APPLICATION OF MULTI-CRITERIA ANALYSIS (MCA) AND REMOTELY SENSED DATA FOR SUPPORTTING OF ROAD PLANNING

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ABSTRACT

Based on the study of the basic principles of the route planning and technical criteria, the research focused on the fundamental principles of mapping out a new route. We have studied the use of multi-criteria analysis (MCA) in combination with satellite imagery data and DEM to map out the most optimal route when determining the coordinates of the starting point and destination. Thanks to the unlimited input criteria and remote sensing technologies's fast information update, the decision makers may make quick decision basing on accurate scientific data, therefore, supporting accurate route information on map and field work. In this study we have used Landsat ETM + images acquired on 12 February 2010 for land cover mapping, topographic maps at 1: 50,000 to create the criteria for route creation of Dak Lak area, Vietnam.

Key words: MCA, GIS, Analytic Hierarchy Process, GPS.

1. INTRODUCTION

Traffic is as the lifeblood of a nation. A strong transportation network that is important contribution to the promotion of economic, social, cultural and political development. Vietnam is a developing country, the planning as well as opening the new roads are as the urgent matter. Especially in the mountainous areas with complex terrain such as steep slopes and affected by natural disasters types: landslides, floods, debris flows, rock slide, erosion ...the new road creation is very difficult. Beside that, the opening new roads have to ensure the technical requirements and consistent with the planning and momentum of development for the region.

In the traditional method for opening new road, it is still using topographic map sheets or digital form. These data is not often regularly updating the changes of terrain. On the other hand, the opening routes are based on the experience of the engineer and it takes a lot of time and effort.

To support the decision for road path planning with high accuracy, timely and effectively, we studied about multi-criteria analysis (MCA) integrated with remote sensed data. Since 1980's, GIS coupled with MCA has helped to enhance multi-criteria decision making associated with planning process (Roy, 1996). The use of GIS, remote sensing and MCA, which is a decision-aid and a mathematical tool allowing the comparison of different alternatives according to many criteria, has helped in the planning process and decision making in conflicting decisions. The use of MCA has helped as a guide for decision makers towards actualizing a desired choice and coupled with geographic information systems to enhance multi-criteria decision making (Chakhar & Martel, 2003).

The optimal achieved with the use of MCA for planning a road path requires an extensive evaluation process in order to identify the best possible path the road can follow. This path must comply with the requirements of the government regulations and at the same time must minimize economic, environmental, health and social cost. The road path selection procedure using MCA and GIS make maximum use of the available information in trying to arrive at an outcome acceptable by most stakeholders and as such requires the processing of a variety of spatial data.

In addition, based on the great advantages of satellite imagery data such as wide coverage, and often updating, there are many different types of data, the ability of automation in classify and establishing thematic maps suitable for the purpose of the MCA's input . The targets are not limited input criteria and the quickly updating of satellite data, it will help decision makers have science foundation to make decisions. Thence, it supports for routing on the map, quickly and accurately.

2. RESEARCH METHODOLOGY

MCA is designed to be an interactive and flexible management tool for geographic analysis and it is well suited for modeling complex sustainability issues. In the context of conflict resolution and policy implementation, MCA decision models are one of the oldest forms of geographical analysis. Their structures consist of an explicit set of objectives decided upon by a decision maker or an expert group for the purpose of determining an optimal solution (Malczewski, 1999). The optimal solutions are recommended through the set of alternatives that satisfy the largest extent of the expert group objectives. MCA is well suited for conflict resolution as many problems incorporate a wide range of highly complex information that otherwise would be overwhelming for manual aggregation or subjective to high levels of human error (Malczewski, 1999).

2.1 Key feature of MCA

A key feature of MCA is its emphasis on the judgment of the decision making team in establishing objective and criteria, establishing relative importance weights and to some extent in judging the contribution of each option performance criterion. An MCA foundation in principle is the decision maker's own choice of objective, criteria, weights and assessments of achieving the objectives (Malczewki, 1999). MCA characteristics make specially for people who decide to set the level of importance for various different factors. The process of multi-criteria analysis involves the following steps:

Step 1: Create the criteria of classes that consistent with the research. The criteria are extracted from the original map by using the spatial analysis function of GIS such as DEM interpolation function, transmission function, vision analysis function, direction function....

Step 2: Make the criteria can be compared with each other.

To make the criteria can be compared with each other, first we have to classify the data in each criterion. With each criterion, there is its own attribute data table. To compare these criteria together, they must be classified in attributes. There are two approaches to classify the criteria:

Boolean approach: Create regions into two groups: the region is suitable with to a few criteria and the other which is unsuitable. Boolean overlay can be done by using a combination Intersection (logical AND) or Union (logical OR).

Factors or continuous classification: Depending on the input data values which are divided according to the taxonomy or continuous scale. For continuous scale can be set according to the type of formula is linear:

$$X_i = (x_i - x_{min})/(x_{maxi} - x_{mini}) \quad (1)$$

In which:

X_i: The marks of elements i x_{mini}: minimum point
x_i: Original point x_{maxi}: maximum point

For taxonomy, the range is divided according to the specified geographical (altitude, slope, temperature ...) or expert opinion.

Step 3: Cost distance functions, Cost path is used to outline an optimal route based on the resulting map overlay.

2.2 The weighting of the criteria

The selection of weighting base on the AHP (Analytic Hierarchy Process) method. The AHP allows users to assess the relative weight of multiple criteria (or multiple alternatives against a given criterion) in an intuitive manner. Its major innovation was the introduction of Pair-wise comparisons which is a method that has been shown by researchers that when quantitative ratings are unavailable, human are still adept at recognizing whether one criterion is more important than another (Malczewski, 1999). Saaty (1980) is the inventor of the AHP methodology and he established a consistent way of converting such pairwise comparisons into a set of numbers representing the relative priority of each of the criteria (Malczewski, 1999).

Each pairwise of two criteria, the relative importance of the criteria than the other criteria are calculated at the rate of 1 / n. Evaluation scaling according to Saaty for optimal pair comparison of the criteria is recognized as follows (Table 1):

Table 1: Saaty table for optimal pair comparison of the criteria

1/7	1/5	1/3	1	3	5	7
Very very few	very few	Few	Equal Importance	Moderate Importance	Strong Importance	Very strong Importance

When the comparison between the criteria finish, the ratio of their values are recorded into matrix of n rows and n columns (n: number of criteria). The Pairwise Matrix will indicate that if the ratio of factor A comparing to factor B is n, the reverse ratio factor B versus A factor of 1 / n. Main diagonal of the matrix has a value of 1. From this matrix, the eigen vector is calculated to obtain a set of weights with the most appropriate. Weighting are automatically overlay after using AHP tools.

Weighting factors are combined in the analysis, the formula below is expressed as follows:

$$S = \sum_{i=1}^{n} (W_i X_i) \prod_{j=1}^{m} C_j \qquad (2)$$

In which: S = suitable index
Wi = weight attached to criteria i
Xi = mark of the standard
Cj = value (0 or 1) of tame level

3. DATA AND EXPERIMENT AREA

Research area is DakLak province where is based around the DakLak Plateau, around six hundred metres above sea level. It adjoins Gia Lai Province to the North, Lam Dong Province to the South, Dak Nong Province to the Southwest, Phu Yen and Khanh Hoa Provinces to the East, and Cambodia to the West. The border between the two countries in Dak Lak is 70 km long.

- The research area belongs to the topographical maps, scale 1:50000 with the code D-49-85-B, and D-49-86-A. There are variety of topographic factors in this area.

- We have used Landsat7 ETM+ acquired at 2 pm on February 12, 2010 with spatial resolution of 30m to establish the land cover map 1:100000 scale

- DEM was created from 1:50000 topographical map.

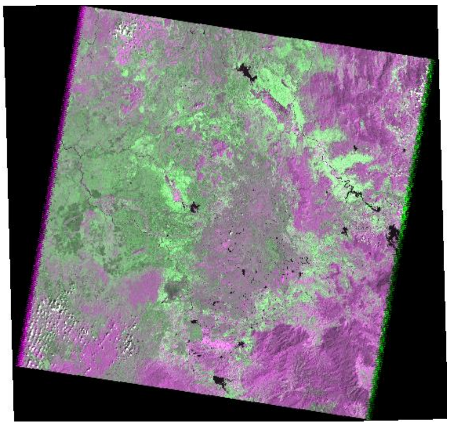

Figure 1. Landsat image

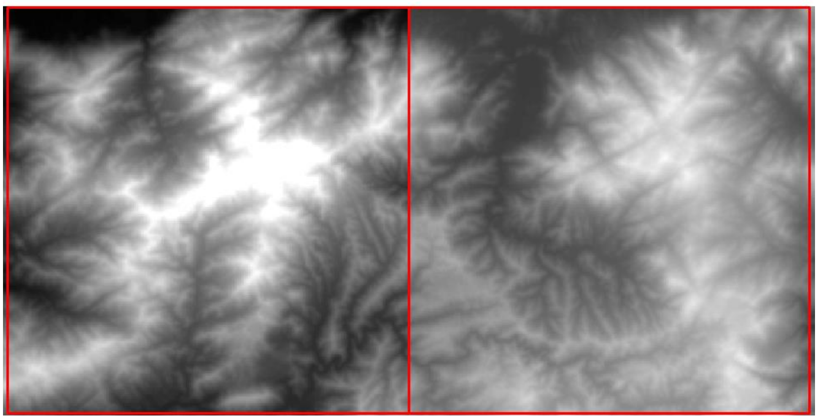

Figure 2. DEM of research area

Analysis processes GIS

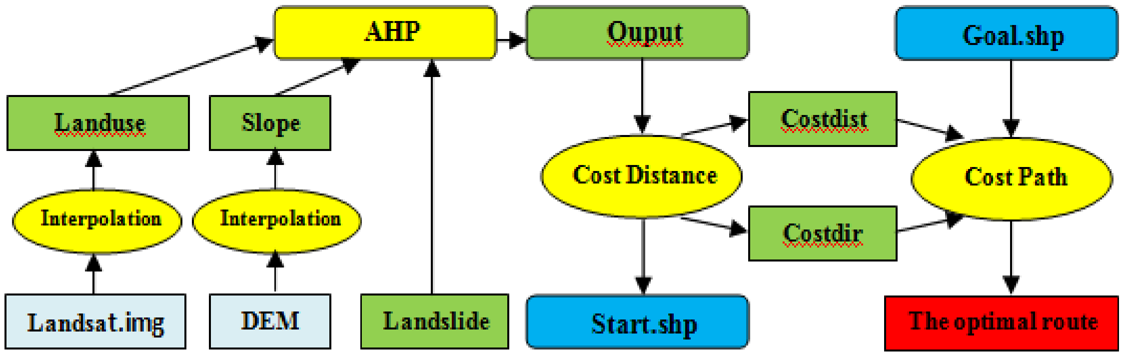

Figure 3. Flowchart of data analysis procedures in GIS for route creation

Establish criteria map

A land use map was creation from LANDSAT image with maximum likelihood classification method. Figure 4 illustrates the land use map with 1:100000 scale.

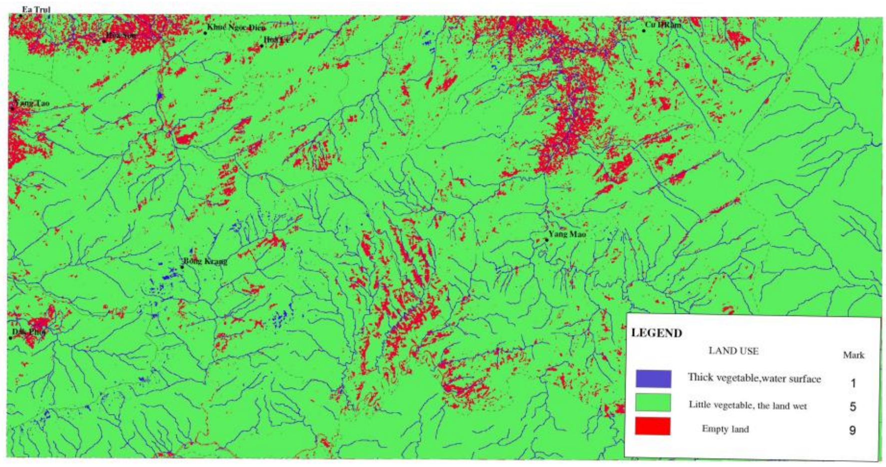

Figure 4: The land use map with 1:100000 scale

A slope map was created from DEM.

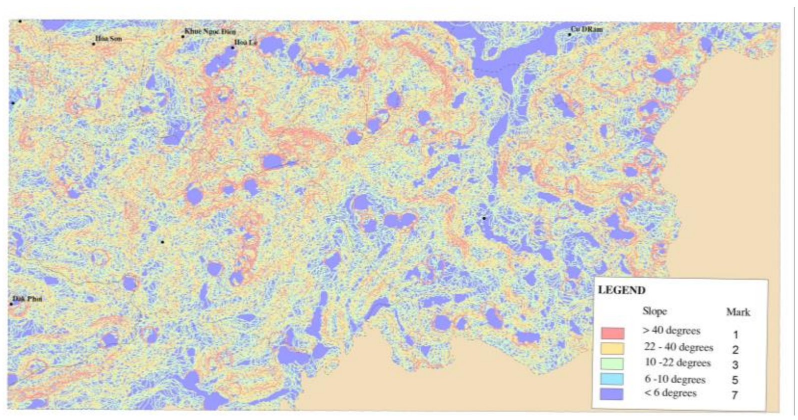

Figure 5: Slope map

- A landslide hazard map was based on the method of multi-criteria analysis according to the following scheme:

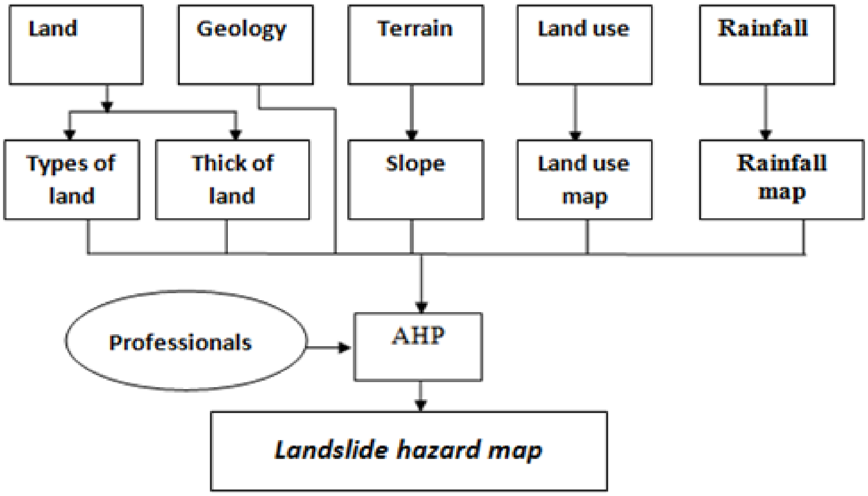

Figure 6: Process of landslide hazard mapping

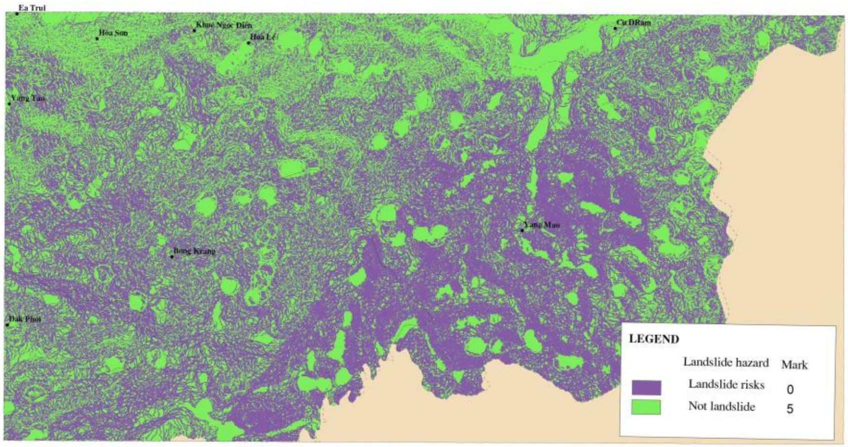

Figure 7: Landslide hazard map

Classifying data in each criterion, the authors use the method of element classification.

The terrain slope is the main factor impacts to soil erosion. The slope increases which conducts to increase the intensity of the flow and thus it accelerates the process of leaching, soil erosion, causing more severe erosion. The slope increases by 2 times, soil erosion increases by 2 to 4 times. Erosion and stabilize soil loss can lead to landslides.

+ The plain terrain is the most convenient terrain for route creation. Plain terrain slope <10%

+ The hilly terrain with slope of 10% to 25% is the average level of difficulty for the road creation.

+ The high hilly terrain with slope of 25% to 30% and mountain terrain with slope > 30% of the terrain is more difficult issues for road creation.

The research area is at risk of landslides in the quite high level. The landslide hazard areas are removed by classifying to marks of 0.

Table 2: The evaluation result of pairwise of criteria according to Saaty scale

<<<<<Importance level >>>>>			
Less Importance	Equal Importance	More Importance	Strong Importance
1/3	1	3	5

When the comparison between the criteria finished, the ratio of their values are recorded in matrix of n rows and n columns (n: number of criteria).

Table 3: Comparison between the three important levels of criteria: slope, the land use, the absolute elevation to the ability of route creating.

	Landslide	Slope	Land use
Landslide	1	3	5
Slope	1/3	1	3
Land use	1/5	1/3	1

- After making the matrix that is comparison between the criteria. The weights of the criteria are calculated based on AHP tool, the result is illustrated in table 4:

Table 4: The weights of the criteria: the slope, the land use, the landslide to the ability of route creating

Criteria	Weights
Landslide	0.637
Slope	0.2583
Land use	0.1047

- From the weights showed in table 5, we have a map of route creation ability. An optimal route planning is outlined when we started entering coordinates and destination point on the map.

(a)

(b)

ID	X	Y
1	897024.7	1379322
2	896994.7	1379292
3	894954.7	1379262
4	894984.7	1379262
5	895014.7	1379262
6	895044.7	1379262
7	895074.7	1379262
8	895104.7	1379262
9	895134.7	1379262
10	895164.7	1379262
11	895194.7	1379262

Figure 8. (a) The optimal route is outlined based on the topographic map and the ability to create route map, (b) coordinates table was exported to GPS output. Each cell is determined coordinates.

The process of optimal route creation is done by the Path distance and Cost distance tools of ArcGIS. In the route creation, distance and direction of travel must be satisfied the shortest traveling distance, the moving way is less rugged conditions while ensuring the absolute height, slope and land use.

The result is the ability to route creation between two points, including an optimal route. The drawing routes are converted to vector and determine the coordinates. The data format is suitable with GPS systems for using in service during construction.

4. CONCLUSION

Planning a route path is complex and brings a lot of challenges to route planners. The result has demonstrated the possibilities of applying GIS and MCA principles and techniques in actualizing a route path avoiding the rigorous method of route planning using the traditional method.

- MCA considering different criteria at the same time, this can not be done by the process of decision-making typically based on a single criterion. The MCA is a clear assessment methodology and transparency. It is easy to check. MCA combined with remote sensing techniques for route creation can get rapid results and high accuracy.

- MCA can support decision making for leaders, policymakers, and sometimes even with the wide community.

5. REFERENCES

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