# Road Network Planning Investigation with Consideration of Valuating Some Effective Factors (Case study: District 3 of Tavir Forest in Golestan Province)

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**Abstract:**
*Forest roads are the main tools in planning and scheduling to achieve optimum management in forest areas. So, the main part of investments in forest regions is related to road construction. Thus is necessary to investigate the planning of road network with consideration of valuating some effective factors. This study was conducted in District 3 of Tavir forestry plan (Ali Abad-Golestan province of Iran). The environmental factors which effects on forest road planning are including slope gradient, geology, slope direction, soil, stock growth per hectare, forest type. The required maps were produced in GIS in shape of digital. To valuate different classes of mentioned maps, the value 1 was assigned to suitable area for passage of road and value 0 was assigned to unsuitable area. In this study the effective environmental factors were considered as coefficient with these values: slope 0.3, geology 0.25, slope direction 0.2, soil 0.13 and stock growth and forest type each of with value 0.06. to determine the suitable area for passage of road the values from 0 to 1 were assigned to 4 classes of very suitable (0.75-1), suitable (0.5-0.75), unsuitable (0.25-0.5) and very unsuitable. Results showed that the length of existence road in areas with suitable and unsuitable status for passage was 84.49 percent. This shows that the road planners attempted to consider all environmental issues to achieve minimum damage to forest stands.*

**Keywords**: road planning, environmental factors of a site, valuation, GIS, Tavir (Golestan province of Iran)

## 1 Introduction

Forest management today has to meet a number of objectives. Planning of multi-functional forest road networks is one essential for meeting the aims of the sustainable forest concept. Road construction damages the natural environment unless it is carefully thought out. As forest engineers we have to consider the protection of nature when designing forest roads (Gumus et al. 2008). In general forest road network as the basic installations has a major role in organization the region, harvesting and transportation goods and services and keeping it. The roads network from planning single route to completing it has technical and principle points that needs to make an exact decision. Up to now most of the designs have made based on economic and harvest goals and paid less attention to environmental issues and the losses that the routs can help the environment (Firozan et al. 2010).

Forest road network planning is an important duty of forest engineers (Ghaffarian and Sobhany, 2007). The most important issue in forest road planning is appropriate scheduling to pass more routes from positive points and fewer routs from negative points. Therefore, accurate and sufficient reorganization of field is necessary for road planning. Decision making is very important to select suitable places for road passage with lowest environmental damage and supply sustainable forest ecosystem (Azizi and Najafi, 2010). The performance of road network increases and the construction cost decreases with planning of suitable road network. Road network planning using traditional methods is time consuming and expensive. So, the number of alternatives is decreased to reduce planning cost and time. This will decrease planning quality. Besides, the new methods of planning with use of the geographical information system and data processing technology can analyze large volume of data as different numeral layers with high speed and accuracy. Thus, the quality, cost and accuracy can improve. According to selection of single tree selection cutting method for northern forest of Iran which require to high density of road, it is necessary to develop forest road network. The new methods can facilitate this operation (Abdi 2005). In road construction projects, the environmental factors are considered for routing process to reduce environmental damage and reach to sustainable development aims. In road network planning these techniques should be done to achieve sustainable development and protect forest ecosystem. Hosseini et al. (2004) investigated the effective factors on forest road routing in Kheirood kenar region in Noshahr. They overlaid numeral maps of slope gradient, slope direction, elevation at sea level, soil, trees volume and current type of forest and finally produced the site capability for routing.

Ahmadi et al. (2005) in a research entitled road routing based on environmental considerations using GIS for road construction in east of Tehran, valuated effective factors with questionnaires and determined the relative weight of factors. Finally they planned different routes in GIS. The optimum road among different routes was determined using analytical hierarchy process. Results showed that optimum road was in agreement with determined priorities and limitations. Naghdi et al. (2008) in district 3 Shafarood forest planned the most appropriate route network in GIS to find suitable regions and prevent from environmental damage to forest ecosystem. The map of existence route network was compared to most appropriate planned route network. Results showed that the most areas covered by existence route network were unsuitable, so route construction can damage to environment. Rafatnia et al. (2006) in their research entitled determining of suitable method to predict forest and mountainous roads in GIS with consideration of environmental factors and forest roads principles recognized the effective factors on routing roads. Results showed that acceptable coverage for tourism and forestry uses was provided in region with passage of roads from areas which have low construction costs.  The purpose of this study was to investigate suitable method for evaluation of planned forest road with consideration of environmental factors using geographical information system and data processing techniques.

### 1.1 Study area

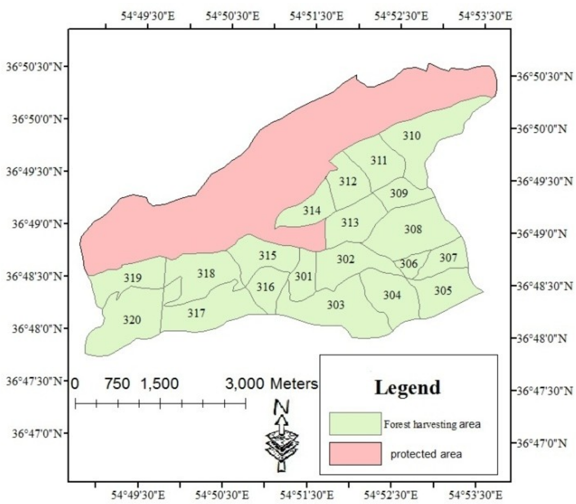


**Figure 1: District 3 of Tavir Forestry**

The study area is located in district 3 of Tavir forestry in watershed number of 87 in region of Ali Abad forestry in general office of natural resources in Golestan province. The forests is located between latitude of 36˚ 48' 4″ to 36˚ 50' 48″ N and longitude of 54˚ 50' 42″ to 54˚ 53' 46″ E. The forest areas of district 3 Tavir are extended on northern slopes of Alborz Mountain from elevation at sea level of 540 meter to 2040 meter. The general aspect of slope is northern. District 3 of Tavir forestry plan with an area of 2240 hectare has 20 compartments and its forest cover is dominant by *Carpinus betulus* and *Parotia persica.* The forest type is uneven aged and silvicultural method used is single tree selection cutting.

## 2 Research procedure

In this research at first the effective factors on forest road routing was determined. These factors were slope gradient, geology, slope direction, soil, volume per hectare, forest type. Then required maps were provided. The maps of geology, soil and volume per hectare and forest type was obtained from database of forestry plan handbook and then they provided as vector and raster layers in GIS using Arc GIS 9.3 software. The maps of slope gradient and slope direction were extracted from digital elevation model (DEM). The road map of the study area was taken using field survey and GIS. Value 0 was assigned to unsuitable area and value 1 was assigned to suitable area for road passage to valuate different classes of mentioned maps. In this study the effective environmental factors with following values as coefficient was considered: slope gradient 0.3, geology 0.25, slope direction 0.2, soil 0.13 and volume per hectare and forest type each of 0.06. After overlaying six effective factors layers, the code of 0 and 1 (suitable and unsuitable) and then the sum of value coefficient was determined. The valued maps were integrated with existence road map. The value of 0 to 1 was classified as very suitable (0.75-1), suitable (0.5-0.75), unsuitable (0.25-0.5) and very unsuitable (0-0.25). With considering the road length in each of these classes the passage percentage of roads from mentioned classes was determined.

### 2.1 Classification of the maps of effective factors on planning

In order to better investigation of effective factors in road planning, each of the mentioned maps was classified into two classes. Regions were suitable for road passage with value 1 and regions were unsuitable with value 0 (Table 1).

**Table1: Classification of the maps of effective factors on planning**

| Slope (%) | | Geology | | Aspect | | Soil | | Stock growth per hectare ($m^3$) | | Forest type | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 30-100 | 0-30 | N.C.R | L | N, E | S, W | UD | SD | 0-200 | 200- >350 | 3,4 | 1,2 |

UD: unsuitable drainage, SD: suitable drainage, L: limestone, N.C.R: non-calcareous rock.

### 2.2 Valuation of the effective factors in planning

The research of Hosseini et al. (2004), Rafatnia et al. (2006) and Mohammadi Samani et al. (2010) has been referenced to valuate effective factors in routing. According to mentioned studies, the value of environmental factors was as: slope gradient 0.3, geology 0.25, slope direction 0.2, soil drainage 0.13, volume per hectare and forest type each with value 0.06.

## 3 Results

### 3.1 The status of existence road passage according to valuated coefficients

With use of the descriptive data in GIS the status of road passage was determined according to valuated coefficient of 48 units. These data is shown for four regions of very suitable, very unsuitable, suitable and unsuitable in Table 2. The coding stages of effective factors are as:

$$(SL\times0.3) + (LIT\times0.25) + (ASP\times0.2) + (SD\times0.13) + (VOL\times0.06) + (FT\times0.06)$$

Where, in this equation SL: longitudinal slope, LIT: geology, ASP: slope direction, SD: soil drainage, VOL: volume per hectare, FT: forest type. The sum of equation is 1 if all factors are suitable and the sum of equation is 0 if all factors be unsuitable. The value of 0 to 1 was classified as four classes of very suitable (0.75-1), suitable (0.5-0.75), unsuitable (0.25-0.5) and very unsuitable (0-0.25).

According to the overlaid layers, the valuated units have 6 codes. For example, the approach of reading values from left to right is as following:

$$(1\times0.3) + (0\times0.25) + (0\times0.2) + (1\times0.13) + (1\times0.06) + (1\times0.06) = 0.55$$

This unit is located in suitable region.

**Table 2: The status of existence road passage according to valuated coefficients**

| Row | Unit code | Sum | Road length (m) | Status crossing | Row | Unit code | Sum | Road length (m) | Status crossing |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 110111 | 0/8 | 1146 | very suitable | 25 | 110100 | 0/68 | 1282 | suitable |
| 2 | 111011 | 0/87 | 3223 | very suitable | 26 | 101011 | 0/62 | 1546 | suitable |
| 3 | 111000 | 0/75 | 3883 | very suitable | 27 | 101000 | 0/5 | 770 | suitable |
| 4 | 111111 | 1 | 1155 | very suitable | 28 | 110100 | 0/68 | 570 | suitable |
| 5 | 111100 | 0/88 | 433 | very suitable | 29 | 101011 | 0/62 | 346 | suitable |
| 6 | 110111 | 0/8 | 109 | very suitable | 30 | 110011 | 0/67 | 3 | suitable |
| 7 | 111111 | 1 | 183 | very suitable | 31 | 110000 | 0/55 | 5 | suitable |
| 8 | 110111 | 0/8 | 128 | very suitable | 32 | 110100 | 0/68 | 5 | suitable |
| 9 | 111011 | 0/87 | 5 | very suitable | 33 | 101011 | 0/62 | 3 | suitable |
| 10 | 111111 | 1 | 1859 | very suitable | 34 | 101011 | 0/62 | 9 | suitable |
| 11 | 101111 | 0/75 | 105 | very suitable | 35 | 010111 | 0/5 | 496 | suitable |
| 12 | 110111 | 0/8 | 3 | very suitable | 36 | 011010 | 0/51 | 413 | suitable |
| 13 | 111011 | 0/87 | 3 | very suitable | 37 | 011011 | 0/57 | 31 | suitable |
| 14 | 111111 | 1 | 3 | very suitable | 38 | 011111 | 0/7 | 1029 | suitable |
| 15 | 111000 | 0/75 | 2 | very suitable | 39 | 011111 | 0/7 | 280 | suitable |
| 16 | 111100 | 0/88 | 2 | very suitable | 40 | 100011 | 0/42 | 992 | unsuitable |
| 17 | 101111 | 0/75 | 19 | very suitable | 41 | 100011 | 0/42 | 151 | unsuitable |
| 18 | 101111 | 0/75 | 13 | very suitable | 42 | 010010 | 0/31 | 149 | unsuitable |
| 19 | 111011 | 0/87 | 12 | very suitable | 43 | 010011 | 0/37 | 390 | unsuitable |
| 20 | 111111 | 1 | 12 | very suitable | 44 | 010000 | 0/25 | 1438 | unsuitable |
| 21 | 110010 | 0/61 | 429 | suitable | 45 | 010100 | 0/38 | 165 | unsuitable |
| 22 | 110011 | 0/67 | 3409 | suitable | 46 | 001011 | 0/32 | 420 | unsuitable |
| 23 | 110000 | 0/55 | 1946 | suitable | 47 | 011000 | 0/45 | 381 | unsuitable |
| 24 | 110110 | 0/74 | 43 | suitable | 48 | 000011 | 0/12 | 257 | very unsuitable |

**Table 3: The status of existence road according to effective factors on planning**

| Effective factors | Slope (%) | | Geology | | Aspect | | Soil | | Stock growth per hectare ($m^3$) | | Forest type | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Value | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| Profile factors | 30-100 | 0-30 | N.C.R | L | N,E | S,W | UD | SD | 0-200 | 200->350 | 3,4 | 1,2 |
| Road length (m) | 5422 | 22778 | 4300 | 23900 | 13000 | 15200 | 19281 | 8909 | 9840 | 18360 | 10880 | 17320 |
| Frequency | 19/23 | 80/77 | 15/3 | 84/7 | 46/1 | 53/9 | 68/3 | 31/7 | 34/9 | 65/1 | 38/58 | 61/42 |
| Area (ha) | 863 | 1377 | 272 | 1108 | 800 | 1440 | 1317 | 923 | 806 | 1434 | 1411 | 829 |
| Road density | 6/28 | 16/54 | 15/81 | 20/25 | 16/25 | 10/55 | 14/46 | 9/65 | 12/21 | 12/80 | 7/71 | 20/89 |

The status of existence road passage from different areas is shown for four regions of very suitable, very unsuitable, suitable and unsuitable in fig 2 and 3.

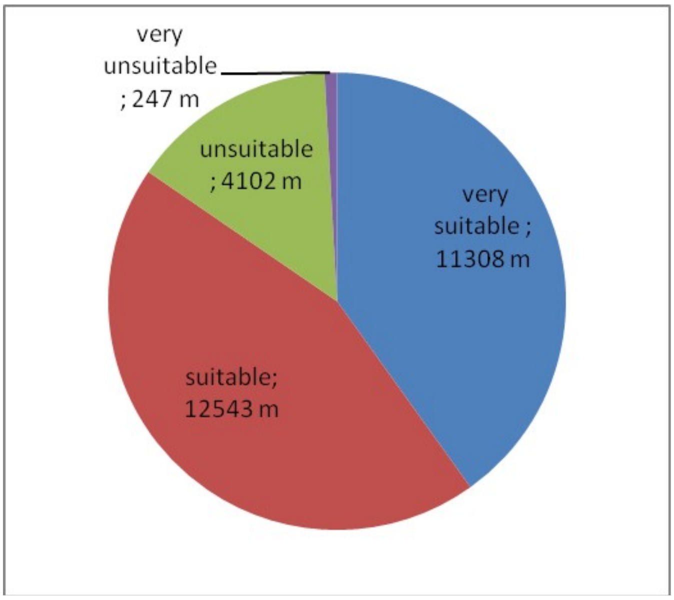


**Figure 2: The length of existence road passage from different areas**

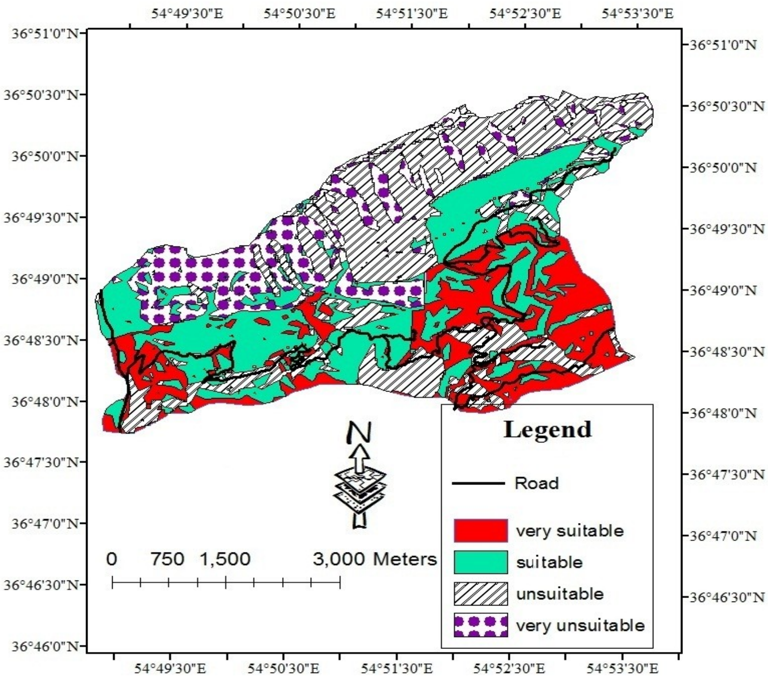


**Figure 3: The status of existence road passage from different areas**

## 4 Discussion and conclusions

The forest area is generally heterogeneous, so large volume of data is required for forest road planning. In evaluation methods of forest roads with use of the GIS, there is possibility of usage large number of layer data. The accurate overlaying these data is possible easily. Therefore, with use of the GIS it is possible to rapidly analysis the region from different aspects point of view. It is impossible in traditional methods (Alizadeh et al. 2010).

Soil moisture, weak drainage and mass wasting of upper layers on beneath layers lead to remove slope stability and make unsuitable area for passage in forest road planning process. If the slope be in direction of sun light, the soil drainage and geology stability be suitable the area would have higher value for road passage. Hillside gradient is another effective factor in road planning. Earth working operations and construction of cut slope can increase soil stability (Azizi and Najafi 2011). According to Table 3, in recent study 80.77% of road length passed from slope gradient of 0-30% and its density was 16.54 meter per hectare which was higher than that of in region with slope gradient of 30-100%. Results showed that the engineers attempted to pass roads according to slope gradient as most important effective factor. The passage status of road from geology, volume per hectare and forest type was suitable similar to slope gradient.

Hosseini et al. (2004), Akay et al. (2004) in their researches concluded that the unsuitable conditions in road planning causes to increase costs rapidly. Besides, the costs can be reduced if the road passes from fertility area with high stock growth. This issue is very important in road planning. 53.9% of road length passed from southern and western geographical direction, but the road density in this area was less than northern and western directions, because the more than half area of southern and western areas has been located in protected areas.

Majnonian et al. (2007) evaluated the alternatives with respect to passage percentage from different classes of slope gradient and slope direction. With determining the passage percentage of alternatives from different slope classes it can be analyzed earthworking volume in construction time, road stability and its effect on forest ecosystem. The use of the valuating method for effective factors on road planning and preparing the map of suitable area for passage of forest road network using GIS is acceptable method. According to results of existence road passage from different areas, the length of existence road passed from suitable and very suitable area was 84.49% of total length of existence road. This showed that the engineers attempted to pass roads based on environmental factors to reduce damage to forest ecosystem.

Hosseini (2003) reported that the providing comprehensive data and thematic maps with high resolution are necessary for northern forests to achieve suitable results and protect and develop forests. Although the planning process can be done in GIS and this facilitate data analysis, but final conclusion to decision making is possible only after field survey and controlling optimum network in nature.

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