1.1 Introduction:

‘The literal meaning of slope instability is how far the slope is potential for movement’. All slope movements are a manifestation of the slope’s instability – when slope move, they fail. Slope failures can result in extensive property damage and loss of life in form of landslides so; there is a close relation between slope instability and landslides.

Investigation of slope instability and landslide hazard has sparked significant interest internationally and it is the primary focus of research initiatives around the world. Therefore the present research direct towards study of slope instability along Darjeeling Himalayas.

The Darjeeling Himalaya is a fragile terrestrial system, which is too often disturbed by various environmental catastrophes. Slope instability along transport and arterial sectors is perhaps the most hazardous among the environmental catastrophe threatening the Darjeeling Himalaya. Nowadays landslides and subsidence especially along the transport and arterial sectors of Darjeeling Himalaya are creating serious problems leading to total disruption of vehicular traffic between the hills and the plains with the consequent disastrous effect on the transport of goods and tourist operation. Therefore, at present slide and subsidence along the main thoroughfares are common problem to the hill people.

The Darjeeling Himalaya, a part of Eastern Himalaya lies between the Nepal Himalaya in the west and Bhutan Himalaya in the east. It is bounded towards north by the Sikkim Himalaya and towards south by Duar Plains of Ganga-Brahamputra Alluvium. The river Teesta flowing north to south across Darjeeling Himalaya, exposes a full cross section of the Eastern Himalaya. Darjeeling Himalayan ranges have suffered mass destruction due to its typical environment, characterized by well-foliated granite-gneissic and phyllitic rocks, huge amount of rainfall and temperature, higher degree of physical and chemical weathering and frequent neo-tectonic movements as well. In this type of fragile terrestrial system, the development of a network of roads and passing of heavy vehicles causing jerks and vibrations on weathered rocks and the continuously changing land use due to increasing human interferences help to initiate landslides and subsidence. The problem has been aggravated since early sixties.
1.2 Location of the study area:

The present researcher has selected the main transport and arterial routes of Darjeeling Himalaya running through Kalimpong Subdivision of Darjeeling District, West Bengal for searching the reasons behind such slope instability along transport and arterial sectors, their effects and for building a model to mitigate such hazard. The study area includes -

- Along the Teesta valley road or the National Highway 31A, (now NH 10) from Sevok to Teesta-bazar that is the main route, connecting the North Bengal plains with hills of West Bengal and Sikkim.

- Roads between Kalimpong-Algara, Algara-Labha-Gorubathan. This is an alternative route connecting the North Bengal plains with Kalimpong and Sikkim.

These routes are located within Kalimpong subdivision, covered by Kalimpong I, Kalimpong II and Gorubathan blocks and bounded by latitude 26° 45' N to 27° 12' N and longitude 88° 25' E to 88° 52' E. (Fig. I.1 and I.2)

1.3 Scope of study:

Slope instability as already been mentioned is one of the most common natural hazard in the geodynamically active Eastern Himalayas, causing destruction of road, disruption in communication, damage to resource and loss of property and human life. The term landslide denotes any down slope movement (rapid or slow) under the influence of gravity of a mass of regolith and bedrock with or without presence of water. Landslides take place when slope materials are no longer able to resist the force of gravity. Whereas the subsidence denotes a landslide, in which there is downward displacement of relatively dry superficial earth material without a free surface and without horizontal displacement.

In general, the stability of slope may be defined according to Cooke, R.U. and Doornkamp, J. C. as a factor of safety (Fs).

\[ Fs = \frac{\text{the sum of forces resisting slope failure}}{\text{the sum of disturbing force}}. \]

Alternatively, \[ Fs = \frac{\text{shear strength}}{\text{Shear stress}}. \]

If \( Fs > 1.0 \) then stability exists but if \( Fs < 1.0 \) then instability exists. The variation in \( Fs \) depends on either increase or decrease in stress and strength.
Figure I.1 Location map of the study area.
Figure I.2 Satellite Image of the Kalimpong Subdivision.
Plate I.1 A view of landslides along Teesta valley road, NH 31A (now NH10).
The scope of the work includes to investigate the stability of slope and to investigate the role of factors leading to decrease in shear strength and an increase in shear stress. The researcher will consider the nature of bed materials, availability of water content, the structure of bedrock, the climatic condition, weathering changes and the presence of pore water pressure etc as the factors leading to decrease in strength. The removal of lateral or underlying support, the increased loading, the changing land use pattern and the transitory earth stresses by earthquake and continual passing of heavy traffic and their vibration effect etc as the factors leading to increase in stress.

Scope of the work also includes detail mapping of some of the individual landslides and subsidences along main routes, which have occurred in recent past. Based on the study of individual slides, an attempt will be made to identify the geological attributes and other causative factors such as hydro-geological, geo-hydrological, meteorological, anthropogenic etc. contributing towards initiation and aggravation of landslides and subsidences.

The researcher expect that the present study is to be of immense value for hilly terrain management, development of roads in new sectors and control of mass wastage of mountainous region due to repeated occurrence of landslides and subsidences.

1.4 Problems of the study area:

Following are the problems of the study area to be undertaken, studied and analyzed by the researcher.

- Transport arteries or lifelines of the hills are highly hazardous particularly in rainy season.
- Decreases shear strength of slope materials of the study area.
- Increase shear stress of slope materials of the study area.
Decreasing shear strength and increasing shear stress leading to increase in instability and decrease in safety.

Unplanned and often destructive land use worsening the situation.

Subsidences are common along transport and arterial sectors, which are embryo of future landslides.

1.5 Research questions:

- Does the slope on which the roads are situated is ideal for their construction?
- Do the climate, rock types and rock structure, vegetation cover and deforestation play positive role in aggravating the situation?

1.6 Research hypotheses:

The highly vegetated slopes on Phyllite and schistose rocks in a wet tropical climate and tectonically unstable zone, as in the study area are not safe for construction of roads beyond a critical minimum angle.

1.7 Objectives:

The objectives of the present research work can be summarized as follows-

- To study the physical and cultural environment of the Darjeeling Himalaya and Kalimpong sub-division in detail.
- To study the causative factors behind slope instability and sliding in general with example of Kalimpong sub-division.
To prepare a landslide hazard zonation map (LHZ) of the study area to identify the risk zones and to suggest a plan for future construction.

To note and to map the shape and surface geomorphology of few selected landslides.

To identify the underlying nature of rock and soil material of the slide area for the measurement of soil gradation and its impact on landslides.

To build up some model to establish the relation between shear strength and shear stress and to find out or calculate the factor of safety (Fs) through Circular Failure Charts (CFC) along the main transport and arterial routes of Darjeeling Himalaya.

1.8 **Methodology:**

The present study deals with slope instability, which occurs frequently, and effects severely in the study area. The methodology is based on the scanning of all available books, journals and literatures regarding slope instability, to have an idea regarding different aspects of slope instability and landslide. The researcher collected topographical maps, geological maps, aerial photographs and satellite imageries of the area to develop an idea regarding the study area, to select and locate the major slides and subsidence zones along the main transport arteries and to plan the fieldwork.

After collecting all necessary information, the researcher proposes to start the actual fieldwork, which is the main part of the study. The research work depends on minute and detailed field observation including investigation of individual slides and subsidence along main transport and arterial routes. The researcher found out the internal factors of decreasing shear strength and the external factors of increasing shear stress. Measurement and mapping of selected individual slides and subsidence, collection of slide materials for grain size analysis from the selected slides. Climate and land use data were also collected to make a complete comprehensive study of the area.
After fieldwork a preliminary analysis was carried out, this part of the research includes compilation and processing of data collected during fieldwork. Geological map, geomorphologic map, slope map, rainfall distribution map, soil, forest and changing land use maps, landslides intensity map and landslide hazard zonation map (LHZ) etc were drawn based on data generated. LHZ map (based on Ambalagan, 1992 and Bureau of Indian Standard, BIS, 1998) of the present study area has been prepared on the basis of the degree of causative factors of instability. From the collected soil samples, grain size distribution and its curve were drawn to identify the nature of slide material as well as conduct laboratory testing to find out the parameters of Circular Failure Chart (based on Hock and Bray, 1981) for calculation of factor of safety. GIS software like ARC-GIS.9.0 and ERDS Imagine 8.7 were used for integrating different thematic maps and assigning their combined effect. These thematic maps were quantified by giving them a relative score. Ultimately, all data were compiled and analysed in detail to formulate an actualistic model for the slope instability along main transport and arterial sectors of Darjeeling Himalaya, which can be correlated with the models already developed elsewhere to identify the peculiarities and specialties of slope instability and landslide.

A flow chart has been prepared to represent the methodology of the research work.

Figure I.3 Flow chart outlining the methodology of present research work.
1.9 Literature review:

The area of study of the present researcher is unique from the viewpoint of its subject matter. However, the physical condition, the climatic characteristics, the condition of the forest cover, the cause and consequent of the landslides etc have all been studied and investigated in detail by various research groups, government authorities, renowned geologist, geographers and engineers.

One of the first attempts of study in Darjeeling Himalaya was made by J.D. Hooker, (1854) who gave a systematic report for the first time on landslides. After that, F.R. Mallet (1874) did geological investigation in Darjeeling and classified the metamorphic rocks into Daling Series and Darjeeling Gneiss. Then P.N. Bose (1900) investigated the mineral resources of Darjeeling. After that, H.H. Hayden (1912) visited Darjeeling to advice, the Bengal Government with regard to the protective measures necessary in Happy Valley tea garden. Then A. Heim and A. Gansssser (1939) visited the area, studied the structural characteristics of the area, and made the first geological map of Darjeeling. S.K. Roy (1947) did another valuable work on the metamorphism of the rocks of Darjeeling area. Then A. M. N. Ghosh (1950) also did a detailed geological mapping in parts of the Darjeeling Himalaya.

Thereafter J.B. Auden (1956) and others of the GSI were examined the Teesta gorge and M. S. Jain (1957) was also carried out a detail geo-technical study of the Lish & Gish Valleys. After that S. Roy and S. B. Sen Sarma, (1965-66) carried out detailed study of the slope pattern around Darjeeling. Then S. P. Nautiyal & K. K. Dutta (1966) studied the landslips of Darjeeling on behalf of Geological Survey. After that, G. N. Dutta (1966) carried out an extensive investigation in the Lish and Chel basin Then B. Biswas, G. V. Bhadram, A. Agarwal and S. Narain (1968) made extensive study on 1968 flood events of Darjeeling and after that, L. Starkel (1970-72) made extensive study in the Darjeeling hills to investigate the role of catastrophic rainfall in the shaping of the relief.

Another valuable work was done by T. Nakata, who (1972) published his thesis on the geomorphic evolution of the mountain front of the Darjeeling Himalaya, which specifically highlighted the neo-tectonic earth movement of the Himalayan region. After that, L. Starkel and a

Another valuable work to be noted, was done by L. Starkel, and S.R. Basu, (2000) operating through the ongoing scientific exchange programmed between the Indian Science Academy and the Polish Academy of Science, which studied some specific landslides in Darjeeling Himalaya in detail and also mapped the slide faces in the monograph titled “Rains, Landslides and Floods in the Darjeeling Himalaya”. Then A. Mukherjee and A. Mitra (2001) conduct Geotechnical study of mass movements along the Kalimpong approach road in the Eastern Himalayas. After that S.R. Basu, (2002) analyzed the process of urbanization and rise of population with decline of forest area and associated environmental changes in his paper titled “Urbanization and Environmental catastrophe in the Darjeeling Himalaya”.

After that C.Paul and T.B.Ghoshal (2009), find out the Major Landslides in Sikkim Darjeeling Himalaya.


The writing of the researchers like P. Basu, R. Maiti, S. K. De, S. Ghosh, Kanungo and Sarkar have also been consulted to understand the landslide hazards, slope degradation, slope instability and human interferences in Darjeeling Himalaya.

None of these papers has attempted a detailed site investigation of landslide and subsidence along main transport and arterial routes of Darjeeling Himalaya (Kalimpong Subdivision), to calculate for find out the factor of safety (Fs). None-the-less the past researchers have also not tried to analyze the grain-size distribution approach for finding Fs by using CFC along main thoroughfares. Therefore, the aim of the researcher is to bridge up the gaps of previous studies, to identify the landslide hazard zone, to find out the Fs for this region and to analyze and measure the effect of construction of roads on landslides and vis-à-vis on such an environment.

1.10 Conclusion:

The researcher will work according to the above-mentioned methodology to fulfill his objectives to produce an elaborate and vivid discussion of the problem with some suitable and applicable solution.
1.11 References:


