Landslide susceptibility assessment for propose the best variant of road network (North of Iran)

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Abstract

This research has studied and investigated some landslides that caused many transportation problems in the region of Bandben-Laie Road in Neka situated in northern Iran. Given the large number of landslides in this path and the high cost of stabilization, first the task of the identification of a new path with a higher safety factor was undertaken. In order to do so, some effective factors in slop instabilities were studied and investigated in this region. In addition, the geographical positions of the previous landslides in and around this path were recorded by GPS. Finally, a digital and raster layers of the effective factors in the landslides of this region using the geographic information system (GIS) was provided. Furthermore, the landslide hazard zonation map was outlined using the density area method in the concerned range subsequent to conducting necessary analyses and computations on the information layers. Using the information obtained from this particular zonation map as well as the desert examinations, the most suitable path was eventually identified and thus proposed.

Key words: landslide, slop instability, Road, Alborz, Iran

1. Introduction

The Mazandaran Province is located in the northern region of Iran and has experienced catastrophic natural hazards. This region, due to its special geological and climatic conditions have been repeatedly the target of landslides that have been causing profound damage to man his property and home as well as depleting natural resources. The presence of natural factors like geological, climatic and topographical properties plus some human factors such as land use and modifications, road and building constructions have been responsible for a considerable portion of the country's landslide phenomena in the northern slops of Alborz. Due to the significance of the dangers and damages of landslides, various studies were carried out in the province such as hazard zonation mapping in the range of the basin area of the upper Siahbisheh Dam (A. Entezari, 2004), the hazard zonation of slop instability in the basin area of Babolrod (M. Fattahi Bandpay, 2007), the effect of land use in the basin area of Nekarod (A. Uromeihy & m. Safaie, 2000) and a study of the effective factors in landslide occurrence and hazard zonation map in the basin area of Shirinrod in Sari (Kalarestaghi, 1381). The main targets affected by these landslides are the transportation and communication pathways which connect the populated areas of this region. The road blocks of the aftermath of these landslides have caused fundamental problems to people that disrupted their lives for days. One of the paths affected by this natural hazard is the Bandben-Laie road in Neka. Thus, a dire need of the landslide hazard zonation map was felt. Given the high frequency of these landslides and the high cost of their stabilization, the researchers of this study identified and proposed a new path with regard to the effective factors in slop instability in this region.

Fig 1: Examples of damages caused by landslides in Bandben-Laie road.

2.Data and Material

The region under study is located in the northern slops of the Alborz Mountain Range in the east of Mazandaran Province (in the southeastern Neka) and is located at the longitude 30'25'53 and 30'39'53 east and at the latitude 00'33'36 and 30'26'36 in the North of Iran.

The roads chosen for this study run under Laksha area from the basin area of Nekarod. The area has low rainfall and the river is filled with water mainly from melted snow and the surrounding springs in the upper parts of the Nekarod area while the middle parts of this area experience floods caused by rainfalls (The Introductory Studies on the Basin Area of Nekarod, 1999). The main and dominant part of this area is covered with dense forest in the mountainous area. Geologically, the eastern-western lithological extension are mostly related to M^m, s,I units (marine, marine sand stone and conglomerate lime sand) and Pe^ml (marine, lime and silt) .Given the presence of clay formations and the considerable amount of rainfall in the area, lithologically, there is a high probability that this area could be afflicted by landslides. Also, a number of faults with NE-SW trends have been observed in the northern and western parts of the area. The folds of this area follow the direction of the slide folds of the area and the axial path takes an eastern to east-northeastern course

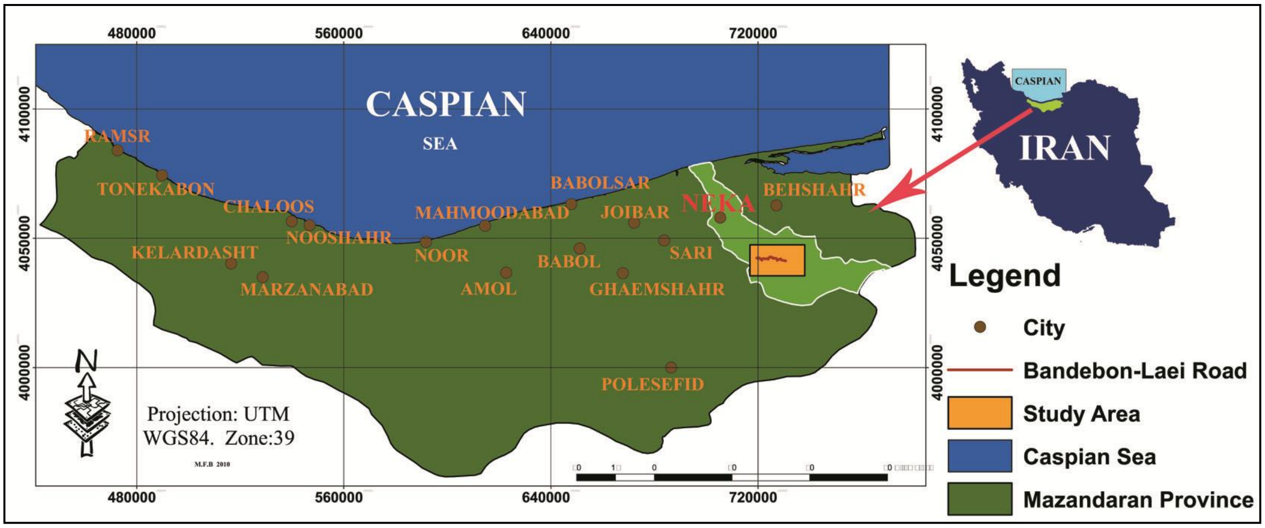


Fig 2: Location map of study area (in north of Iran)

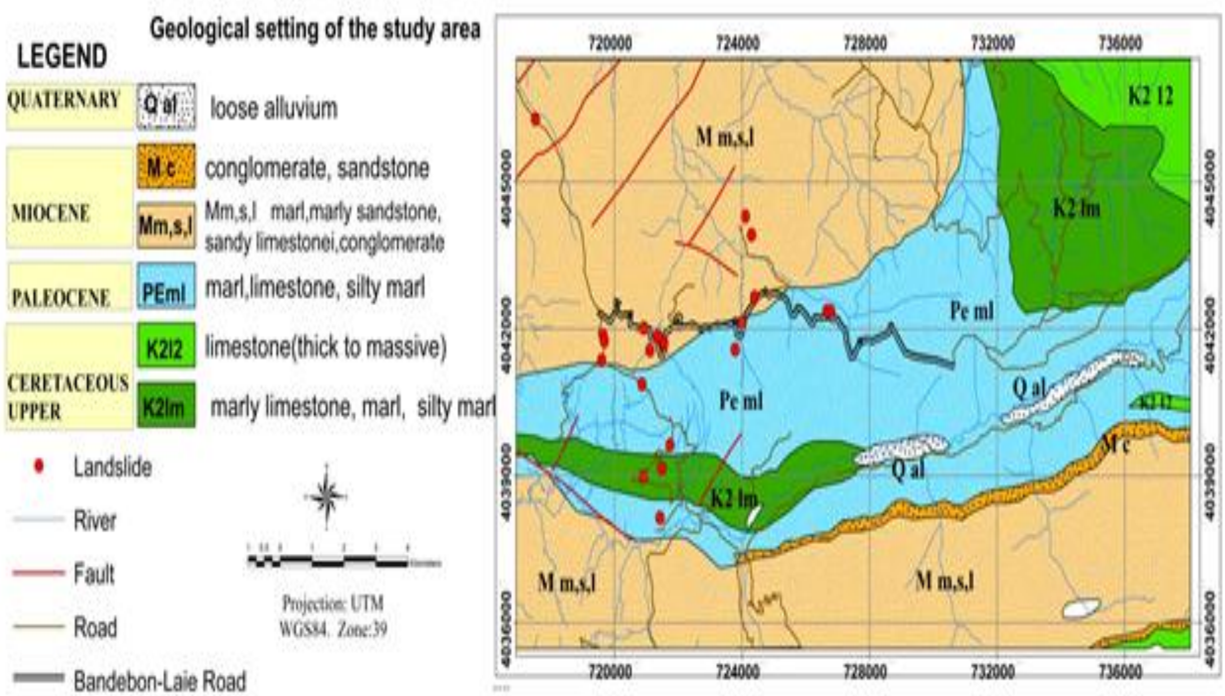


Fig 3: The geological setting of the study area and location of landslides

3. Research Methodology

The researchers zonated the landslide hazards in the area under study in order to study the landslides in Bandon-Laie road and identify a path with a higher safety and stability than the present state. The main aim of hazard zonation map is to predict the location in which landslides occurrence is possible without a clear sign of the possible occurrence time. Thus, the method used in this research is the bivariate statistical method of density area.

Landslide susceptibility is defined as the spatial correlation between environmental factors (slope, land use, litology, etc.) and the distribution of observed landslides in the study area (Brabb, 1984; Crozier and Glade, 2005).The main concept of the statistical approaches such as the bivariate is that the controlling factors of future landslides are the same as those observed in the past (Carrara et al., 1995).Several types of bivariate (densities methods including area and number density , frequency of ratio , information value ,certainty factors and weights of evidence) methods were applied for landslide susceptibility assessment with the application and limitation mentioned by Yin and Yan (1988), Carrara et al. (1995), Soeters and van Westen (1996), Atkinson and Massari (1998), Aleotti and Chowdury (1999), Guzzetti et al. (1999), Dai et al. (2002), van Westen (2004) and van Westen et al. (2003, 2006), Guzzetti et al. (2006).

3.1 Bivariate statistical method

In addition to the information layers of the area, zonation through the bivariate statistical method requires the landslide distribution map which should have been already scaled with each of the thematic maps of the area to obtain the landslide percentage in each unit. Using the mentioned equation, the weight of each unit in each floor will be calculated then and the maps will be created according to the weigh in GIS. The created maps will be integrated according to weight in order to make the zonation map; then, the zonation map will be achieved through the algebraic addition of the weights of the overlapping units and finally, the landslide hazard zonation map will be created through the categorization of the mentioned map according to the apexes of the visual diagram of units weight frequency.

3.1.1 The bivariate statistical method of density area

In this method, the related weight of each class of each parameter is obtained with regard to the following equation and all layers are added together subsequent to calculating the weight of the classes of each parameter. Then the zonation map is created which will be divided into five hazard classes (very low, low, medium, high and very high) when the map is

$$\mathbf{D}area = A/B * 1000 \quad (1)$$

$$\mathbf{W}area = \mathbf{D}area-(C/D * 1000) \quad (2)$$

A, is the landslide area for each unit

B, is the surface area of each unit

C, is the total surface area of the landslides

D, is the total surface area of the watershed

Darea, is the surface density of landslides and Warea, is the weight of density area

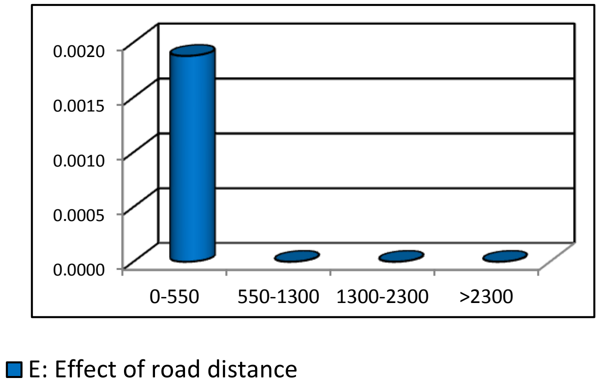
In order to carry out the zonation through this method, a number of effective geological and geomorphologic parameters effective in and stimulating landslide in the target area were identified and the necessary analyses and computations to provide the landslide hazard zonation map were carried out using the geographic information system (GIS).
In the first stage, the information layers related to the effective factors in slop instability of the area were provided in the computer software Arc GIS and were digitalized which include the information layers of the folds, rivers, roads, slope direction, slope, geological and land use in addition to the present landslide layers which was recorded as the main layer by GPS and was inserted into GIS. Generally, these factors are among the effective factors used in most landslide hazard zonation methods. In the next stage, all the mentioned factors were classified as follows: the RASTER distance map was first created for the lineal digital layers like folds, rivers and roads and when the mentioned RASTER layer was provided, they were classified with regard to the area conditions and the aggregated pixels frequency diagram in each layer. Later, the slope and slope direction map was created as these layers were provided from the height digital model and is in RASTER form. Concerning the slope map, classification was also done like the above layers and the slope map was classified into the four main directions namely northern, southern, eastern and western. The geological and land use maps were classed with regard to their contents (the type of litology and land use variety) (Table 1).

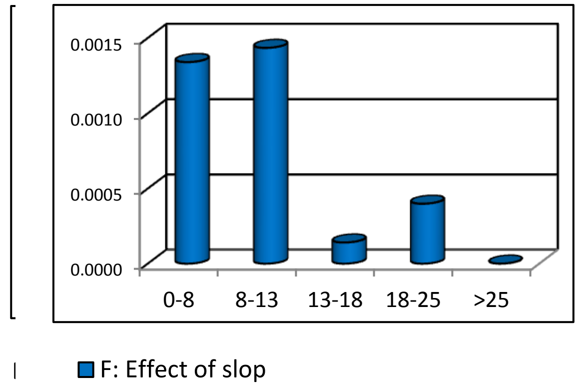
After preparing different layers and classifying them in Arc GIS in the next stage, each layer was scaled with the existing landslide layer in the area to obtain landslide density rate in each class of each factor which indicates the degree of the effect of that class of the involved factors on landslide occurrence. Later, the landslide density diagram for each layer was drawn to analyze the obtained results. (Figure 4)

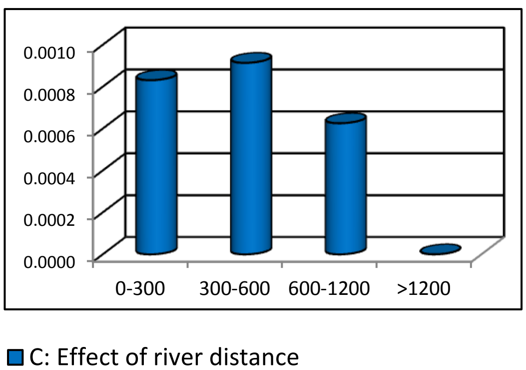
4. Results and Analysis

After preparing different layers and classifying them in Arc GIS in the next stage, each layer was scaled with the existing landslide layer in the area to obtain landslide density rate in each class of each factor which indicates the degree of the effect of that class of the involved factors on landslide occurrence. Later, the landslide density diagram for each layer was drawn to analyze the obtained results. (Figure 4)
Given the layers of distance from road, distance from river and distance form fold, if landslide density decreases with the increase in the distance of these factors i.e. we have the highest landslide density near these factors, these layers will be used later as the related diagrams confirm it. The only layer omitted in this stage is the slope direction layer. Given that according to the previous studies (Shariat Jafari, 1996), northern and western slope directions have a higher moisture due to little sunshine and less evaporation, they have a higher potential of landslide and the southern slope direction shows less landslide density due to more sunshine (in the northern hemisphere). Comparing this principle with the obtained diagram of landslide density in the slope direction layer, we find out that the expected result is not yielded and this layer was thus not used anymore.

The diagrams related to land use, geology and slope show the degree of the effect of each class in the occurrence of landslides with regard to the density of landslides in each class which were later used.







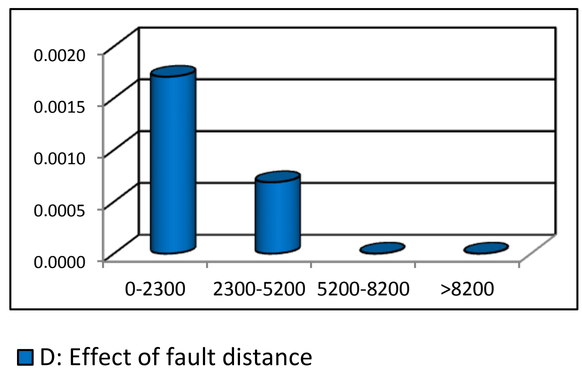


Fig 4: Effect of various factors on development of landslide in south of Neka.

In the final stage and after obtaining the landslide density in each class of factors, the weight of each class was calculated with regard to the mentioned formula for the are density method and the calculated weight was exercised in the information table. At last, the final raster map was created through overlapping and adding all these information layers (which were classified and weighted). The landslide hazard zonation map in the involved area was created after classifying this map into five hazard classes as very low, low, average, high and very high.

Table1. Classification and weighting of effecting factors of landslide.

lithology	**landslide**	**class area-hectares**	**Darea=A/B*1000**	**C/D*1000**	**Warea**
K2^lm	2	3128.20	0.639	0.786	-0.146
M^m,s,l	11	13009.68	0.846	0.786	0.060
Pe^ml	7	7813.03	0.896	0.786	0.110
…	0	1502.45	0.000	0.786	
Landuse	**landslide**	**class area-hectares**	**Darea=A/B*1000**	**C/D*1000**	**Warea**
(I)dense forest	13	22523.27	0.577	0.786	-0.209
(II)mix(dryfarming_ follow_modforest)	7	1858.08	3.767	0.786	2.982
……	0	1072.01	0.000	0.786	-0.786
River distance	**landslide**	**class area-hectares**	**Darea=A/B*1000**	**C/D*1000**	**Warea**
0-300	11	13236.09	0.831	0.786	0.045
300-600	6	6565.79	0.914	0.786	0.128
600-1200	3	4795.62	0.626	0.786	-0.160
>1200	0	888.24	0.000	0.786	-0.786
Fault distance	**landslide**	**class area-hectares**	**Darea=A/B*1000**	**C/D*1000**	**Warea**
0-2300	17	9954.92	1.708	0.786	0.922
2300-5200	3	4354.09	0.689	0.786	-0.097
5200-8200	0	3768.12	0.000	0.786	-0.786
>8200	0	3677.41	0.000	0.786	-0.786
Slop	**landslide**	**class area-hectares**	**Darea=A/B*1000**	**C/D*1000**	**Warea**
0-8	7	5222.53	1.340	0.786	0.555
8-13	10	6970.86	1.435	0.786	0.649
13-18	1	7107.78	0.141	0.786	-0.645
18-25	2	5009.83	0.399	0.786	-0.387
>25	0	1174.75	0.000	0.786	-0.786
Road distance	**landslide**	**class area-hectares**	**Darea=A/B*1000**	**C/D*1000**	**Warea**

0-550	20	10650.25	1.878	0.786	1.092
550-1300	0	4054.92	0.000	0.786	-0.786
1300-2300	0	2072.54	0.000	0.786	-0.786
>2300	0	7639.09	0.000	0.786	-0.786

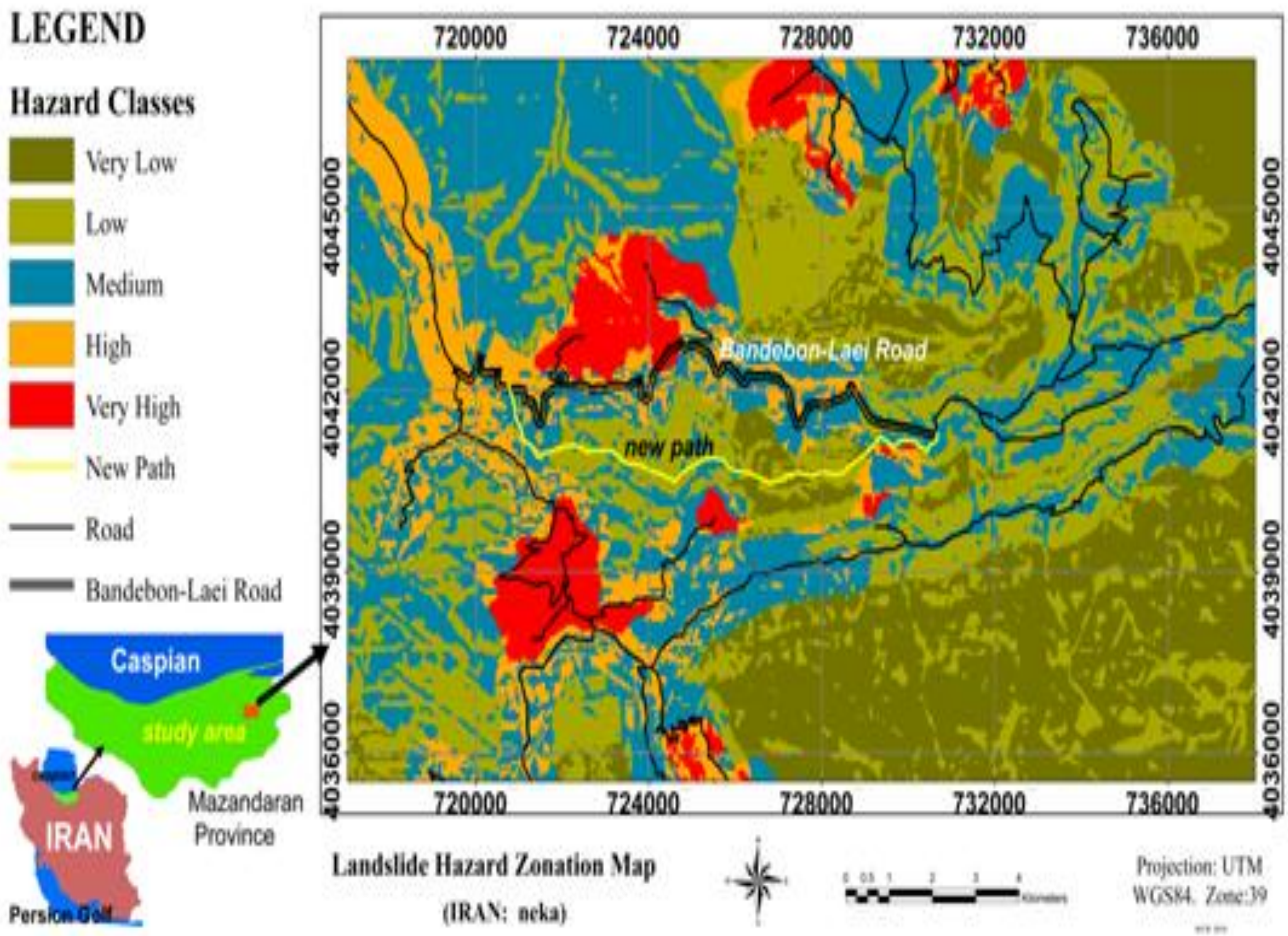


Fig5: Landslide hazard zonation according to Area Density Method

5. Conclusions

The area under study has the potential for slop instabilities with regard to the geological and geomorphologic conditions dominating it. Studying the effective factors in this area, the main factors in the landslides of this clay formation region were identified. Land use change in the forest covered area which has significantly increased in recent years and the traffic imposed on the path has intensified these factors and so, caused road landslides in this path.

Generally, one of the main factors causing instability in such litology is the establishment of cut slop without regard to geological and morphologic conditions of the slops. Disturbing the natural drainage of the area, slop slope and slop loading (Slope range and time range setting) are some of the most important factors such landslides occur due to their effects in many parts of this area and other regions of Mazandaran and cause the damage and destruction of mountainous roads. The occurrence of such problems can be reduced by the location of potential landslide areas, predicting and considerably reducing their effects of landslides by conducting engineering geological studies before carrying out any form of projects.

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