Application of analytical hierarchy process in decision support software for control measure (DSSCM) to mitigate landslide risk

Chaturvedi, P.
Srivastava, S.
Bhutiyani, M.R.
Defence Terrain Research Laboratory, DRDO, Delhi,India

Abstract

An unusual aspect of landslide is the degree of uncertainty of the magnitude of the losses in terms of life and property. A vigorous effort is the need of the hour to mitigate the efficacy of this recurrent disaster which can be accomplished through construction of appropriate control measures on the loosened slope. This research ponders upon developing a software application which may identify and assist user in the selection of most economical and technically appropriate structural landslide mitigation measure. An application termed as Decision Support Software for Control Measure (DSSCM) has been developed to provide an exhaustive list of available control measures for different types of landslides worldwide. DSSCM selects the best measure from the list on the basis of user inputs and expert scores [1]. The underlying algorithm of the software involves implementation of Linear weighted and Analytic Hierarchy Process (AHP). AHP is one of the Multi Criteria decision making methods which attempts to suggest the best control measure based on available factors and choices. A mathematical process is used to extract the information including consistency checking and provide a prioritized ranking of all decision alternatives in terms of their relative importance. The advantage of using AHP algorithm is that the validity of results is ensured by Consistency Ratio (CR). Top five control measures derived from the said algorithms of the software help in improved understanding of technical experts in making appropriate decision in selection of control measures for the particular slope.

1. Introduction:

Landslide, a catastrophe causes severe problems to the victims and covers many aspect namely social, political (infrastructure), economical and environmental problems. These aspects are inter-related in the sense that one aspect cannot be blamed alone for the occurrence of landslide in the region [1].The Indian Himalayas being the hilly terrain comprises of tectonically unstable geological formations subjected to severe seismic activity such as landslides which lead to huge destruction of mankind and other utilities. The estimation of damage caused by landslides in the Himalayan region shows that it costs more than US$ one billion besides causing more than 200 deaths every year, which contributes to 30 % of such losses happening worldwide[2].Eventually, Landslide risk mitigation plays a radical role in the Disaster management cycle [3]. Landslide mitigation defines the construction and other man-made activities on slope with the goal of lessening the effect of landslides. Hence to mitigate the consequences of landslides, various structural and non-structural control measure techniques are used worldwide. One of the European ProjectSafe land has worked in this direction by identifying a compilation of cost-effective structural and non-structural risk mitigation measures for Landslide. Some of the structural mitigation measures include surface protection and control of surface erosion, modifying ground water regime, transfer of loads to more competent strata etc. Based on the ability and suitability for different types of Landslide in different conditions, expert score are given and a decision support matrix is established.

This paper emphasizes on the application of Analytic Hierarchy Process (AHP) and its analogous study with respect to Linear Additive algorithm in suggesting the best suitable structural control measure with the aid of Desktop based application termed as Decision Support Software for Control Measure (DSSCM) on the basis of user input and Expert scores. AHP, a Multi Criteria decision making method provides a prioritized ranking indicating the overall preference for each of the decision alternatives [9].

The main purpose of software is to assist in decision-making and to guide the experts in the selection of the most pertinent mitigation measure. Further the notion of validity of the algorithm with Consistency ratio has also been discussed in the subsequent sections. Linear weighted algorithm on the other hand defines the best measures on the basis of weights and factors which rank the measures on the basis of the decision support matrix, and on the basis of the risk level estimated at the site. Other features of Software like data management, Slope stability analysis including various models like Bishop's Simplified method, Infinite Slope stability are also included. It also provides a roadmap within a methodical framework filled with details of tools available as well as their efficiency, acceptability and ability for landslide control. The software can be a part of a framework (risk management, urban planning, and sustainable development) and decision-making model and become the focus point where models and frameworks will be assembled and a decision-making instrument.

2. Methodology:

The Desktop Application DSSCM proves to be a one of the approaches for the risk assessment and management of Work on "Stakeholder process for choosing an appropriate set of mitigation and prevention measures". Software has been designed in C#Microsoft Visual Studio as an Integrated Development Environment (IDE) and back end database is maintained in open-source SQLite. A database is generated after a detailed literature survey on the world wide available control measures or mitigation strategies and out of them selected forty-five control measures has been stored in database. Weights are assigned to different control measure techniques based on experience, practice, techniques and expert judgment as per their applicability in the considered studyarea [4]. Weighted additive algorithm is used for calculation of scores of different selected control measures and AHP generates the goal of suggesting top five control measures on the basis of available factors and choices and validating the result with Consistency ratio.

The software uses expert ranking of various mitigation measures for a given type of landslide situation. The list ofcontrol measure with the top scoreswill assist experts in deciding the bestmeasure for the landslide site under study.

2.1 Linear Weighted Algorithm:

To rank the selected mitigation measures, a simple additive algorithm with weighted scoring factors for both default criteria and user-defined criteria in the toolbox is developed. The ranking (Ri) is therefore done on the basis of the summation of weights (wi) and contributing factors (Fi) for each evaluation criterion:

$$R_i = \sum_{i=1}^{n} \text{wifi} \tag{1}$$

Where,
i = mitigation measures selected by the user for analysis, 1, 2, n
w = weighted factor proposed by the toolbox; the default value for all wi at start is 1, 0 and can be changed by the user.

The scoring factors (f_i) for all the ranking parameters are scaled from 1 to 10 where 1 is least favorable and 10 are most favorable. And the weighting factor (*wi*) reflects the relative importance of criteria or corresponding scoring factors is in the range of 0 (least) to 1 (most). The default value is set to zero, and the software assigns a values of unity (1) as a function of the input provided by the user in the following technological criteria categories: type of movement, type of sliding material, depth of movement, rate of movement, groundwater, and surface water [5].

2.2 Analytic Hierarchy Process: Ranking Algorithm:

AHP is a well defined technique for structuring and inspecting complex decisions based on mathematics and subjective assessmentwhich aid the decision maker to set priorities and make best decision. The algorithm was introduced by Thomas L. Saaty in 1980. The importance of AHP lies in the construction of a series of Pair wise comparison matrices of complex decisions. N-1 comparison would be done for the case. Withpair wise comparison matrix for n items the decision maker indicates the suitability or importance of item i with respect to item j [6]. It takes into account a set of evaluation criteria and a set of alternative options among which the best decision is to be made. Finally, the AHP combines the criteria weights and the options scores, thus determining a global score for each option, and a consequent ranking. Hierarchical structure of AHP to model a given problem is given in Figure1. Here, goal at level 0 is to suggest the best possible control measures which depend upon the factors and choices at level 1 &2.

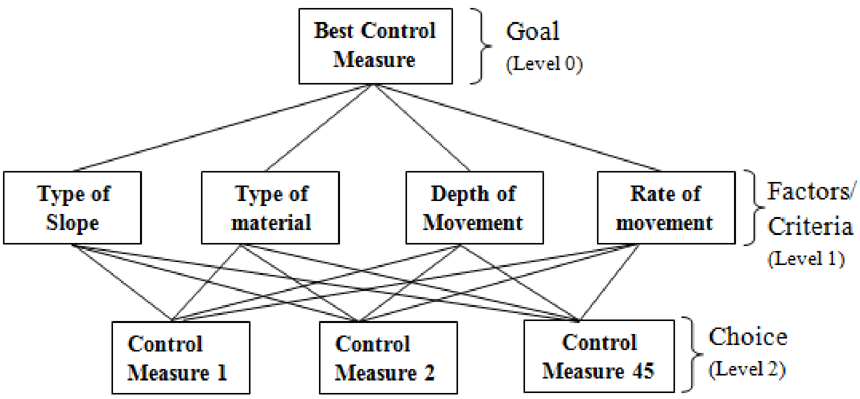

Figure1Hierarchical structure of AHP

For our case study, six criteria categories or factors are considered namely: Type of Slope, Type of Material, Depth of Movement, rate of movement, Ground water, and

Surface water on the basis of which forty five choices or alternatives are defined. Intensity of importance of these factors is defined in Table1:

Table 1
Ratings of Factors as per Satty scale

Intensity of Importance	Definition	Factors
1	Equal importance	Surface water
1	Equal importance	Ground water
3	Somewhat more important	rate of movement
5	Much more important	Depth of Movement
7	Very much more important	Material
9	Absolutely more important	Type of Material

Working of AHP can be described in six steps[7]: (i) Define the unstructured problem, (ii) Developing the AHP hierarchy, (iii) Pair wise comparison, (iv) Estimating the relative weights, (v) Checking the consistency, (vi) Finding of overall rating
After calculating the pair wise comparison matrix, the relative weights of matrix can be obtained from equation 2:

$$\mathbf{(A-\lambda_{max}\mathit{I}) \times W=0} \qquad \mathbf{(2)}$$

Where λ = largest eigenvalue of matrix A, *I*= unit matrix

To ensure that judgement of decision maker are consistent or not, consistency of matrix is checked. Consistency Index (*CI*) is calculated by (Vahidnia et.al. 2008):

$$\mathbf{CI =(\lambda_{max\,-}\ n)/\ n\text{-}1} \qquad \mathbf{(3)}$$

Consistency Ratio, which is a comparison between Consistency Index and Random Consistency Index is a normalized value and is divided by an arithmetic mean of random matrix consistency index [8]. Equation of CR is formulated by:

$$\mathbf{CR = CI/RI;should\ be <= 10\%\ (0.1)} \qquad \mathbf{(4)}$$

If CR value is less than 0.1, the judgements are consistent otherwise comparison matrix will be checked for errors. Literature shows that estimation of different RI's is done by Alonso and Lamata using simulation methods and various other methods. Random Consistency Index value till n=39 is given in the literature, subsequently for n=45, RI has been derived by plotting a curve fitting graph shown in Figure 2. RI value for n=45 comes out to be 1.7624.

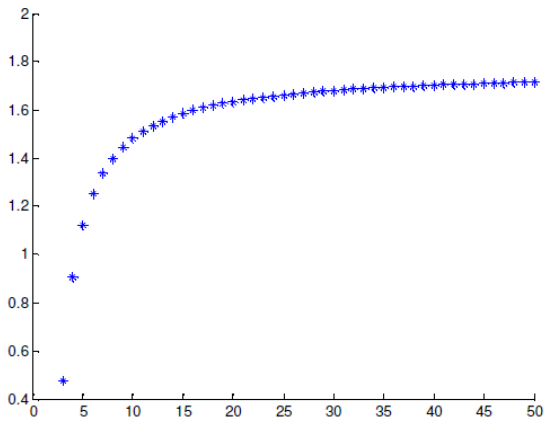

Figure2Representation of curve fitting for n=45

Complete work flow of the structure of software is explained in Figure 3 where user has the option to choose between the two algorithms and validate the results depending on the severity of risk.

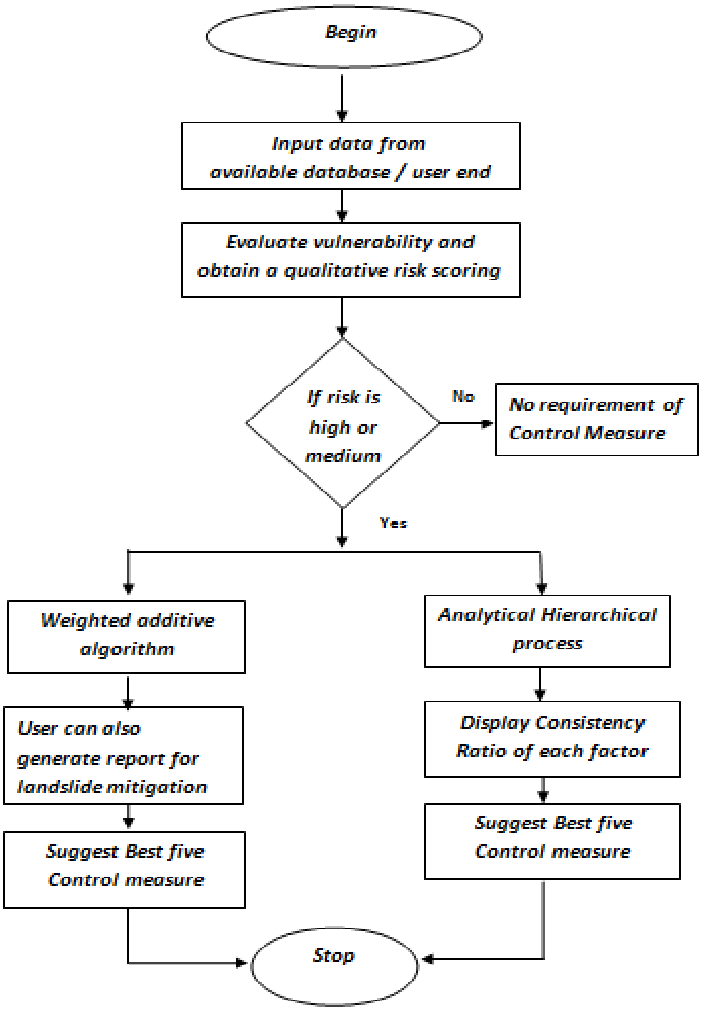

Figure3 A flowchart of the Decision Support software for Control Measure of Landslide.

3. Result & Discussion:

Case Study

The customization, calibration and validation of the software are done on the basis of geophysical parameters mentioned in Detailed Project Reports (DPRs) of various states. The results of the software are compared and validated with measures suggested in DPRs by the state governments. A case study of Landslide in Ramhlun, Aizawl, Mizoram is taken for validation purpose with following parameters as an input:

Table 2
DPR of Ramhlun landslide

S.No.	Particulars	Description
1	Location/ Locality	RamhlunVengthar
2	Length	45 m.
3	Breadth	25 m.
4	Height	47 m.
5	Area	10137.29 sq. m.
6	Depth	3 m.
7	Type of Material	Rock cum debris
8	Type of Movement	Translational Slide
9	Rate of Movement	Slow
10	Style of Movement	Multiple
11	Geology	Carbonaceous shale bands; further down the slope sandstone with shale and siltstone occurs.

DSSCM toolbox generates the best five lists of Control measure on the basis of user inputs and risk valuesaccording to both the algorithms Linear weighted and AHP. This report describes about the basic parameters of the study area which include type of slope, ground water, depth and rate of movement, triggering mechanism etc.

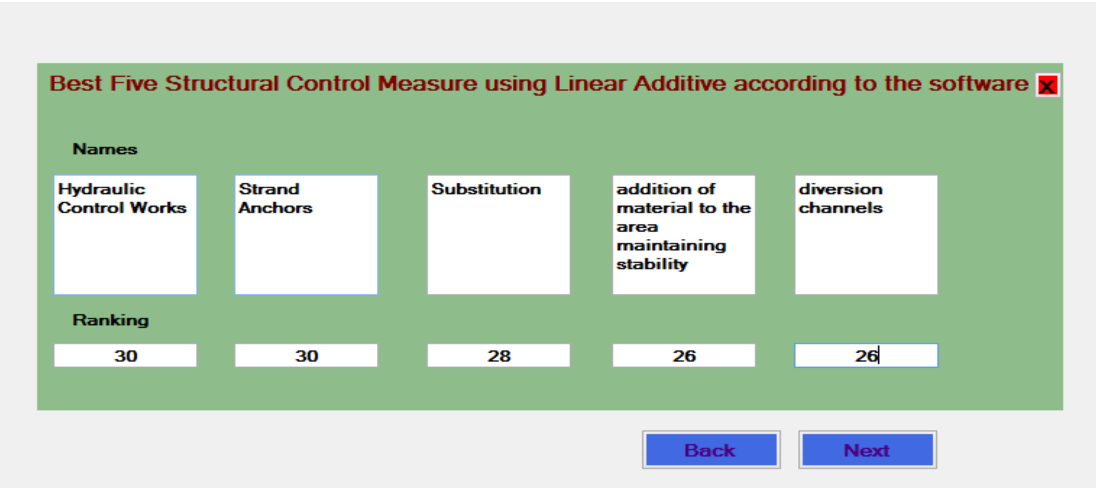

Figure4 Top five Control measure according to Linear Additive

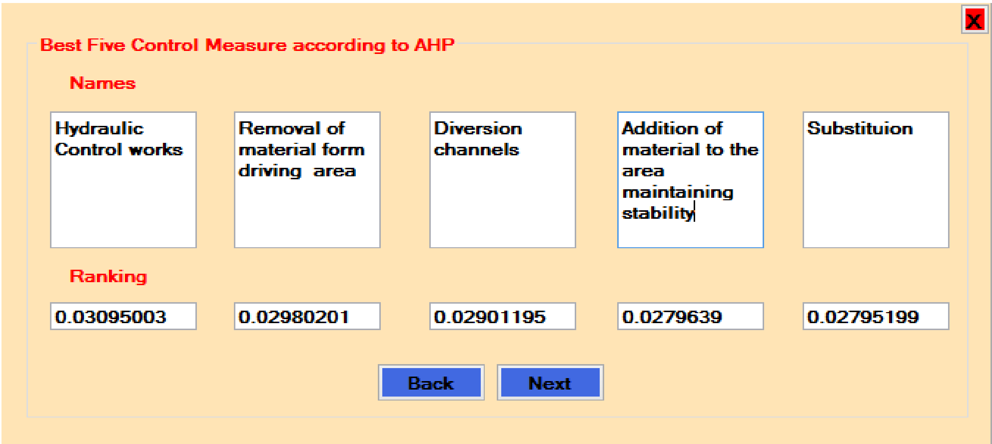

Figure5Top five Control measure according to AHP

Analysis of result depicts that hydraulic control works and strand anchors with a score of 30 are best suited mitigation measures for this landslide. Also, Substitution with score of 28 is next suited measure, however considering the establishments and houses near the crown restrict from exercising this option. Next suitable measures with a score of 26 include addition of material to the area maintaining stability, diversion channels, deep trenches filled with free drainage material, low pressure grouting with cementitious or chemical binder, reinforced soil structure, gabion walls and crib walls.The measures suggested in DPR include river training wall, counterfort retaining wall, RCC retaining wall with contour drain and supplementary drain, micro piles and check dams.

Hence, the measures like river training wall and check dams are validated by the toolbox as it also suggests hydraulic control works (channel lining and check dams) as the foremost suited measures. Software gives equal score to reinforced soil structure, gabion walls and crib walls of 26, hence in place or in addition to RCC and counterfort retaining walls the above stated measures may also be taken up wherever suitable according to the site. Piles are given a score of 20 by the toolbox, hence micropiles may be avoided. In place of piles, strand anchors are suggested to be more suitable according to the landslide characteristics. Additionally, deep trenches filled with free drainage material may also be constructed at suitable locations along the slide to make some efforts towards modifying the groundwater regime.

4. Conclusion and Future work:

This Research concentrates on application of AHP in the development of a DSSCM and its comparative analysis from Linear weighted additive algorithm. A study has been done on Landslide site of Aizawl, Mizoram with their given DPR's provided by state government. Results shows that AHP dominates over linear additive in providing best suitable choice of control measure of landslide. The reason being that the factor of consistency ratio is considered which incorporates the validation of user choices and allows them to change their chosen weights or choices. Results of AHP algorithm are somehow aligning with measures suggested in DPR of Ramhlun, Aizawl, and Mizoram landslide site. For pilot study, evaluationof software is done on more than one site which includesSerchhipTuikhuahVeng landslide of Mizoram, Dwada Landslide of Mandi on NH 21, Mangan Landslide of North District, Sikkimand HuntharVeng landslide of Aizawl on the NH-54. Substantially good results are observed from the software satisfying the prevailing conditions of the Landslide site. Aspects of Slope stability is also considered in the software to validate the users to get a notion of factor of safety of the slope in study using various models like Bishop's and Infinite slope stability model.

In future, assessment of the software will be done for implementing the more complex algorithms which would analyze the geographical and geospatial factors also accounting for deciding appropriate control measure for landslide. Cost factor can also be considered which would decide the feasibility of construction of particular mitigation measure with respect to other or modification on particular slope. Refinement of expert score may also be done considering the geological condition of our country.

5. Acknowledgements:

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