

INVESTIGATION INTO ROAD SUSCEPTIBILITY ASSOCIATED WITH LANDSLIDE HAZARD OF THE LAO NATIONAL ROADS IN THE NORTHERN REGION

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1. INTRODUCTION

In Laos, the road sector is one of the most vulnerable sectors exposed to several types of natural disasters, especially a landslide which is triggered by heavy rainfall and has been the main cause of road damage. The critical zone, particularly, in the northern region whereas the topographical condition is dominated by mountainous terrain and complex geological condition. Moreover, due to the increase in frequency and amount of climate change-induced rainfall recently, the level of susceptibility of road infrastructures in the northern region of Laos seems to be increased. The increase of the vulnerability of roads concerns the Lao government greatly as Laos is evolving from a landlocked into a land-linked country with its strategic location in Greater Mekong Subregion (GMS). Particularly, there are three major land transport routes of GMS pass through the northern region of Laos, namely the North-South Corridor, Northeastern Corridor, and Central Corridor. This investigation was conducted to evaluate the level of road susceptibility associated with landslide hazards of Lao national roads. The scope of the study is limited within the northern region which consists of nineteen (19) national roads with a total length of 3,578 km. The study considered ‘rainfall’, ‘geological condition’ and ‘slope gradient’, as landslide occurrence influencing factors. And a semi-quantitative approach was used to analyze the level of road susceptibility.

2. METHODOLOGY

A methodology used in the study is a semi-quantitative approach that considered a number of influencing factors for a landslide occurrence. A process consists of several steps. First, select a number of influencing factors and create thematic layers with different values of weight for each layer. Second, classify criteria in each layer into appropriate classes and rank them from safe conditions to the most prone condition for a landslide occurrence. Third, combine those layers by weight overlay method, in this step, a ‘landslide susceptibility map’ is created. Lastly, overlay the road alignment on the ‘landslide susceptibility map’ to create a ‘road susceptibility map’ with ranks of 1 to 5 which define a level of road susceptibility associated with a landslide, from safe (negligible) to very susceptible (very high).

The road map was acquired from Department of Roads (DoR), Ministry of Public works and Transport of Lao.

3. Classification and Ranking

3.1 Rainfall

Rainfall is weighted 25% contribution for landslide occurrence. The data used for analysis is an average rainfall in August from the year 2009 to 2017 obtained from 7 rainfall stations in the northern region acquired from Department of Meteorology and Hydrology (DMG), Ministry of Natural Resource and Environment of Lao. A reason for using rainfall data of August is that the rainfall of August showed the highest value compared to other and closely related to the landslide in the northern region of Laos. August rainfall is also conventionally peak in the monsoon season when flood and landslide occurred throughout the whole

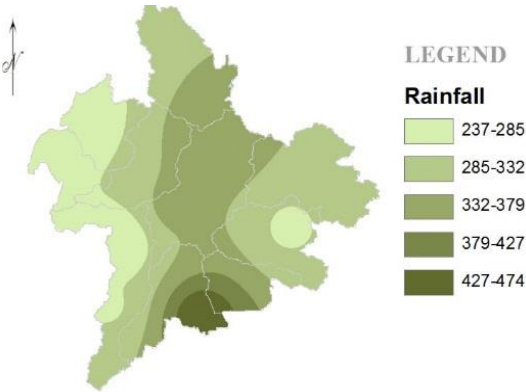


Fig. 1: Average August rainfall distribution

Table 1: Rainfall class and Ranking

No	rainfall (mm)	Ranking
1	237-285	20
2	285-332	40
3	332-379	60
4	379-427	80
5	427-474	100

Table 2: Geological class and ranking

No.	Symbol	Ranking
1	G	20
2	PR, U	40
3	Pz1, Pz2, Pz3	60
4	Mz1, Mz2	80
5	Q	100

Keywords: Laos national roads, Landslide, Road susceptibility, Rainfall, Geological condition, Topographical condition
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region (Asian Disaster Preparedness Center [ADPC], 2014). Rainfall distribution is illustrated in **Fig.1**. As shown in **Table 1**, rainfall is classified into 5 classes, and each class is ranked with a different score from 20 to 100, where the value of 100 represents the most susceptible to landslide occurrence.

3.2 Geological condition

Geological condition (Lithology) is weighted 25% contribution to landslide occurrence. As shown in **Table 2**, the geological is classified into five (5) classes, and each class is ranked with a different score from 20 to 100, with a value of 100 as the most susceptible to a landslide occurrence (ADPC, 2014).

The geological map of Laos was acquired from Department of Mines and Geology (DMG), Ministry of Energy and Mine of Laos. The symbol column related to the geological map illustrated in **Fig. 2**.

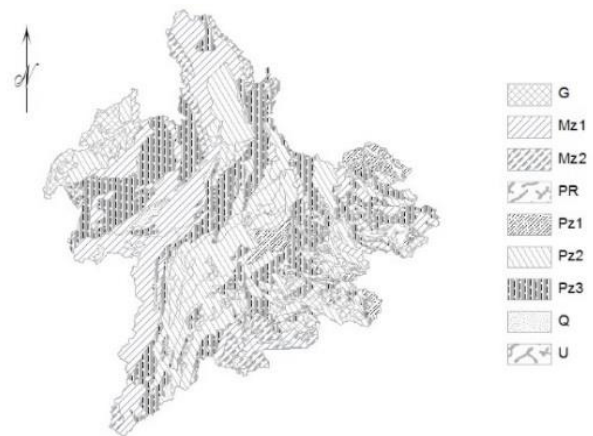


Fig. 2: Geological map

3.3 Slope gradient

Slope gradient is a very important factor; it is weighted 50% contribution to landslide occurrence. As shown in **Table 3**, slope gradient is classified into 7 classes, and each class is ranked with a different score which presents its susceptibility to an occurrence of the landslide. A range of the score has been set from 20 to 100, which value of 100 represents a very susceptible area to a landslide occurrence (ADPC, 2014).

A slope gradient map was produced by utilizing a digital elevation model from SRTM3 (National Aeronautics and Space Administration [NASA], 2015).

Table 3: Slope gradient class and ranking

No.	Gradient (°)	Ranking
1	0-5	20
2	5-12	40
3	12-18	60
4	18-24	80
5	24-40	100
6	40-45	60
7	45-90	60

4. RESULT and CONCLUSIONS

Table 4 showed the distribution of different levels of landslide susceptibility to each road. As shown in **Table 4**, at 27 % in coverage rate, low susceptibility (level 2) is much higher than the other four susceptibility levels shown. Negligible (level 1), at 23 %, and medium (level 3), at 20 %, are similar to each other in coverage rate. Whereas the distribution of high and very high susceptibility (level 4 and 5) are only at 19 % and 12 % respectively.

Despite its less dominance compared to the susceptibility level 1, 2, and 3, the distribution of high and very high susceptibility (level 4 and 5) are outstanding in some important strategic roads. Particularly the national road No.13N which is a part of the Central Corridor that links China-Laos-Thailand; with the distribution of level 4 at 108 kilometers and level 5 at 96 kilometers in length, road No.13N is a much longest road exposed to landslide at high and very high susceptibility (level 4 and 5). And national road No.2 (2E+2W) which is a part of the Northeastern Corridor that links Vietnam-Laos-Thai; with the distribution of level 4 at 94 kilometers and level 5 at 85 kilometers in length, road No.2 (2E+2W) is a second-longest road exposed to landslide at high and very high susceptibility (level 4 and 5).

Table 4: The length of national road exposed to different levels of landslide susceptibility

Road No.	Susceptibility Class					Total Length (km)
	L1	L2	L3	L4	L5	
1A	3	55	23	26	37	144
1B	5	26	16	36	26	109
1C	59	48	72	48	38	265
1D	51	16	5	7	0	79
2E	7	0	52	43	68	171
2W	37	59	25	51	17	190
3	123	83	54	34	0	294
4	162	93	52	34	25	366
4A	31	53	25	16	0	125
4B	14	31	28	28	14	114
5	6	78	78	48	66	277
6	56	40	34	31	15	176
6A	20	35	40	30	0	124
6B	0	0	0	26	0	26
7	15	8	9	8	3	42
11	42	42	21	5	11	121
13N	102	196	131	108	96	634
17	59	18	22	18	0	118
19	18	71	27	80	9	204
Total	809	951	715	677	426	3,578
%	23	27	20	19	12	100

5. REFERENCE

- ADPC. (2014). *National and Provincial level Risk Assessment Report of Lao PDR – Volume I: Hazard Assessment and Elements at Risk*. Ministry of Planning and Investment, Lao PDR
- NASA. (2015). *SRTM3 Digital Elevation Model (DEM), Lao PDR Area*. The National Aeronautics and Space Administration (NASA). Retrieved from <https://earthexplorer.usgs.gov/>