Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 9 (18): 3364-3370, 2009
ISSN 1812-5654

The Assigning of Suitable Model for Valuation of Effective Factors in Forest Roads Network Planning (Shanderman Forest, Northern Iran)

[1]H.R. Maskani Jifroudi, [2]R. Naghdi, [3]A. Firozan and [4]M. Haghighi
[1]Iranian Academic Center for Education, Culture and Research,
Institute for Environmental Research, GIS Department, Rasht, Guilan, Iran
[2]Department of Forestry, Faculty of Natural Resources, University of Guilan,
Somehsara, P.O. Box 1144, Iran
[3]Department of Forestry, Faculty of Natural Resources,
Islamic Azad University, Lahijan, Guilan, Iran
[4]Iranian Academic Centre for Education, Culture and Research,
Institute for Environmental Research, GIS Department Rasht, Guilan, Iran

Abstract: This study with the aim of making the best model for forest roads planning, at the first step examined the important factors in road construction and then categorized them according to the internal importance of each factor. GIS technique was used to make numeric form of these factors. Valuation between layers has been made according to the designing expert's ideas, forest road construction and AHP method. Consequently, the model of road designing has been achieved. This model has been applied in GIS framework on the zone. At the next step, horizontal and vertical curves of road have been designed and corrected by system according to their placement position on the zone in GIS framework. The above research showed that with the submitted model and method in Arc GIS, there is the possibility of planning suitable road in mountain areas.

Key words: Forest roads network planning, GIS, AHP

INTRODUCTION

Natural resources in the frame of dynamic economic play more important role. Therefore, we may call natural resources as the bed of many generator industries. In this manner, some improvement activities in natural resources can make useful or harmful effects due to exploitation and or scientific supervisions. Road is on of the structures that has useful role in the maintenance of these resources if is made correctly. If the road constructed none technically, special in mountain areas, it can induce the signs as movement and massive erosion. Therefore, road planning at forestry areas should follow environmental measures more than technical measures. On the other hand it shouldn't be forgotten that the present speedy system of production wants a method to maintain the system calmly when the skillful person exits from system or a young engineer enters into it.

Therefore, the best action is the establishment of system with using new knowledge. Through this way, the old experience with new technology transfer to the young designers.

So, the environmental issues are noticed and it becomes a transferred bridge of old experiences to future. This aim shows off itself among forest experts during more times. Chegini (1992) in the study of forests in Noshahr of Iran designed the skid trails with consideration to slope of area. He controlled and corrected them by recursion to their domain. Gumus (1994) in his study with GIS designed the forest roads in Turkish forests. In this study with using prepared numeric maps, the designing of the best line of forest roads is made with the minimum cost by GIS. This act is done by access to the cells with the minimum cost and their connection together.

Dahlin and Fredrison (1995) studied the effective factors on assessment of forest roads in Canada forests. They submitted some models for designing road. This model included the cost functions and collecting statistics of growing model.

Rapaport and Snickars (1998) studied a method for compounding environmental factors. In this study, a method submitted for comparing factors two-by-two without needing a quantitative way. In the study, with the

Corresponding Author: R. Naghdi, Department of Forestry, Faculty of Natural Resources, University of Guilan, Somehsara, P.O. Box 1144, Iran

title of assessing the road making effects on the forest environment with GIS (in the district of Patom in kheyroud kenar in Iran) used two ways of layers placement and Leopad reflection matrix that is corrected for Iran. The results showed that the fissures of area, Marni main stone and heavy texture of soil are the effective factors in probable increasing of slip and soil erosion due to road construction (Sajadi, 2002). Lotfalian (2001) in a research as studying of effective factors on assigning of optimum forest road network density in Sangdeh of Mazandaran Province in Iran has introduced the logging method as one of the important factors for assigning the kind of roads, density and the way of forest roads networking. He has assessed the optimum density of road 21 m ha.

Audrey (2001) suggested the GIS and GPS application for managing of forest roads network. In this study the positive and negative required points entered into GIS as informational layers. This study made road planning with the management of multiple aims and considering to environmental issues.

Rogers and Schiess (2001) introduced a program PEGGER at the form of Geographical information sites and GIS software. This program created for selecting line on the topographic map, instead of traditional ways and installed on Arcview program as an annex. Musa and Mohammed (2002) looked for a new method based on GIS for forest roads network process. In this study, three road networks were planned with three different ways. In two ways, Geographical information site and planning in traditional form were used. In these researches, the GIS method had good capabilities. Hosseini (2003) in a study which was carried out in khiroodkenar Noshaer (Iran) showed that the road network designed using GIS was more suitable and better than the existing road network in terms of accessibility, skidding distances, environmental damages, construction costs and excavation.

Akay (2003) analyzed the minimization of construction cost, maintenance and transporting the forest roads with helping automatic plan and computer. He explained the planning power points with computer. He pointed that 3-D maps with high resolution make the finding way is done with high accuracy. He used LIDAR for providing Digital Elevation model and verified its capabilities for designing forest roads. Murthy (2003) in a research in India planned the way with the minimum cost by using remote measurement and GIS. The required maps for the certain area were supplied by IRS satellite data.

In this study, river was considered as an option for transporting. Suvinen *et al.* (2003) studied the best road finding way by using GIS. They formed cost level based on car, land and tree coverage and climate situations (conditions) factors. Akay *et al.* (2004) studied the height numeric model with high resolution power. In this study, a 3D optimum model of forest roads is made. This model is based on height numeric model resulted from LIDAR data. They finally found the ways to use of remote measurement and height. Chung and Sessions (2001) studied the network algorithm for planning transportation system in the forest. In this study, a method was explained for optimizing the transportation planning and a raster network modeled an exploitation plan. Now, the aim of this research is creating a model that plans the best line in mountain forests, with using Arc GIS software capabilities (Possibilities) in the situation of presenting many problems for reaching to layers with high resolution power.

MATERIALS AND METHODS

The study was carried out from May 2007 to August 2008 in Shanderman, a forest district covering approximately 1546 ha of Shafaroud watershed in Guilan Province, Northern Iran. The area is in 46 to 49.03 longitudes and 37.34 to 37.38 latitude. The altitude ranges between 250 to 1550 m above sea level.

After selecting the region with recognition of the zone, all positive and negative required points were interpreted by GPS. The interpreted positive and negative required points are:

Positive required point: Natural terrace-open space-flat areas-sand and gravel mines-important zones in the view of tourism-rural area-the beginning and the end of road pivot that should be plan or other branch point of road.

Negative required point: Fissure- spring-stone and rock areas-steep slope areas-regeneration in vast domain-the type of index growing place.

The interpreted points transferred to the system and finally on the map by using Arc GIS Software and different informational layers were extracted from them. It is ordinary that in each layer, the studied variable doesn't have similar values, for example at the time of constructing road, 80% slope has less value than 10% slope. This case is true in other layers, too. On the other hand, it's needed to have a stable criterion for each layer during decision making, due to equalizing values. Therefore, the value of 1 to 9 is selected for all layers, so that for the best class in each layer is given 9 values and for the worst class is given 1 value and for the other layers is given 1 to 9 values, in ratio. This process is done as follow:

Slope map: For supplying surface maps, it's required to have elevation model of zone. Therefore, by using RS

Table 1: The desirability of slope classes

Building road	Slope (%)	Values
Without limitation	0-10	9
Building road as italic form	10-30	7
Building main way in lowest level	30-60	5
That's better not to build road	60-80	3
Don't build any roads	>80	1

knowledge and present layers in GIS, the layers with height dimension turned into shape file and transferred to RS perimeter. DEM of zone is built from mentioned layers with Geomatica PCI software. Turned into image format and reversed to Arc GIS and the surface maps like slope are built. Slope is one of the main factors that should be noticed at planning forest roads network. Road planning in too slope areas made the increasing of fill and cut volume and finally increasing the environmental damages. In this study, the slope map of area is supplied by Digital Elevation Model (DEM) and classified and denoted values according to Table 1.

Direction map: According to different geological direction, duration and intensity of sun ray are different during the day and follow it, the amount of soil moisture is different in various geographical directions, so that width slopes with Northern direction have more humidity than southern directions. Therefore, Southern slopes are more suitable areas for road crossing. For supplying the direction map, the layer of Digital Elevation Model (DEM) is used and major and minor and one level direction are considered as flat areas (without direction) and denoted according to Table 2.

Geology layer: The land layer is like layers that can have important role in planning the forest roads network with considering to stability coefficient of rocks and determination of the areas that are apt to erosion. For supplying this informational layer, it's used from geology map in the present forestry plan book and then, digiting of maps in done, finally this map divided into three parts by Arc GIS software as: sensitive, semi sensitive and stable, according to stability coefficient of rocks and present information in plan book and denoted according to Table 3.

Soil stability layer: Basically, the form of planning the forest roads can be different in various parts of land according to soil stability. Soil stability is one of the main and maybe the most important factor that should be noticed it in the planning of forest roads network. In this study, first 28 soil samples are gathered for careful determining of the soil texture type, so that in each parcel, one sample is taken, on the average. For sampling, a hole with 60 cm depth (the bounds of road buildings) is dug and its soil is taken for determining size and percent of the comprised particles. Hydrometrical tests showed the specification by using of the soil texture triangle. Finally, the complete map of soil texture is provided by Krijing interpolate model.

In this step, for providing stability map, it's used from the ecological model of soil and rock power by Makhdoum (2006). The stability map divided into three levels as: good, middle and weak and denoted according to Table 4.

Table 2: The desirability of geographical direction classes

Geographical direction	Value according to desirability
North	1
North-East	2
East	3
Plain	4
North-West	5
West	6
South-East	7
South-West	8
South	9

Table 3: The desirability of land stability classes

Land stability	Value according to desirability
Stable	9
Semi sensitive	5
Sensitive	1

Table 4: The desirability of different classes of soil stability

Soil stability	Value according to desirability
Good	9
Middle	5
Weak	1

Table 5: The desirability of flat areas classes

The extent of flat areas	Value according to desirability
>1000	9
<1000	5
Non flat areas	1

Flat areas map: Flat areas are suitable to build forest roads according to the forest roads planning strategies. Because these areas induce the decrease of fill and cut volume through the way. Also, these areas have good places for landings therefore, accompanied with field operation, all flat area and natural porches and the places that have capability for road crossing or even have ideal situation about landing and wood collecting place, were found situation with GPS set, then were done topography for them and denoted according to Table 5.

Reproductions layer and the young handing plant masses: In planning of forest roads network, the observing of protection and supportive issues is one of the noticeable factors. In this relation, all handing plant masses and reproduction of special species or natural reproduction in large size, were found position and transferred on the map and finally the mentioned map was

Table 6: The desirability of different reproduction classes

No. per hectare	Value according to desirability
>1400	9
100<V<1400	5
<100	1

Table 7: The desirability of different classes of asset in hectare

No. in hectare	Value according to desirability
>250 m^3	9
100-200 m^3	5
<100 m^3	1

Table 8: The desirability of different classes of growing place type

Growing place type	Value according to desirability
Rash with other flat-leaf species	9
Carpinus betulus with other flat-leaf species	6
Mixed flat-leaf	3
Empty points	1

supplied, with considering to presence in the field. The size of handing plant masses caused that the number of trees in these new stands were analyzed statically as one hundred percent and denoted according to Table 6.

One of the other aims in planning forest road network is wood exploitation from forest. This act should be done with minimum damages for environment. Also, the protection from forest and environment should be noticed as a main factor in preserving nature and stable development. Therefore, the book of review plan of asset in hectare is studied and digited by Arc GIS software, with the aid of the map of asset in hectare position is received and denoted according to Table 7.

The map of growing place type: One of the important factors in road building that has direct relationship with being protective of being industrial is type. According that, in these studies the map of forest type is supplied with using the last information and statistical forms in separation of present type in forest and after coding for each classifications, it was ready for entering to software, then by defining the specifications of each code, the forest type map is supplied in three levels and denoted according to Table 8.

The parametric value of slope won't be like the parametric value of direction. On the other word, if the slope of a part is in 9 value (in denoting of each factor level) and its direction has 1 value and in return, slope in another place has 1 value and its direction has 9 value, these two places don't have similar value, although the algebra plus for both of them are 10. Slope has more value in road building. This issue is quite visible between slope and direction, but it's not obvious between reproduction and direction. Therefore, it's needed a method to study the importance of each factor in ratio to other factor. So, it's used from two-by-two comparing process in hierarchical analysis method for determining relative weight of each layer. Each layer is given weight separately, in return to other specifications. Then relative weights entered into two-by-two comparing matrix and the importance coefficient of each layer is calculated separately. For determining the importance coefficient of each layer, a questionnaire is planed for using the different experts' ideas. This questionnaire is distributed among experts and the professors of forest road building. After collecting the questionnaires, their input information, the first node is specified as an aim that is, way determination. Then, the first level that includes necessary criteria for aim achievement is determined. In the words, this level includes the supplied informational layers such as: slope, direction and soil.

In this step, the extracted information from questionnaire analyzed and the ratio of discordantly for different ideas is calculated. Saaty (1992) proposed that if the ratio of discordantly for each questionnaire is more than 0.1, its better that decision maker reviews about the judgments. Therefore, the ideas that have total difference with other ideas, eliminated from results. Finally, resulting and geometrical average-making of them were done by giving-weight logic. The numbers were analyzed in Expert Choice (EC) software and then importance coefficient of each layer was calculated. After calculating each layer value, road building was done with the aim of recognizing the best places for road crossing, by evaluating multivariable indigenous model. In above model, the coefficient of each layer is a king that exited from expert choice software and its variables are the layers that denoted in previous step.

Providing the power of zone for finding way: The road network shouldn't cross from some areas such as springs, rocks, landslips and moving places, mines, too slope areas and totally negative required points. It's necessary to provide a layer known as limitations layer, so that the all points in map cells were introduced in zero value, In fact, the limitation map is a kind of map that the value of each cell shows the prevention in way crossing. The above map with zero value was covered on area restricted and the zone with crossing restriction exited from studying domain. With noticing this point: Road shouldn't cross in these areas at all. At the next step, the submitted model in previous step was applied on map by Raster calculate tool and a raster map was provided. In this part, zone was divided to 5 parts by reclassify tool into classes: very bad, bad, middle, good and very good.

The planning of proposed road based on indigenous model of road in GIS perimeter: Therefore, the provided map based on submitted model, is noticed as cost layer and the value of each cell is reversed by multiplying in (-1). Because, in cost layer the more value of cell, the more its stability in road crossing, this case is unsuitable to areas meaning. For that, cost layer is provided based on the reversed model and according to previous step reclassify in 5 levels and the entrance of roads in near places is looked as entrance points to the zone. With considering to the area shape, the opposite side is looked as exiting polygon. Distance and weighted layers are built by cost weighted tool in 3D analyst and the first line is planned by shortest path tool. It should be noticed that in all cases cell size should be in the size of road bounds, if not, shortest path won't have good response.

The correction of returned horizontal curves: Naturally, the above line has some problem that needs to review, for example the parts that system crosses the first line from up slope-known as returned horizontal turns or lock pin turn- should be determined by system. The above lines at first turned into the section between balance lines of height by unique value. The maximum slope is determined 10% and the maximum distance for 10% slope is 100 m. Some parts of road that have above specifications are specified by select by Attribute Table and put in a separate map. In next step, returned turns are corrected by topography lines.

The examination of vertical curves: Vertical turns are the kind of turns that occurs in geographical change directions in 180 degrees. The limit maker factors in system planning are as kind that decreases the possibility of creating dangerous vertical turns, because slope limitation under 10% is required the movement in the lines with near azimuth. Therefore, dangerous vertical slopes won't be present in above planning. After this step, system planning is finished.

RESULTS AND DISCUSSION

According to the submitted method in materials and methods, each specification is given a weight by multicriterion measurement methods. With using this way, the concord coefficient become 0.07, because this value is less than 0.1, there are possibility of using calculated weight in continuation of study process (Saaty, 1992).

According to the above subject, the best place for crossing road at the study area is:

$$P = 0.192\,T + 0.174\,S_L + 0.165\,V + 0.164\,S_O + 0.089\,F + 0.075\,D + 0.073\,G + 0.069\,R \quad (1)$$

Where:

- P = Value of each pixel
- T = Type layer according to making value of type table.
- S_L = Slope layer according to making value of slope table
- V = Volume layer according to making value of volume table
- S_O = Soil layer according to making value of soil stability table
- F = Flat areas layer according to making value of flat areas table
- D = Direction layer according to making value of direction table
- G = Geology layer according to making value of geology table
- R = Reproduction layer according to making value of reproduction table

The above model is special for the North forests of Iran or the forests that have the similar characteristics.

Providing the best crossing places map: Before submitting, above model on the studied area, as we mentioned in procedure, the limitation layer was created and applied on the zone, so that those areas in limitation layer exited from acting limitation. Then, Eq. 1 was applied on the zone. This formula is the road building model in the North of Iran. In this way, the best crossing places map was provided and the road was planned by present tools in 3D analysis (Fig. 1).

The returned horizontal curve that have to plan for too slope or hard were specified by software and corrected with considering to the area topography and then completed road was made (Fig. 2).

The planned road density is 19.1 m ha. It seems that this study confirms Sarikhani's (2000) idea about suitable density of 20 m ha and also Ranjbar's (1999) idea about suitable density of 19.5 m in ha.

The positive point of this study related to previous studies is creating the first lines and turning them into project line. Nevertheless, this study confirms Ahmadi's (2002) research on using layers and hierarchical analyzing two-by-two value making and gives suitable result. The recent study wanted to make compatible the technology used by Akay (2003) with present situations in many countries, because Akay used DEM with high separation power for road planning. Also, he had

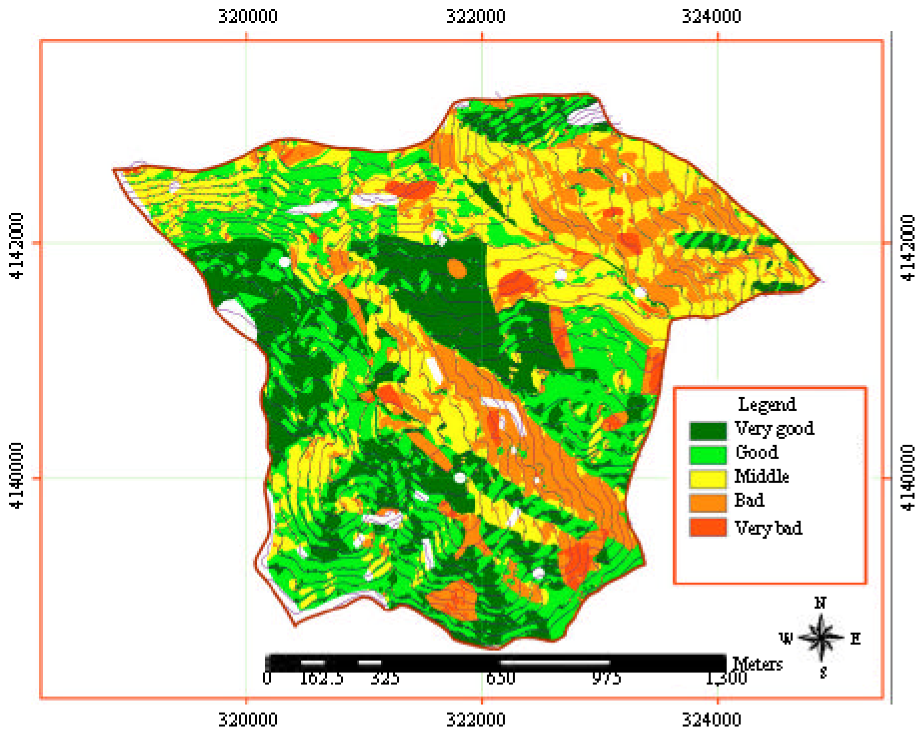

Fig. 1: The best crossing places map that the road was planned

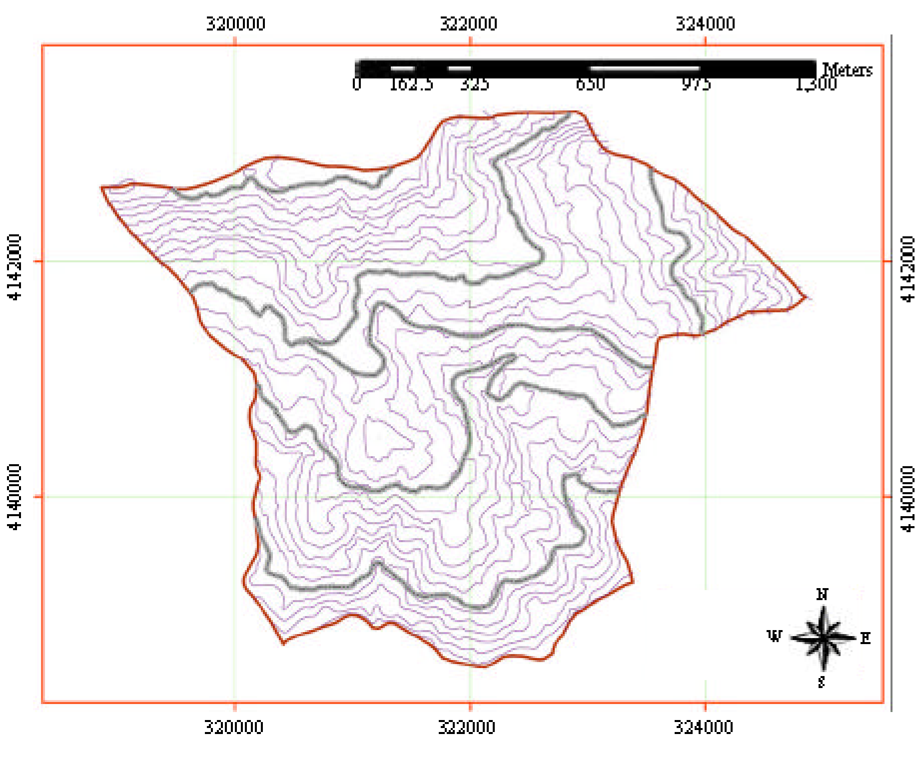

Fig. 2: Final road

1/10000 maps that its availability is different in many countries in layer size. For this reason, the present research made practical the project line planning in forest by submitting a simple model and practical ways based on GIS knowledge.

REFERENCES

Ahmadi, H., 2002. Road location in according to environmental standards by GIS. M.Sc. Thesis. Natural Resources Faculty, Tehran University.

Akay, A., 2003. Minimizing total cost of construction and transportation costs with computer-aided forest road design. Sadhana, 31: 621-633.

Akay, A., I.R. Karas, J. Sessions, A. Yuksel, N. Bozali and R. Gundogan, 2004. Using high-resolution digital elevation model for computer-aided forest road design. Proceedings of Geo-Imagery Briding Continents XXth ISPRS Congress, 2004, Istanbul, Turkey, pp: 1090-1095.

Audrey, M.M., 2001. Development of environmental routing strategies for the management of forest access roads using GIS and GPS. Ph.D Thesis. National University of Ireland, Dublin.

Chegini, M., 1992. Designing of skid trails and determine of skidding distance coefficient. Master Degree Thesis. Natural Resources Faculty, Tehran University.

Chung, W. and J. Sessions, 2001. Transportation planning under multiple objectives. Proceeding of the International Mountain Logging and 11th Pacific Northwest Skyline Symposium, 2001, IEEE Xplore, pp: 194-200.

Dahlin, B. and J. Fredrison, 1995. Computer-assisted forest road planning. Int. J. For. Eng., 35: 65-73.

Gumus, S., 1994. The use of geographical information system in selecting forest road routes. Turk. J. Agric. For., pp: 611-619.

Hosseini, S.A., 2003. Planning of forest roads network using GIS, Khiroudkenar forest. Ph.D Thesis. Tarbiat Modares University, Tehran, Iran, pp: 145.

Lotfalian, M., 2001. Evaluation of effective factors to determine optimize accumulation of forest road network. Ph.D Thesis. Natural Resources Faculty, Tehran University, pp: 154.

Makhdoum, M., 2006. Fundamental of Land Use Planning. 4th Edn., Tehran University Press, Tehran, Iran, ISBN: 964-03-4025-1, pp: 295 (In Persian).

Murthy, A.R., 2003. Selection of least cost paths for extraction of forest produce using remote sensing and GIS. http://www.gisdevelopment.net/application/environment/pp/pdf/114.pdf.

Musa, A.K.A. and A.N. Mohamed, 2002. Alignment and location forest road network by best-path modeling method. Malaysian Center for Remote Sensing. http://www.gisdevelopment.net/aars/acrs/2002/for/092.pdf.

Ranjbar, H., 1999. Evaluation of the best forest road network in according to silvicultural goals in Vaz forest. M.Sc. Thesis. Gorgan University.

Rapaport, E. and F. Snickars, 1998. GIS-Based Road Location in Sweden: Geographical and Planning. Springer Verlag, Berlin, pp: 136-153.

Rogers, L. and P. Schiess, 2001. PEGGER and ROADVIEW. A new GIS tool to assist engineers in operation planning. Proceeding of the International Mountain Logging and 11the Pacific Northwest Skyline Symposium, 2001, IEEE Xplore, pp: 117-181.

Saaty, T.L., 1992. Multicriteria Decision Making: The Analytical Hierarchy Process. RWS Publications, Pittsburgh, PA, pp: 291.

Sajadi, S., 2002. The effect of road making on forest environment by GIS. To complete forest road network in namkhane in kheyrood kenar forest. M.Sc. Thesis. Natural Resources Faculty, Tehran University, pp: 117.

Sarikhani, N., 2000. Forest road planning guideline. Manage. Plann. Org. J., pp: 148-200.

Suvinen, A., M. Saarilahti and T. Tokola, 2003. Terrain mobility model and determination of optimal off-road route. http://www.scangis.org/scangis2003/papers/16.pdf.