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A Review of Methods of Analysis and Mitigation of Landslide

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***Abstract* – Cities around the world that are located on a hilly and mountainous areas are always faced with the challenge of landslide, which can be disastrous and always result to loss of life and properties when it happens, and large expenditures are being incurred by Governments on the investigation, design and implementation of mitigation and preventive measures to reduce the likelihood of the loss of life and economic losses due to landslides. Landslide analysis can be based on hazard or susceptible. The formal is based on evaluation of probability of a landslide failure within a specified period of time and within a given region, while the later is based on classifying the region into several successive classes with different potentials of landslide. Based on the forgoing this paper is focused on the review of landslide hazard analysis and mitigation. There are four ways to a modern landslide hazard analysis which include Inventory approach, Heuristic approach, Statistical approach and Deterministic approach. Mitigation of landslide is based on the type of landslide, the different types of landslide has its own mitigation method which was discuss in this paper type by type. The four approaches can be applied for regional landslide hazard mapping. All the approaches have their shortcomings. The inventory analysis require a lot of maps which require interpretation, the heuristic analysis require a long- period landslide data, which may be insufficient in length of historical records, incompleteness in inventory and a possible mixing of extreme events, the statistical approach looks better as comparing with the weakness of the other three approach, but there still are some further development needed to predict landslide.**

***Keywords*: Cities, Landslide Analysis, Landslide approach, Mitigation, Mapping**

I. INTRODUCTION

Landslide is mass wasting of soil, which involve mass movement of material down a slope, this is normally caused by gravitational forces, ground water movement, loss of shear strength by the soil [1].Landslide is a general term used to describe the down slope movement of soil, rock, and organic materials under the effects of gravity and also the landform that results from such movement. They also stated that varying classifications of landslides are associated with specific mechanics of slope failure and the properties and characteristics of failure types. It is very pertinent to understand how and when these failures will happen and ways of mitigating against them. Over the years there has been the challenge of evaluation of landslide hazard which according to Chyi-Tyi lee, [2] is due to:

- The problem of attempting to quantify landslide hazard over larger area.
- Challenge of mixing landslide types in the analysis
- To use a multi-temporal landslide inventory or an event landslide inventory .
- The selection of mapping unit in the analysis.
- The selection of the analytical method.

Table 1: Approaches used in analysis of landslide.

Type of analysis	Techniques	Regional 1:100,000	Medium 25,000	Large 10,000
Inventory	Landslide distribution analyses	Yes but (*)	Yes	Yes
	Landslide activity analysis	No	Yes	Yes
	Landslide density analysis	Yes but (*)	No	No
Heuristic analysis	Geomorphological analysis	Yes	Yes but (**)	Yes but (**)
	Qualitative map combination	Yes but (***)	Yes but (**)	No
Statistical analysis	Bivariate statistical analysis	No	Yes	No
	Multivariate statistical analysis	No	Yes	No
Deterministic analysis	Safety factor analysis	No	No	Yes but (****)

Landslide hazard is defined as the probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon [3]. Also landslide analysis is a regional hill slope stability analysis concerning the probability of instability at any given point within a specific period of time [2]. There are four different approaches used in analysis of landslide which are displayed in a tabular form with the scale of analysis in table 1.

Source: International Institute for Aerospace Survey and Earth Sciences 2015.

A comparison of the four approaches and how to mitigate against these hazards will be considered. Which kind of approach is more appropriate and more promising in the further development of LHA will also be discussed. The issue of landslide analysis is very important to ascertain the extent to which a landslide can occur, this will help in finding a proper mitigation measure to deal with it.

II. LANDSLIDE METHODS OF ANALYSIS

Before the use of any method of analysis certain things need to be considered as stated by Cees van Westen, [4] which is as follows:

- The objective of the study
- The scale of the study
- The type of analysis that will be followed
- The types of input data that will be collected.

Landslide hazard analysis can be made for any different purposes. Some of these might be:

·For an environmental impact study for engineering works

- For the disaster management of a town or city.
- For the modeling of sediment yield in a catchment.
- For a watershed management project.
- For a community participation project in disaster management.
- For the generation of awareness among decision makers.
- For scientific purposes.

Each of these objectives will lead to specific requirements with respect to the scale of work, the method of analysis and the type and detail of input data to be collected (4).

Scale of analysis

The type of approach adopted for the analysis will depend on the scale and we have different scales which include:

i) National scale

This scale is smaller than 1:1.000.000, covering an entire country, mainly intended to generate awareness among decision makers and the general public. Maps on this scale are often included in national atlases.

ii) Regional scale

This is between 1:100.000 and 1:1.000.000, covering a large catchment area, or a political entity of the country. The maps at this scale are mostly intended for reconnaissance phases for planning projects for the construction of infrastructural works, or agricultural development projects.

iii) Medium scale:

This is between 1:25.000 and 1:100.000, covering a municipality or smaller catchment area. This is intended for the detailed planning phases of projects for the construction of infrastructural works, environmental impact assessment and municipal planning.

iv) Large Scale

This is between 1:2.000 and 1:25.000, covering a town or (part of) a city. They are used for disaster prevention and generation of risk maps, as well as for the design phase of engineering works.

v) Site investigation scale

This is between 1:200 to 1:2.000, covering the area where engineering works will be carried out, or covering a single landslide. They are used for the detailed design of engineering works, such as roads, bridges, tunnels, dams, and for the construction of slope stabilization works.

2.1 Landslide Inventory Approach

The landslide inventory represents the most basic and simple method of landslide hazard analysis. In its basic form, the hazard map is derived directly from the landslide inventory map. This method is only partially satisfactory because attributing null hazard levels to areas outside the landslide boundaries excludes areas in which landslides have not currently been recognized. For this reason, this method is suitable only to areas in which easily recognizable landslides are prevalent [5].

2.2 Heuristic Approaches

They are usually based on geomorphological analyses aimed at recognition and correct interpretation of the factors that control landslide occurrences. The hazard assessment is carried out by a geomorphologist, through both fieldwork and aerial photointerpretation. In some applications, the analysis is accomplished by combining several thematic maps in which factors affecting landslide occurrence are weighted on the basis of the skills and experience of the earth scientists responsible for the analysis. Heuristic approaches
have been criticized repeatedly by several authors because of their highly subjective nature (6).

2.3 Deterministic Approaches

They consist of slope stability analyses generally designed to determine a safety factor. Application of deterministic models requires detailed geotechnical and hydrological

data and the correct knowledge of the failure mechanisms affecting the investigated slopes. Except for failure mechanisms that can be interpreted through infinite slope models [7], [8], deterministic models are suitably applied only to small areas, at the scale of a single slope. This physical-based method is theoretically perfect, but it is practically doubtful. Because it requires soil strength, soil depth, and hydrological parameters and these are difficult to collect in a large region [2].

2.4 Statistical Methods

These methods are more appropriate for hazard zoning, since the degree of subjectivity is reduced to a minimum. Results of the inventory are compared with the physical terrain factors influencing landslides. In particular, multivariate statistical approaches (black-box models such as factor analysis or discriminant analysis) have been successfully applied in landslide hazard mapping [9], [10], [11], [12]. However, such approaches, although conceptually simple, also have some limitations because of the great complexity in identifying the slope-failure processes, systematically collecting and representing all predisposing factors related to landsliding, and applying geomorphological predictive modeling of failure over large areas (13). Theoretical limitations could arise from transforming nonparametric variables, usually codified on the basis of an ordinal scale, into absolute scale measured variables.

III. MITIGATION MEASURES

There are a lot of measures used to mitigate against landslide occurrence which we are going to discuss in this paper. The hazard of landslide can be reduced by a good mitigation measure. Landslide, being a phenomenon that occurs when the soil lost its shear strength, this can be due to increase in water content of the soil which can be caused by rain, rise in ground water level or earth quake which causes the soil to flow down like a semi solid fluid. Landslide mitigation measure is highly dependent on the type of landslide, there are different types of landslide which include fall, topple, slide, spread, or flow which depends on the type of material and movement of the mass.

3.1 Mitigation of Fall

Rock curtains or other slope covers, protective covers over roadways, retaining walls to prevent rolling or bouncing, explosive blasting of hazardous target areas to remove the source, removal of rocks or other materials from highways and railroads can be used. Rock bolts or other similar types of anchoring used to stabilize cliffs, as well as scaling, can lessen the hazard. Warning signs are recommended in hazardous areas for awareness. Stopping or parking under hazardous cliffs should be warned against [1].

3.2 Mitigation of Topple

In rock there are many options for the stabilization of topple-prone areas. Some examples for reinforcement of these slopes include rock bolts and mechanical and other types of anchors. Seepage is also a contributing factor to rock instability, and drainage should be considered and addressed as a corrective means [1].

3.3 Mitigation of Slide

On the part of slide the mitigation will depend on the type of slide suspected and we have three of them: rotational slide, translational slide and spread slide

3.3.1 Mitigation of Rotational Slide

Instrumental monitoring to detect movement and the rate of movement can be implemented. Disrupted drainage pathways should be restored or reengineered to prevent future water buildup in the slide mass. Proper grading and engineering of slopes, where possible, will reduce the hazard considerably. Construction of retaining walls at the toe may be effective to slow or deflect the moving soil; however, the slide may overtop such retaining structures despite good construction [1].

3.3.2 Mitigation of Translational Slide

Adequate drainage is necessary to prevent sliding or, in the case of an existing failure, to prevent a reactivation of the movement. Common corrective measures include leveling, proper grading and drainage, and retaining walls. More sophisticated remedies in rock include anchors, bolts, and dowels, which in all situations are best implemented by professionals. Translational slides on moderate to steep slopes are very difficult to stabilize permanently [1].

3.3.3 Mitigation of Spread Slide

Liquefaction-potential maps exist for some places but are not widely available. Areas with potentially liquefiable soils can be avoided as construction sites, particularly in regions that are known to experience frequent earthquakes. If high ground-water levels are involved, sites can be drained or other water-diversion efforts can be added [1].

3.4 Mitigation of Flow

Flows usually cannot be prevented; thus, homes should not be built in steep-walled gullies that have a history of debris flows or are otherwise susceptible due to wildfires, soil type, or other related factors. New flows can be directed away from structures by means of deflection, debris-flow basins can be built to contain flow, and warning systems can be put in place in areas where it is known at what rainfall thresholds debris flows are triggered. Evacuation, avoidance, and (or) relocation are the best methods to prevent injury and life loss [1].

Other mitigation measures that can be applied to landslide as stated by Kwong, Akl e*t al* .,[14] are;

For soil slopes:
i. trimming and cutting;
ii. retaining wall with or without tie-back;
iii. re-compaction of fill slopes;
iv. soil nailing;
v. mini-piles
vi. slope surface protection including hydro seeding, sprayed concrete and reinforced concrete grids
For rock slopes:
i. scaling and trimming;
ii. bolting and dowelling;
iii. meshing and shotcreting;
iv buttressing and
v. anchoring (occasional)
.

IV. CONCLUSION

Landslide hazard analysis is a important task to carryout in every slope, majorly slopes of mountainous areas so as to dictate the likely hood of occurrence of landslide which will aid in selection of appropriate mitigation method to reduce the economic, social and human loss when it eventually occurs, because some landslides cannot be prevented from happening only mitigation of the impact can be done, through evacuation of communities leaving around the to be affected area or preventing people from building houses in such areas.

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