Road Geohazard Risk Management Framework with Insights from Brazil and Serbia

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Innovation Lab:

Data & Risk Assessment

- Mainstreaming effective data use into Risk assessment in Country operations
- Tool kit development and demonstration

Communication

- International Conference
- Public Seminars, BBLs, Websites, Workshops

Literature Review 1

Key findings from the literature review on mainstreaming of DRR in the transport sector of developing countries:

- Two key domains for mainstreaming resilience in transport systems proposed by the World Bank's analytical framework.
  - ✓ One is management domains (e.g., policies and institutions, financial arrangements, and technical planning and design.
  - ✓ Another is temporal dimensions (e.g., risk assessment, emergency response, and postdisaster recovery and reconstruction).
- Most transportation asset management plans do not currently detail causes of failure and risks of hazards that affect its ability to provide a reliable and safe service.

Literature Review 2

Literature review provides details of practices and techniques for six pillars that authors initially set up:

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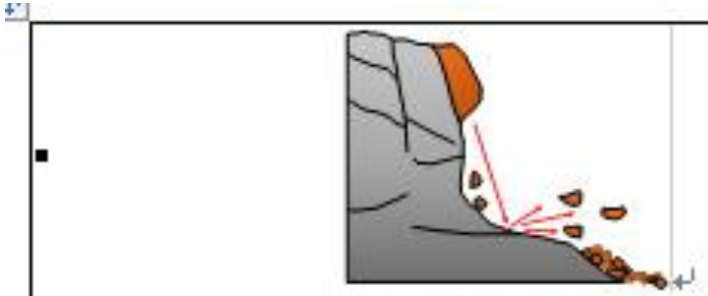
- Country capacity review
- Inspection and identification of road hazards
- Evaluation and planning
- Structural measures
- Non-structural measures; and
- Emergency response, recovery and reconstruction

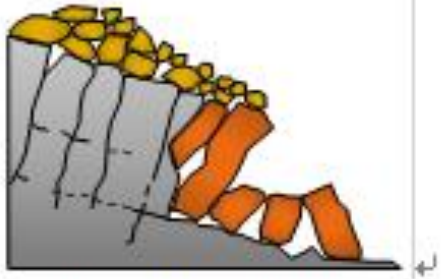
Study methodology to develop the framework

1. The best practices of road geohazard risk management in the world have been analyzed.
2. The framework makes it possible to manage road geohazard risks step by step, depending on the capacity and financial constraints of the project-implementing country.
3. The framework is devised so that simple/low-cost technology or high-cost technology could be selected.
4. Technical validity of the framework was confirmed with the World Bank's experts, etc.
5. Case studies in Brazil and Serbia were conducted to verify the applicability of the framework.

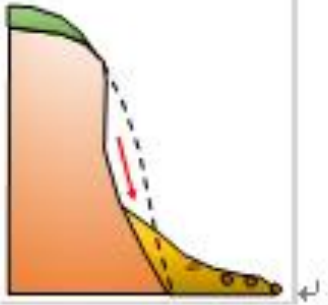
1-5 Road Geohazard Types



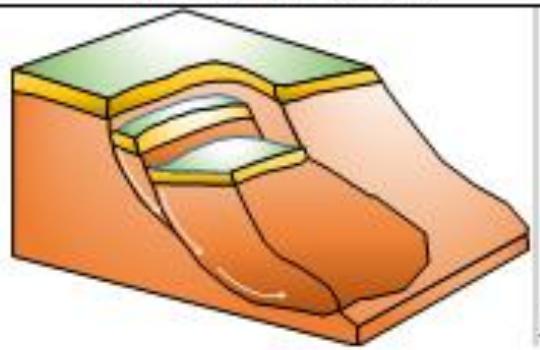
(a) Fall (rockfall)



(b) Collapse (rock)



(c) Collapse (soil)



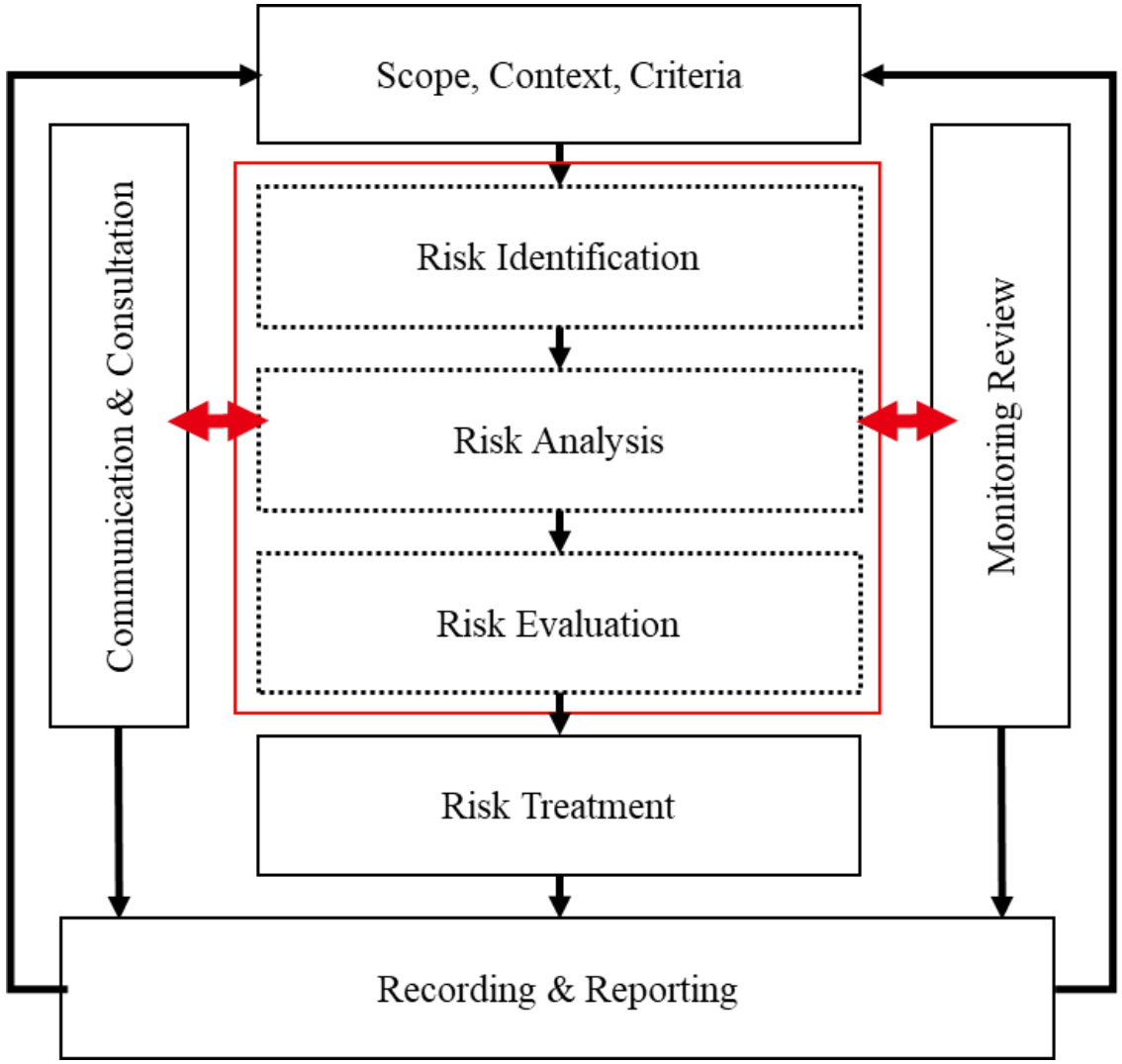
(d) Slide

(e) Flow

(f) Erosion (river erosion)

1-6 Risk Management Process (ISO 31000)

Risk management process involves the systematic application of policies, procedures, and practices to the activities of communicating and consulting, establishing the context and assessing, treating, monitoring, reviewing, recording, and reporting risk.



Framework for Road Geohazard Risk Management

Stage	Institutional Capacity and Coordination	Systems Planning	Design and Construction	Maintenance and Operation	Contingency Programming
Key Moments and contents	Institutional Setup - Laws, regulations, and technical standards - National or sub-national plans/strategies - Mechanisms for implementation	Risk evaluation of geohazarad - for new roads - for existing roads Geohazard risk management planning - for new roads - for existing roads	Structural Measures - Design - Construc-tion	Nonstructural measures	Post-disaster Response and recovery

Setup targets for strengthening road geohazard risk management

ASPECT OF ROAD GEOHAZARD RISK MANAGEMENT	STEP-UP TARGET		
	ESSENTIAL	INTERMEDIATE	ADVANCED
Laws, regulations, and technical standards	Formation of key laws and regulations pertaining to responsibilities for road geohazard management and response	Review and updating of laws and regulations Formulation of technical standards and guidelines	Further review and updating of laws and regulations
Risk evaluation	Starting with basic method of risk evaluation (such as simple risk qualitative evaluation, using multiple criteria)	Review and updating to immediate method of risk evaluation (for example, risk-level rating)	Further review and updating to advanced method of risk evaluation (for example, economic risk evaluation as potential annual loss)
Structural measures	略	略	略
Nonstructural measures	略	略	略
Postdisaster response and recovery	Preparation and fundamental practice for postdisaster response, including preidentification of responsibilities and budgets to address geohazard events	Enhancement of postdisaster response, including formalized plans to address specific geohazard events	Further enhancement of postdisaster response and recovery (for example, formation and training of special task force for wide-area severe geohazard event)

2-2 Systems Planning (Risk Evaluation)

Identification and mapping of geohazards:

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- Basic method. Road maintenance staff identifies any abnormality
- Intermediate method. Geotechnical experts conduct an engineering survey of hazard-prone road locations
- Advanced method. Geology experts conduct detailed hazard mapping

Assessment of geohazards:

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- Basic method. a simpler qualitative evaluation in terms of the likelihood and consequence of a risk event occurring,
- Intermediate method. risk rating of an endangered road location is calculated by evaluating the likelihood and magnitude of damage
- Advanced method. Potential annual economic loss is calculated.

For existing roads:

- approach may be constrained to a single site, a single road, or expanded to the entire network of roads.
- the outcome of the geohazard risk evaluation is to develop a prioritized list of sites for mitigation.

For new-road alignments:

- approach needs to ensure full coverage of all potential road alignments.
- risk evaluation process should ensure that there is a basis for proper planning to avoid cost overruns, construction delays, and costly operation and maintenance outcomes.

There is a need for proper investment of time and money in project-level option selection.

For existing roads:

- different options can be compared using life-cycle cost analysis on the presumption that each option will broadly offer the same benefits to road users.

For new-road alignments:

- the decision will typically involve multiple factors, such as cost, safety, social and environmental impacts, cultural issues, and so on.

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Also need another approach to consider how the road network could function in case of disasters.

Engineering solutions to prevent road infrastructure damages due to geohazards:

- proactive measures to lower the risk of geohazard failure
- emergency works in highly susceptible areas
- recovery works in a postdisaster stage

Example of structural measures for mountain fall or collapse

PRIMARY CATEGORY	SECONDARY CATEGORY	TERTIARY CATEGORY	PROCEDURE FOR CONCEPT DESIGN LAYOUT
Slope stabilization measures	Cutting or removal of unstable rock and soil	Slope cutting	• Unstable rock or soil on the slope is identified through visual inspection. • Estimate the volume for cutting or removal of the mountainside slope.
		Trimming	
		Scaling	
	Prevention of erosion or slope surface instabilities	Slope drainage	• Lay out slope drainage and vegetation for soil slope. • For the spring portion or identified erosion, drainage shall be laid out to drain surface water.
		Vegetation or bioengineering	
	Slope reinforcement	Rock bolting	• Area of unstable soil or rock on the slope is identified through visual inspection. • Estimate the volume of the slope reinforcement area.
		Pitching work	
		Slope framework (grid beam)	
		Buttress walls (cavity filling)	

Nonstructural measures to enhance road geohazard risk management involving no major physical construction:

- routine maintenance of previously constructed structural measures
- monitoring of geohazards using automatic measuring devices
- road closures to prevent injury before a geohazard event

Geohazard monitoring types and equipment used

GEOHAZARD PHENOMENA	HARDWARE SUPPORT
Surface movement	Monitoring CCTV camera, Rockfall detector, Extensometers, Crack gauge, Surface tilt meter, GPS devises, LiDAR
Subsurface movement	Borehole inclinometers, Pipe strain gauge meters
Groundwater fluctuation	Groundwater meter, Piezometer
Rainfall	Rain gauge, Automatic weather station

2-7 Contingency Programming

Contingency programming issues, such as postdisaster response and recovery, and funding arrangements:

- emergency preparedness before a geohazard event
- emergency response in the immediate aftermath of an event
- recovery following the emergency to restore full functionality to the road network

Contingency programming activities

PROGRAMING PHASE	KEY ACTIVITY
Emergency Preparedness	• Development of an Emergency Preparedness and Response Plan • Preparedness Training • Funding
Emergency Response	• Emergency Inspection or Postdisaster Needs Assessment • Emergency Traffic Regulation and Public Notice • Emergency Works
Recovery	• Management of the Recovery • Repair • Rehabilitation and Reconstruction

Brazil Case Study

Case study's findings and recommendations for the enhancement of road geohazard risk management in Brazil include, but are not limited to:

- **Ad hoc methodology for geohazard risk assessment**

- Road administrators are identifying and assessing road geohazard risks substantially depending on the experience of local engineers, normally through the visual inspection of roads.

- However, many of the occurrences start outside of the right-of-way or are in inaccessible areas where the human eye cannot observe.

- This obstacle could be overcome by using advanced technology such as unmanned aerial vehicles (UAVs) to observe the terrain and identify critical spots.

- Also, an additional assessment by experts in geology with the support of local geological institutes would enrich the engineer's evaluation and provide a better solution, combining the transport and geological points of view.

- **No cost-benefit assessment for geohazard mitigation measures**

- Specific funding for mitigation measures is almost nonexistent in the federal and state roads throughout Brazil.

- Although geohazard mitigation could bring a substantial economic benefit by preventing a chronic need for the recuperation of roads after disasters, the economic assessment of geohazard mitigation measures from the life-cycle viewpoint has rarely been conducted.

- This often leads to a low priority of these works given to the serious budget constraints.

- **Little data-sharing among stakeholders in geohazard management**

- Brazil does not have a law or plan that relates and directly integrates disaster risk management into the country's transport sector.

- However, for successful road geohazard risk management, data are one of the most valuable assets, and as such, it becomes fundamental that every institution involved in the area is aware and knowledgeable about all the available data.

- Sharing key information, being aware of the other institutions' actions and plans, and keeping a continuous relationship are fundamental for effective prevention of and rapid response to natural disasters.

- **No strategic contingency program**

- Although a certain protocol exists at the local unit level of road agencies for preparing for geohazard events, no official and written procedures or contingency plan has been developed, which is key to reduce potential losses of life or assets under a natural disaster threat.

- A more protocolized contingency plan is recommended to establish clear guidelines and criteria of the preparedness actions based on the historical disaster data in Brazil.

- Such plan will be able to promote close coordination between the involved stakeholders to carry out the appropriate actions in the most efficient way possible.

Serbia Case Study

Road geohazard risk management is still a new terminology, for which there is not yet a specific law or clause in Serbia.

- **There are no separate technical standards, guidelines, or operational manuals for road geohazard management.**

- Risk evaluation and prioritization is ad hoc, depending on the affected road category and level of damage.

- Risk evaluation of endangered road locations is provided by experienced road agency's maintenance staff by visual inspection.

- Landslides, flash floods, and floods are the primary natural

Serbia Case Study

- **Damaged section of the road will be repaired whatever the cost may be, considering the importance of the road**.

- The assumption is that all roads must be maintained, and the only decision concerns which repair solution offers the lowest life-cycle-cost solution and what priority each repair is given.

- As is the case with developing countries, the governments would tend to take reactive approach by retrofitting existing roads after disasters.

- There is a lack of understanding of the importance of investing for the promotion of proactive disaster prevention.

Serbia Case Study

- **There were no geohazard risk reduction plans for existing state roads within operational maintenance programs.**

- Disaster risk management plans for existing roads are part of road maintenance activities such as reconstruction and rehabilitation.

- Road geohazard risk management planning starts with a risk assessment by the road agency's maintenance staff based on visual inspections and geohazard risk related data from the field.

- Although countermeasure planning and strategies for road disaster risk reduction are prepared annually within Serbia's regular road maintenance budget, the agency focuses mainly on emergency response and repair activities after a geohazard event.

4 Summary

1. Framework for road geohazard risk management includes 5 stages, i.e., institutional capacity and coordination, system planning, design and construction, maintenance and operation, and contingency programming. Efforts need to be made in various directions.

1. Due to different national conditions, countries face different problems in road geohazard risk management. Recommendations for the enhancement of road geohazard risk management need to be contextualized.

Thank you for your attention

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