Developing a Framework for Assessment of Landslide Hazard Risk Associated with Critical National and Provincial Roads in Lao PDR

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ABSTRACT: Much of the road network of Lao PDR is located in hilly and mountainous terrain and, while the majority of the landscape is forested, landslides pose a considerable hazard to road operations. These landslide occurrences often coincide with periods of heavy monsoon rain. The climate of the country generally is monsoonal with a distinct summer wet season. The annual rainfall totals reach over 4500 mm in general. Landslides in Lao PDR cause frequent hold-ups to traffic on affected roads, creating direct economic impact. More over this frequent transportation disruptions create inconvenience to road users and the wider community. The cost of landslide repairs is also high, and can account for between 50% and 80% of emergency maintenance costs of the road sector annually.

The purpose of the proposed framework for country-wide landslide inventory for critical national and provincial roads is to facilitate taking suitable proactive cost effective measures in order to reduce landslide related disruptions to transportation network during monsoon periods. This framework also will serve as a guideline for designing new slope stabilization measures during implementation of road expansion/improvement projects. Presently road engineers usually do not take into consideration land-slide risk potential during road improvement projects. Hence related excavations at times lead to subsequent slope destabilization. Recommendations will be included in the framework for identifying likely high risk landslide prone areas, which need special attention during road construction for implementation of priority mitigation measures. Landslide risk evaluation begins with the identification of potential hazard within respective road sections, physical evaluation of the exposed slopes and characterization of the level of risk. The draft framework, also will provide methodology for inventorization and documentation of past landslides, as well as potential hazardous areas and delineate the potential future risk to transportation network. The degree of susceptibility to landslide hazard will be determined through physical evaluation of the upper and lower slopes of the road sections.

The paper presents the methodology adapted for assessment of landslide hazard risk associated with critical national and provincial roads.

1 INTRODUCTION

The Lao PDR is bordered by Vietnam to the east, Thailand to the south and west, China to the north. It has a population of around 6.5 million. Lao is a landlocked country, which has an area extent of 236,800 km^2. Elevations within Lao PDR range from 500 to 2000 meters above sea level and more than 75% of the land area is dominated by hilly and mountainous landforms.

The geology of Laos is complex and includes a wide variety of rock types, of a range of igneous, sedimentary and metamorphic origins. Many rock masses exposed in road cuttings and in the natural slopes are highly disturbed and jointed due to tectonic processes, and so are vulnerable due to potential instability. Rainfall pattern of Laos is dominated by the south-west monsoon. Annual rainfalls of 3000 to 4000 mm are not uncommon and rainstorms can yield intense rainfall, with 100 mm in 24 hours being common. Therefore rainfall and the mountainous relief are considered to be the key factors in triggering slope failures. (SECAP, 2008)

2 LANDSLIDE SITUATION IN LAO ROAD NETWORK

The road network within the mountainous regions of Northern Lao is disturbed often due to occurrence of most common types of landslides such as shallow debris slides and cutting failures. The depth is usually limited to 1-2 m and frequently originate in the upper, more weathered portion of the cut slope. They also often occur along the rock head surface which usually dips out of the cutting as such formations present ideal conditions for sliding. The failure usually occur due to increased soil saturation and increase in pore pressures within the residual soil layer and

highly weathered mass as rainwater and subsoil drainage usually percolates down through relatively impermeable surface (SECAP 2008). A typical failure in a road slope is shown in Fig 1. In addition there are occasional rock falls and deep sliding or slope failures in cuttings but they are less frequent. Such failures are often creating major problems to DoR due to either complete or partial blockage of the road way and subsequent maintenance expenditure associated with reconstruction work. Shallow as well as deep failures often occur in the weathered formations, along adversely orientated joint planes or in colluvium deposits. Such failures are responsible for removal of several meters thick soil mass, occupy a wider area on the up slope and/or down slope and lead to subsequent gradual expansion. Rock falls often occur on the roadway upslope along adversely orientated joint planes.

3 ROAD SLOPE ASSESSMENT AND INVETORIZING PAST LANDSLIDES

The a direct socio-economic impacts and cost of landslide repairs due to frequent hold-ups of traffic is high, and can account for between 50% and 80% of annual emergency maintenance costs of national roads. In order to mainstream the process of landslide risk reduction in the road sector, a study was performed by the Asian Disaster Preparedness Center (ADPC), Thailand. This has been initiated by the Ministries of Planning and Investment, (MPI) and Public Work and Transport (MPWT) in Lao PDR. Main objective of the study was to introduce a landslide inventory framework and road slope assessment methodology for National and provincial roads.

Fig 1. A typical slope failure in the road network.

The pilot study area selected covers a total length of 23 Km (257 to 280 Km) in the Vientiane-Luang Prabang national highway and located in the Phoukhoun district of Luang Prabang Province. During the study several landslide sites were located and mapped out in detail.

4 LANDSLIDE RISK ASSESSMENT

Landslide hazard map at National scale has been prepared by ADPC- Thailand under the Multi-hazard Risk assessment project initiated by UNDP. Using the same, major National and provincial road sections that are prone to landslide hazard has been identified. The list of such road sections have been provided to DoR for undertaking further vulnerability assessments. The pilot study area selected is one of the important sections of the National road network and found to be highly vulnerable to landslide hazard.

4.1 *The road slope assessment*

A road slope assessment has been introduced for the road sections that have been identified as the most vulnerable road sections during the national level landslide hazard zonation mapping. The underlying geology, degree of weathering, typology of rock formations, jointing, hydrology etc. combined with the steep topography associated with the road trace, create conditions in which landslides can occur. Variations in the storm rainfall trends, drainage and land use can accelerates slope instability of road sections in the mountain terrain. A sample check list and the ranking that can be used in road slope hazard assessment is provided in Table 1. It has been introduced to help engineers of the DoH for conducting independent landslide risk assessment during routine inspections as well as in designing new roads, undertaking road expansions, road rehabilitation and reconstruction work etc.

Table 1. Road slope assessment check sheet and ranking

Items	Category	Rank
(1) Height of slope , H (m)	50 m ≤ H	10
	30 m ≤ H < 50 m	8
	10 m ≤ H < 30 m	7
	H < 10 m	3
(2) Angle of Slope, α	1 : 0.6 ≤ α	7
	1 : 1.0 ≤ α < 1 : 0.6	4
	α < 1 : 1.0	1
(3) Overhang	Formed in no walled Slope	7
	Formed in walled Slope	4
	Not formed	

(4) Geology	Many unstable stones	10
	Many stones on the surface of slope	7
	Very weathered rock	6
	Gravelly soil	5
	Weathered rock	4
	Cracked rock	4
	Sand	4
	Clay	1
	Intact rock	0
(5) Thickness of weathered soil layer	More than 0.5 m	3
	Less than 0.5 m	0
(6) Water flow	Flow observed	2
	No flow	0
(7) Frequency of rock fall	Often	5
	Occasional	3
	None	0
(8) Deformation of	Deformed	5
	Not deformed	0
(9) Rock falls observed	Occurred	5
	Not occurred	0
(10) Cut or fill on slope	Many cut or fill	10
	Few cut or fill	5
	Nothing	0
(11) Deformation of re-	Deformed	5
	Not deformed	0
(12) Condition of the retaining walls	Unstable	10
	Moderately Stable with visible crack formations	5
	Very stable	0

Classification of the slope
(A): More than 40 - slope failure very likely, constant vigilance is recommended.
(B): 40-20 - slope failure probable, routine inspections during rainy season are recommended.
(C): less than 20 - slope failure not likely

5 DEVELOPMENT OF A FRAMEWORK FOR INVENTORIZING LANDSLIDES IN NATIONAL AND PROVINCIAL ROAD NETWORK

The framework expected to help DoH in establishing a system for recording, documenting and archiving the data related to landslide occurrences within the national and provincial road network in order to develop a landslide inventory database. The framework will facilitate risk sensitive decision making so that suitable proactive cost effective measures can be taken timely in order to reduce disruptions to transportation network due to landslide occurrences in future.

Direct intended audience of the landslides inventory framework is DoR staff at various levels in district, provincial and national offices. Indirect audience is other stakeholders such as National Disaster Management Office (NDMO), line ministries and agencies, road users, NGOs, communities living adjacent to major roads.

5.1 *Scope of the inventory*

At the moment the occurrences of landslides are not recorded in a systematic manner. Usually debris after minor road slope failures are cleared up by the local officers of the DoR and no proper assessments or subsequent slope stabilization measures are taken to improve the stability of slopes. The framework looks at the roles and responsibilities of different levels of DoR in inventory preparation, data storage and sharing as well as in follow up interventions, utilization of inventory data in managing a reliable road transportation system in Lao. The inventory provides an opportunity for DoR to analyses the vulnerability and risk in a systematic way and take appropriate decisions in a timely manner.

6 ASSIGNED ROLES AND RESPONSIBILITIES OF DIFFERENT STAKEHOLDERS IN IMPLEMENTATION OF THE FRAMEWORK

Department of roads (DoR):
- Carry out vulnerability and risk assessment to road sections affected by landslides
- Inventory preparation
- Data storage and sharing
- Follow up actions including clearance of debris, providing sign boards etc. to ensure safe transportation
- Utilization of inventory data in design of slope stabilization measures

NDMO:
- Assessment of vulnerability and risk to local communities
- Informing the local communities about impending danger
- Provide Landslide EW to road users
- Public awareness creation on road safety during rainy seasons

Local governments:
- Provide necessary assistance to DoH, NDMO
- Resettlement of families living in highly vulnerable areas
- Traffic control through local police
- Public awareness creation on road safety

Road users (Individuals and agencies):

- Be watchful in areas where road signs on danger of landslides are displayed.
- Inform the DoR, NDMO, Local Government, Local Police when landslides are observed during rainy periods

7 INVENTORY DATA COLLECTION

Following information related to slope failure of landslides will be collected by DoH in order to develop the inventory:

- Date (and if possible, time) of occurrence
- Rainfall
- Location (coordinates–latitude and longitude-road section description, name of nearest village/city)
- Explanation of the material moved (volume) and slope characteristics after the landslide
- Land use (upslope and down slope), seepage, drainage, general slope characteristics, geology
- Type of landslide. Using the Cruden and Varnes (1996) classification, specifying at least: material (Soil-earth or debris or rock) and characteristics of the movement (fall, topple, slide, spread, flow)
- Consequences (quantification of the extent of the damage)
- Possibility of reoccurrence and impending danger to communities living in the upslope and downslope
- Hazard level

Each new landslide will be assigned a number and inventory data will be plotted using the GPS data on the map in a GIS environment and for each location above description will be provided in the map.

8 CONCLUSIONS

Presently road engineers do not take into consideration landslide hazard and risk potential during road improvement project implementation and the proposed framework for country-wide risk–based landslide inventory and road slope assessment for critical national and provincial roads will help in mainstreaming landslide risk management activities within the road sector.

The framework will help in systematic Inventory preparation, data storage and sharing. This will facilitate proactive cost effective decision making in order to reduce disruptions to transportation network due to occurrence of landslides. Framework also will help in obtaining useful information and data for identifying likely high risk landslide locations or prone areas with high hazard, which need special attention. This will serve as a guideline for designing new slope stabilization measures as well in implementation of priority mitigation measures, where necessary during implementation of road expansion / improvement projects. That will help in reducing the losses to road sector annually in maintenance of roads and expected to improve the safety of the road network in future.

The inventory database can provide information to other stakeholders such as NDMO, Local government etc. for carrying out vulnerability and risk assessment for the upslope and downslope areas with human settlements and undertake risk reduction measures.

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