CREATION OF PHYSICAL CHARACTERISTICS INFORMATION FOR LANDSLIDE DISASTER MANAGEMENT ALONG PHUNTSHOLING – THIMPHU HIGHWAY (NH-1), BHUTAN USING REMOTE SENSING AND GIS

SS. Asadi ¹, Kinzang Wangchuk ², C.L.Das ³, Jigme Dorji ⁴, Pema Wangchen ⁵

¹. Associate Professor, Dept.of Civil Engineering, KL University, Green fields, Vaddeswaram-522502, Guntur(D.t) A.P, India,

²,³,⁴,⁵. Students, Department of Civil Engineering, K L University, Guntur, A.P, India.

ABSTRACT

The landslide is sometimes called as mass wasting. Failures of land mass are attributed to several factors. It may be manmade or natural. The morphology of the slopes and consequent to the slope failures are complex and controlled by many factors, such as lithology, rock mass strength and other physical properties. This study is useful to locating the vulnerable to landslide pockets along the highway within the study area and to prepare a risk zonation map is our concern. Once prepare the physical characteristics maps also useful for identifying the intensity of risk, the decision makers would take sufficient care to avoid from possible risk of landslide which would result into a blockage of road. The vulnerability of the valley to landslide disasters also increased relatively due to recently thimphu highway double lining projects. The Thimphu-Phuentsholing Highway is the most important highway for Bhutan. With the rapid increasing rate of development in the country, the efficient road networks are essential. This particular highway is the most risky route as per the study conducted between 1991 to 2002 by the road safety and transport authority. The major portion of country’s economy is being endangered due to the blockages along the highway. Keeping this in view The study has taken to create the physical characteristics information this information is useful to study the impact of landslide hazards.

KEY WORDS: Landslide impacts, Hillsides, slopes, physical characteristics, Remote sensing and GIS.

Corresponding author: SS. Asadi
1. INTRODUCTION

Bhutan is a part of Himalaya Range wherein has no exception encountering the landslide hazard elsewhere in the world. It has a very fragile terrain and geologically it is unstable region. Bhutan is just seating over the active earth quake zone (Zone- IV and V) and if we don’t keep ourselves prepared, dreadful disasters are sure to come. Bhutan is a small kingdom covering an area of 38,000 square kilometers in the eastern part of the Himalayan Range between latitudes 26° 40’ and 28°20’ North and longitude 88° 45’ and92° 7’ East. Many developing countries are located in mountainous regions, and suffer from poor road access and lack of data concerning topography, geology and environmental hazards. Bhutan is also a developing country for Bhutan had initiated and accelerated its development works since early nineties. Landslides caused hazards are one which required most attention particularly at this juncture for Bhutan. About 15% of the Country’s investment is made in road infrastructures. This being the one of the manifestos of the present government for which 202 grogs to be connected by feeder and farms road, east west highway expansion to be completed by 2020 and expansion works of Phuntsholing to Thimphu highway is at the verge of completion. This road serves as the life line to the country’s capita (Thimphu). We cannot afford to ignore this highway from strengthening for which otherwise would lead to damaging environmental hazards in these areas, causing loss of life, loss of livelihood and disruption to road traffic and economic activity. Many authorities lack the required information and know-how to overcome these problems, and the purpose of this project was to develop information regarding landslides risk probability along the road corridor of landslide assessment and management. This highway is maintained by Project Dantak (Border Road Organization, India). Ever since its construction as single lane road (3.4m). It is surrounded by the Tibetan Plateau in the north, the Bengal and Assam Plains in the south, Arunachal Pradesh in the east and the Darjeeling and the Sikkim Himalaya in the west.

As per the National Road Network information of Bhutan, there is a total stretch of 4544.73 Km road and there are two most important highways namely Thimphu – Phuntsholing highway and Thimphu- Tashigang highway. Thimphu-Phuentsholing highway is the main route being used for travelling and transportation of goods to most of the Dzongkhags (Districts). This highway is maintained by project DANTAK (Border Road Organization of India) and the divisions of road are given in table -1 for NH-1 (Doji Checki et al, 2010). In order to reduce the enormous destructive potential of landslides and to minimize the
consequential losses, it is necessary that the hazard must first be recognized, the risk analyzed and an appropriate strategy developed at the national or regional level to mitigate its impact.

Table 1: Detail road length

<table>
<thead>
<tr>
<th>Road Name</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phuentsholing - Rinchending</td>
<td>5</td>
</tr>
<tr>
<td>Rinchending - Ganglakha</td>
<td>24</td>
</tr>
<tr>
<td>Ganglakha - Jumja</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
</tr>
</tbody>
</table>

2. STUDY AREA.

2.1 Description of Study Area.

The study area is located along the National Highway within the longitude of 89°22’E to 89°30’E and latitude 26°50’N to 26°56’N towards the southern foot hills of the country in which the National Highway (NH-I) connects between the capital city of Bhutan and major border towns (second largest in the country), where the most economic activities and commercial industries are established. Geographically, the terrain features of our study area are within the range of steep to very steep slope and its elevation ranges from 230 m to 2055m as per the GPS record during the site visit. It starts from 0+00km (Phuntsholing) and ends at 42+00km (Jumja) along the stretch from Phuntsholing to Thimphu highway. The study area is buffered 500m on either side of the road. It has the area of 50sq.km. There are two major locations where mostly the landslide occurs; they are namely Sorchen and Jumja located at 29 km and 41 km respectively from border town besides several minor slides within the study area. The occurrence of landslide along the roads, during the monsoons is a regular phenomenon in Bhutan, especially in the above sighted two areas. This was reveal by the blockage of roads ceasing the complete transportation system lasting for weeks and months to clear out the blockage, there by affecting the country’s economy. Mostly the highway alignment runs through the forest and at some point through little settlements areas as reveal from the topo-map. The population within our study area is very thin with sparsely spread settlement; this is due to the steep terrain condition and being the forested area with no proper cultivable land available to them. The farmers are mostly depending on cash crops like orange, ginger and cardamom and selling of live stock products. Some depend on daily wedges basis who are near by the towns.
2.2. Importance of National Highway

The National Highway No.01 (NH-01) contributes roughly about 70% of the country’s economy. Besides serving as a lifeline to the capital and other six major districts (Chukha, Punakha, Paro, Wangdi, Haa and Thimphu), the country’s most vital projects are along NH-01. The 1020 MW Tala hydroelectric project at 46km, 336 MW hydroelectric project at 88km, Capital city at 179km, 1095 MW Punatsahngchu-I and 990 MW Punatshangchu-II hydroelectric project respectively which is under construction is located at 245km. Thus it is one of the most crucial roads required country’s highest attention. The various black spots on the highway depending on the number of blockages have been identified and the loss due to road blockage and the accidents has been estimated to be Nu.51 million per day which is 11.73 % of the Gross Domestic Product of the country for the year 2009, Dorji cheki, et al. Landslides along the highway sometimes become hazardous as they claim lives and properties.
2.3. Climate and rainfall

Bhutan has a wide variety of climate conditions influenced by topography, elevation and rainfall patterns. In general, precipitation diminishes significantly from south to north. The winters are dry and rainfall is heavy during June and August. In the study area climate is tropical in southern plains, cool winters and hot summers in central valleys, and severe winters and cool summers in northern Bhutan Himalayas. The maximum elevation in the area is 2055m from mean sea level and minimum of 230m. The rainfall gauge stations in the study area are placed in Phuntsholing and Gedu. The Maximum rainfall experiences in this area are about 1632mm to minimum of 4mm (Ministry of Agriculture). The highest rainfall in this area experiences during the rainy months of June and August. The temperature ranging from $15^0C$ in winter and steadily increasing to 32 in summer season in the southern part while $2^oC$ in winter and $28^0C$ in summer in the northern part of the study area. Starting from 32+00km (Ganlakha) to 42+00km remains most humid and wet almost throughout the year. This stretch is considered as the most threatened and risky area for the the travellers not only within the study area but throughout the highway. The amount of risk can be seen in the figure: 3

2.4 Socio-economic Resources

As per Population and Housing Census (PHCB 2005), Chukha Dzongkhag has second highest population in Bhutan, 74,387 people. There are 11 Gewog namely Sampheling, Darla, Lokchina, Phuentsholing, Bongo, Bjachho, Chapcha, Dungna, Getena, Geling, Metakha and one Drungkhag (sub district) under the Dzongkhag(district). The Small Area Estimation of Poverty in Rural Bhutan, 2010, jointly carried out by World Bank & National Statistical Bureau (NSB), confirms the number of poor in the geog to be 1072. The poverty rate for geog is estimated to be 16%.

3. METHODOLOGY

3.1 Demarcation of study area.

For demarcation of study area, initially it was observed that the landslides are only along the corridor which was due to the unstable steep slopes, so on those area was considered which have landslides and which can have landslides in future along the road corridor. A buffer zone of 500m is kept on the right and left sides of the road respectively. This zone is demarcated in such a way that all landslides are in between the area and also the zone which have no landslides but could affect the road.
3.2 Data Collection:
Different data products required for the study include SOB toposheets bearing the numbers No.78F/5 on 1:50,000 scale, fused data of IRS–1D PAN and LISS-III merged satellite imagery obtained from National Remote Sensing Centre (NRSC) and collateral data collected from related Government organizations and demographic data.

3.3 Field data collection
Landslide risk assessment is a procedure which requires a lot of field investigation. To collect the information of geological and structural information.

3.4 Data Input and Conversion:
IRS-ID LISS-III and PAN satellite imageries collected from NRSC are geo-referenced using the ground control points with SOB toposheets as a reference and further merged to obtain a fused, high resolution (5.8m of PAN) and colored (RGB bands of LISS-III) output in ERDAS Image processing software. The study area is then delineated and subsetted from the fused data based on the latitude and longitude values and a final hard copy output is prepared for further interpretation.

Fig3 : Satellite Image

3.5 Database Creation and Analysis:
Creating a GIS spatial database is a complex operation, which involves data capture, verification and structuring processes. Raw geographical data are available in many different analogue and digital forms such as toposheets, aerial photographs, satellite imageries and
tables. Out of all these sources, the source of toposheet is of much concern to natural resource scientist and an environmentalist (Ref.No.-7 John R.Jensen 2003). In the present study, different thematic layers viz., Base map, Land use / Land cover map. Geomorphology, Slope, Soil, Geology, Drainage network maps are generated from toposheet and satellite data using visual interpretation technique.

The paper-based maps are converted to digital mode using scanning and automated digitization process.

3.6 Digitization

The topo sheet map that had been so collected required to be digitized in order to develop and generate the required maps related to the aims and objectives of the study. Digitization can be done either in Arc GIS software or in Auto CAD. We had carried out the digitization work in both the soft ware as an exercise and further more to understand that both soft wares had their own limitation and drawbacks. Arc GIS has the capability to analyse the data digitally while Auto CAD does not. However, it is much handy and easier to use Auto CAD for the beginners and learners although it is labourous. These maps are prepared to a certain scale and show the attributes of entities by different symbols or colouring. The location of entities on the earth’s surface is then specified by means of an agreed co-ordinate system. It is mandatory that all spatial data in a GIS are located with respect to a frame of reference. For most GIS, the common frame of reference co-ordinate system is that of plane, Orthogonal Cartesian co-ordinates oriented conventionally North-South and East-West (Ref.No.4-Cracknell and Hayes 1996). This entire process is called geo-referencing. The same procedure is also applied on remote sensing data before it is used to prepare thematic maps from satellite data. This digitized data is then exported to ARC/INFO and further processed in ArcView GIS software to create digital database for subsequent data analysis.

4. RESULTS AND DISCUSSION

4.1 Base Map Generation

The base map is prepared using Survey of Bhutan Toposheet (78F/5) on 1:50000 scale. A base map consists of various features like the road network, settlements, rivers, streams, canals, vegetation etc, which are delineated from the toposheet. The map thus drawn is scanned and digitized to get a digital output. The major settlements in the present study area are Kamji, Suntalakha and Ganglakha.
Figure 4: Flow chart showing the methodology adopted for the present study
The drainage map prepared from the toposheet forms the base map for the preparation of thematic maps related to surface and groundwater. All the rivers, tributaries and small stream channels shown on the toposheet are extracted to prepare the drainage map. In the study area dendrite drainage patroon and dense drainage density has been observed.

4.2 Drainage pattern

Contour lines are curved or straight lines on a map describing the intersection of a real or hypothetical surface with one or more horizontal planes. The configuration of these contours allows map readers to infer relative gradient of a parameter and estimate that parameter at specific places. Contour lines may be either traced on a visible three-dimensional model of the surface, as when a photogrammetrist viewing a stereo-model plots elevation contours, or interpolated from estimated surface elevations, as when a computer program threads contours through a network of observation points of area centroids. In the latter case, the method of interpolation affects the reliability of individual isolines and their portrayal of slope, pits and peaks.
4.4 Slope Map:

Survey of Bhutan Topo maps on 1:50,000 scale are used for deriving the information. Contour lines on topographic maps are particularly useful for preparation of slope map. Closed space contours on the map reflect steepness when compared to widely spaced contours. The different classes of slopes have been categorized as per the guidelines suggested by NRSC. The study area has been categorized into two slope classes. Almost all the study area comes under very steep class very less area is representing steep slope class. In general, the elongated shape of the contours suggests the elongated morphology of the hills.

![Slope Map](image)

Fig 7: Slope map

4.5 Lithology map

In the study area six rock types present in the area. These are Phyllite, talcose phyllite, buff colour qurzite phyllite, quartzite, dolomite, limestone. The quartzites are stronger than the other rocks in the area. However, all the rocks are folded, faulted, and sheared to varying degrees, and they have been subjected to high levels of weathering along the drainage channels. Marked by the changes in the lithology, from the dominant phylitic rock in the buxa formation to the dominant quarlitc unit in the shumer formation. Occurs around Ganglakha in the west, and Jaishi Dangra and below in the south central Bhutan and Tokarong area eastern Bhutan. The lower part occurs at P/Ling and the surrounding areas. The upper parts occur at Pugli. Kalishore, Khanaburty and Khagrekhola areas. The lower part occurs at P/Ling and the surrounding areas. The upper part occurs at Pugli. Kalishore, Khanaburty and Khagrekhola areas. Phyllite, talcose phyllite, and buff colour qurzite at the
lower part with deficient of carbonate rocks whereas the upper part of the buxa formation is characterized by the presence of carbonate rocks. At the lower part of the buxa formation, phyllite of varying colours such as grey, purple, green and brownish clour without carbonate bands. The upper part consists of mainly phyllite, quartzite, dolomite, limestone. The lower part occurs at P/Ling and the surrounding areas.

Fig 8: Lithology map

4.6 Soil map
Soil survey, or soil mapping, is the process of classifying soil types and other soil properties in a given area and geo-encoding such information. It applies the principles of soil science, and draws heavily from geomorphology, theories of soil formation, physical geography, and analysis of vegetation and land use patterns. Primary data for the soil survey are acquired by field sampling and by remote sensing. Remote sensing principally uses aerial photography but and other digital techniques steadily gaining in popularity. In the past, a soil scientist would take hard-copies of aerial photography, topo-sheets, and mapping keys into the field with them. Today, a growing number of soil scientists are bringing a ruggedized tablet computer and GPS into the field with them. The tablet may be loaded with digital aerial photos, topography, soil geodata bases, mapping keys, and more. The present study area four types of soils has been identified that is Black loam soils, Dark brown loam soils, Sandy silt soils, Reddish brown soils.
4.7 Geomorphology map

Geomorphological maps are one of most important end products of investigations made by geomorphologists on the territory. Furthermore they are of great usefulness to many other professionals dealing with the landscape and landforms like engineers, urban planners, soil and forest scientists, agronomists, land conservationists, etc. Information on landforms is an important input for land management and identification of weathering zones. There are three different features Residual hills, Denudational hills that we could interpret from the satellite image in which the feature like lineaments are continuously stretches throughout the study area.

CONCLUSION:

Based on the above studies in the study area there has been rapid changes in Geological and Geomorphology, structures characteristics like fractures, liniments, joints and Land use changes also observed like decrease in forest area, increasing shifting cultivation etc which
has serious consequences on the environment as well as on climatic condition. This type of studies can useful to create the awareness of people for sustainable management of the land and Prevention of landslides. This type of Advanced Technology like Remote sensing is useful to good geological engineering design and to take preventive measures to control and minimize the losses. Furthermore GIS software can be useful to create operational database for taking remedial measures to protect the Landslide zones and also useful to take remedy measurements around the sensitive areas for the future planning.

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