG) Rail track, switches and crossings (GDG) Tunnels (DSA) Electricity Infrastructure (AIA) Dams (DSA)



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## Bridges - Flooding







Kinzua (US) Tornado 2004



Bonnybrook (US) Flooding 2009



Bejar Ravine, Murcia, Spain 2012



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### Slope Stability – Rainfall



### Rock Falls (Freeze-Thaw)







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### Tracks (temperature and rainfall)





Choked ballast and concrete sleepers are Lateral buckling of the track due to the high damaged due to poor drainage, Slovenia temperatures, Slovenia

**Tunnels – Role of Water** 







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### **Erosion due to Coastal Flooding**



**Bray-Greystones** 

### **Remediation Strategies**



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### **Remediation Strategies**







### **Remediation Strategies**













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#### A two-stage ranking procedure:

Stage 1: In the first stage, for each type of landslide (shallow, deep, flows, rock falls), different natural hazards considered in WP2 of the RAIN project, have been analysed and ranked (Table 1) depending on their impact (according to the scoring table: see Table 2). Some hazards such as freezing rain or thunderstorms have no impact on triggering landslides whereas heavy rainfall has the strongest impact for triggering landslides.

Type of landslides	Wind-storms	Heavy rainfall	Floods	Thunder-storm gust	Tornado	Hail	Lightening	Snow and Ice loading	Freezing rain	Wildfire
Shallow	0	5	1	0	2	0	0	4	0	3
Deep	0	3	5	0	2	0	0	2	0	0
Flows	0	4	5	0	3	0	0	2	0	0
Rockfalls	1	5	1	0	3	0	0	4	3	0

# 0 No impact 1 Low impact 2 Low to medium impact 3 Medium impact 4 Strong impact 5 Very strong impact



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Table 1 List of weather hazards and their impact on landslides

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### Technical Impact Matrix **RAIN**

#### Stage 2:The separate headings were scored

#### Table 2 Example of effectiveness of different remediation measures on shallow landslide probability of failure or consequence

Shallow landslides remediation strategies	Technical Effectiveness	Cost	Human and financial loss	Positive environmental impact
Barriers	4	1	4	3
Nets	1	2	2	2
Drapes	0			
Wire ropes	0			
Shortcrete	3	1	4	1
Anchors	0			
Drainage	5	4	3	4
Monitoring	3	2	3	4
Vegetation	4	5	2	4

0	No impact		
1	Low impact		
2	Low to medium		
2	impact		
3	Medium impact		
4	Strong impact		
-	Very strong		
5	impact		



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Landslide risk management (Fell 1997)

# Hazard Analysis – Mostly based on visual assessment



### Failure of Existing Berm





### **Geophysical Survey**

### **Early Warning Systems**



No.1 Cause of Bridge Failure in the US (22 Bridges per year)



### Field Test – Vibration Response to Induced Scour

### Field Test – Vibration Response to Induced Scour





### **Numerical and Experimental Results**



### Intelligent Infrastructure

- By moving to intelligent objects that communicate their safety condition during extreme events we will provide a means of virtually eradicating sudden catastrophic failure of infrastructure objects.
- (ii) If we use **Open Linked Data** formats to manage all data and inputs from other sources. Mitigation actions can be taken and warnings of the increased risk level can be transmitted to other agencies







### **Interacting Networks**







### **EU Directive on Tunnel Safety**





Conclusion



- 1. Detailed understanding of potential failure mechanisms for critical infrastructure were developed
- 2. The most effective means of mitigating risk were identified for each failure mode, considering technical, cost, human and environmental impact
- 3. This formed input to the RAIN risk assessment
- 4. Hazard analysis is key to understanding risk and opportunities for improving this aspect were highlighted





### **RAIN Project**

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