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PROGRAMMING AND FOREST ROAD PLANNING

MEHRAN NASIRI* AND MAJID LOTFALIAN

Department of forest engineering, Sari Agricultural Sciences and Natural Resources University, PO Box 737, Mazandaran province, Sari, Iran.
*Corresponding Author: Email- me.nasiri@Sanru.ac.ir

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Abstract- In this study a new method of forest road planning was presented with the composition of the source of programming codes and formulas of forest roads planning in Microsoft Visual Basic 6.0 software. In this method the road was planed automatically with operator edition. Operators can select the best route among different alternatives based on their experts. This program (FORENG 1.0) is not optimization software but it has high accuracy in planning after considering all effective factors. If the operator has sufficient experience, the planned route with this method will have high accuracy. For planning of route with this method high expert in computer and software sciences is need. The planner must be educated in programming languages to apply all effective factors in forest road planning. Of course, with providing of this software under open code and with replacing user formula through users this problem is solved.
Keywords- Forest Road, Programming, Planning, Formula, Source codes.

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Introduction

A well planned, designed, constructed and maintained system of forest roads is essential to facilitate forest management and protection of natural resources [17-23]. Road design is the process of determining the "what, where, when and how" for a new road construction, road improvement, or extra-ordinary road maintenance project [19, 25-30]. Traditionally, the planning of low-volume road networks highly depends on economical and social considerations. In recent years, forest road construction and maintenance activities have become controversial, because of increasing public concerns about short- and long-term effects of forest roads on environment and the value that society now places on road less wilderness [20]. Advances in personal computers (PCs) have increased interest in computer-based road-design systems to provide rapid evaluation of alternative alignments [2]. Methods for storing the data vary from contour lines, to cell-based raster datasets, to triangulated-irregular-networks or TINs. Most route location software relies on some form the raster data model in which each cell in the data is assigned a particular elevation value. The appropriate cell size to use for forest route location is specific to the particular software application and geography of the area. Many have suggested that a cell size of between 1.0 and 3.0 meters is sufficient for operational route location [2, 3, 6, 16]. While many road design packages exist (RoadEng, AutoCAD, F.L.R.D.S…) only one has given the user the ability to quickly look at alternative road locations at varying scales, ROUTES [24]. Traditional road design software relies on survey data collected in the field to generate terrain models and very detailed engineered road location and construction plans. Others have taken a more holistic approach and looked at optimization of road locations for a particular set of topographical, environmental or economical constraints [11, 25]. There are many references on the successful applications of methods for the investigation of forest road planning. Coulter and Chung [11], developed a method of forest road design using high-resolution DEM data (1mx1m) from LIDAR. In the method, road elevations were assigned to each pixel within the road template to calculate earthwork from the difference between road and surface elevations. This method was only applicable to straight road segments and could not locate horizontal or vertical curves. It also could not calculate total road cost or consider environmental requirements [2]. A computer program, PEGGER, was developed to automate initial forest road design through the use of a Geographic Information System [25]. Akay and Sessions [3], excuted to using from computer technology actualizing and 3 dimensions designing software executions such as tracer and specialized methods of the forests road designing same as linear programming and created method of the path finding and subjected to 3 using exist DEM concluded to the road path designing and the skid trail and in conclusion they excluded that this methods caused and raised into cost reduction that are related into execution costs and the path designing per (km) and costs and it pluses into reduction of designing time and speed ness of construction execution that has more importance. Erichson [8], indicated into one investigation that called to helping of the forests owners for their management in U.S.A. that execution of actualizing pegger software and using from ROADNEG program leads into GIS system execution and the way designing engineering software can obtain to one optimized designing with reduction of the cost into least and the most precision of it. In this study a new method of forest road planning was presented with the composition of the source of programming codes and formulas of forest roads planning in Microsoft Visual Basic 6.0 software.

Material and methods

Description of the Study Area

Pashakola forest with an area of 1826 hectare is located south of the city of Savadkooh in Mazandaran province, Iran. The latitude and longitude of this forest are 36° 23' to 36° 26' N, 52° 09' to 52° 19 " E, respectively (Fig 1).

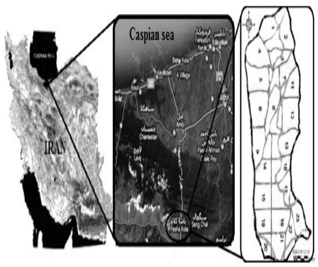

Fig. 1- Maps showing the geographical location of the study area

Large areas of these forest are located on steep to very steep slopes with an average altitude greater than 1000 m above sea level. The main system for wood extraction in the Pashakola forest is based on ground skidding by skidder 450 C and HSM (Fig 2). In Iran, there are two methods for designing road. In first method (field survey) road designing is conducted based on route survey using NIVO CTM mapping camera and taking geometric specifications of longitudinal and cross sections of road (Fig 2). Second method (routing softwares) is carried out on DEM/DTM (Digital Elevetion or Terrain Model) of research area.

In this study the Visual Basic software was used to plan forest roads. Thus the Terrain software (FORENG 1.0.0) was provided with programming in Visual Basic software (Figure 3). The Terrain software helps planner with providing three dimensional area and special analysis. Software for planning forest road was provided with writing the codes of program and inserting the mathematical equations of forest roads planning in programming window. In order to plan, at first the topography map of the region was converted to triangular irregular network (TIN) through 3D analysis in Arcinfo software. Then this layer was transferred to FORENG 1.0.0 software to plan forest road. In this software the road was planed automatically with operator edition. Therefore, after the determining of the start and end point of a route, the software automatically propose several routes to operator according to the topography, slope direction, intersection with canals or streams, maximum and minimum of longitudinal slope, variation in longitudinal slope, stopping sight distance (according to structural formula) and sandard criteria. Operators can select the best route among different alternatives based on their experts. After the selection of the best possible route, the length of road on different slope gradient and direction was measured. Moreover, the Roadeng software was used to determine the earthworking volume. The earthworking volume was automatically calculated after inserting the tin layer achieved from FORENG software to Roadeng software.

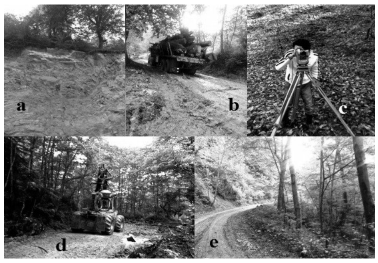

Fig. 2- Primary (d) and secondary (b) transportation, Field survey (c), steep slopes (a and e)

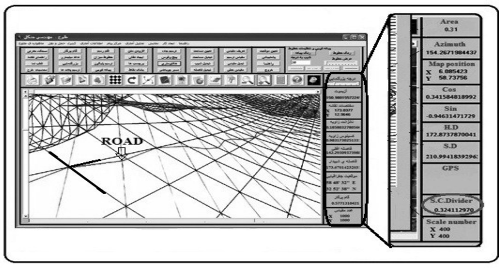

Fig. 3- Using TIN layer in FORENG software to forest road simulation

Structural formula

$$\text{Stopping Sight distance (SSD)} = V + \frac{0.13\,V2}{30\,F}$$

$$\text{Horizontal sightline offset (M)} = R\left(1 - \cos\frac{\beta}{2}\right) - \left(\frac{W}{2} + 1.5\right)$$

$$\text{Minimum curve radius} = \frac{15}{tg\,\frac{\beta}{2}}$$

$$\text{Compass step} = tg\,\alpha$$

Where SSD = required stopping sight distance, V = speed, f = coefficient of friction.

Where M = required horizontal sightline offset, R = horizontal curve radius, β = Central angle of curves,

W = width on curve

Required minimum curve radius, β = Central angle of curves

Required compass step, tg α = Ϭh/Ϭd

Sample source code

Matrix Build source code (Fig 4)

```
Private Sub MatrixBuild(ByVal X As Double, ByVal Y As Double,
ByVal z As Double)
' this sub builds the rotation matrix with x, y and z as axis angles
Dim SinX, CosX, SinY, CosY, SinZ, CosZ, C1, C2
SinX = Sin(X)
CosX = Cos(X)
SinY = Sin(Y)
CosY = Cos(Y)
SinZ = Sin(z)
CosZ = Cos(z)
RM(0, 0) = (CosZ * CosY)
RM(0, 1) = (CosZ * -SinY * -SinX + SinZ * CosX)
RM(0, 2) = (CosZ * -SinY * CosX + SinZ * SinX)
RM(1, 0) = (-SinZ * CosY)
RM(1, 1) = (-SinZ * -SinY * -SinX + CosZ * CosX)
RM(1, 2) = (-SinZ * -SinY * CosX + CosZ * SinX)
RM(2, 0) = SinY
RM(2, 1) = CosY * -SinX
RM(2, 2) = CosY * CosX
End Sub
```

3D draw source code (Figure 4)

```
Private Sub Draw3D()
Dim XPoint As TDPoint 'for rotations
Dim Light As Integer 'how light the polygon is
Dim AddedLight As Integer 'overflow light
Dim threshold As Integer 'how tall a given value is in 3D scale
Dim ResBlock As Integer 'size of a polygon
Dim Luminance As Integer 'reflective value
Dim waterdiff As Integer 'difference between water level and un-
derwater land
Dim beach As Integer 'beach length
Luminance = scrLum.Value
If OptHiRes.Value = True Then
 ResBlock = 1 '1 polygon per point (doesn't get much better)
ElseIf OptMedRes.Value = True Then
 ResBlock = 4 '1 polygon per 4 points
Else
 ResBlock = 8 '1 polygon per 8 points
End If
beach = scrbeachheight.Value
waterdiff = scrwaterdiff.Value
threshold = thresh.Text
'build the 3D rotation matrix
MatrixBuild scrollX.Value * pi / 180, scrollY.Value * pi / 180,
scrollZ.Value * pi / 180
'we start at -64 so that the middle of the map is at 0,0
'this way the map rotates around the middle and not the upper-left
corner
For Y = -64 To 63 - ResBlock Step ResBlock 'make it one less so
as not to get a drop-off at the edge
For X = -64 To 63 - ResBlock Step ResBlock
'rotate the three corner points and put them in an array for the
polygon DLL call
XPoint = RotatePoint(X, Y, -HeightArray(X + 64, Y + 64) / thresh-
old)
PointList(0).X = XPoint.X * zoom + ViewX
PointList(0).Y = XPoint.Y * zoom + ViewY
XPoint = RotatePoint(X + ResBlock, Y, -HeightArray(X + 64 +
ResBlock, Y + 64) / threshold)
PointList(1).X = XPoint.X * zoom + ViewX
PointList(1).Y = XPoint.Y * zoom + ViewY
XPoint = RotatePoint(X + ResBlock, Y + ResBlock, -HeightArray
(X + 64 + ResBlock, Y + 64 + ResBlock) / threshold)
PointList(2).X = XPoint.X * zoom + ViewX
PointList(2).Y = XPoint.Y * zoom + ViewY
XPoint = RotatePoint(X, Y + ResBlock, -HeightArray(X + 64, Y +
64 + ResBlock) / threshold)
PointList(3).X = XPoint.X * zoom + ViewX
PointList(3).Y = XPoint.Y * zoom + ViewY
' a crude shading technique
'basically it's saying that if the left side is higher than the right side
of
'the polygon then the polygon is tilted away from the source and
make it a negative
'correction factor. Otherwise, it's positive, so the polygon is bright-
er
OverFlowLight = 0
Light = (HeightArray(X + 64, Y + 64) - HeightArray(X + 65, Y +
65)) * Luminance + 127
If Light < 0 Then Light = 0
If Light > 255 Then
OverFlowLight = Light - 255 'catch extra light for fading to white
Light = 255
End If
'draw for land
If HeightArray(X + 64, Y + 64) > water + beach Then
Picture2.FillColor = RGB(OverFlowLight, Light, OverFlowLight)
ElseIf HeightArray(X + 64, Y + 64) <= water Then 'under water
If water - MapArray(X + 64, Y + 64) > waterdiff Then Pic-
ture2.FillColor = RGB(0, 0, 127)
If water - MapArray(X + 64, Y + 64) <= waterdiff Then
 'shallow water math
 If chkshallow.Value = 1 Then Picture2.FillColor = RGB(0, wa-
terdiff - (water - MapArray(X + 64, Y + 64)), 127)
 'simple
 If chkshallow.Value = 0 Then Picture2.FillColor = RGB(0, 64, 127)
End If
Else
Picture2.FillColor = RGB(Light, Light, Light / 2)
End If
Picture2.ForeColor = Picture2.FillColor
If XPoint.z * zoom > -500 Then Polygon Picture2.hdc, PointList(0),
4
Next X
Next Y
End Sub
```

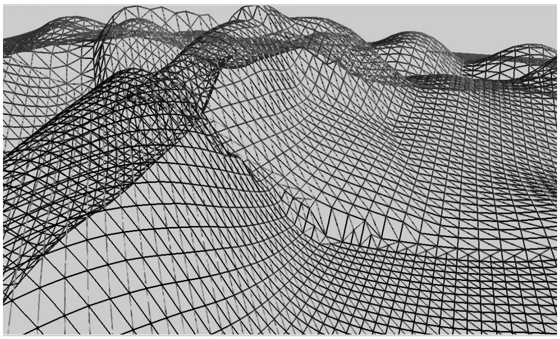

Fig. 4- Terrain model acorrding to programming source code (Matrix build and 3D draw)

Results

Results showed that alternative 1 (a composition of the alternative 2 and 3) has suitable condition in point of view passage status as compared with other alternatives. The best status of roads in passage of geographical direction is for alternative 1. Alternative 2 in point of view road length and alternative 3 in point of view slope gradient have more suitable status as compared with alternative 1 (Fig 5). The maximum and the minimum volume of earthworking operation (Fig 6) and cost of road construction were reported (Table 3) for alternative 3 and alternative 2 respectively. The comparisons were shown in Table 1, 2 and 3.

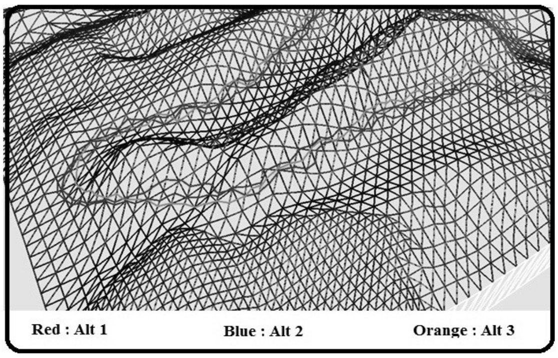

Fig. 5- Designing forest road (Alternatives) using FORENG software

Table 1- Comparison of the road lengths (%) in different slope classes

Slope classes (%)	Alt (1) Passage (%)	Alt (2) Passage (%)	Alt (3) Passage (%)
0 - 30	44	41	47
30 - 60	47	48	46
X> 60	9	11	7

Table 2- Comparison of the road lengths (%) in different aspect direction

Aspect	Alt (1) Passage (%)	Alt (2) Passage (%)	Alt (3) Passage (%)
North	22	19	26
West	34	31	22
East	25	28	31
south	29	22	21

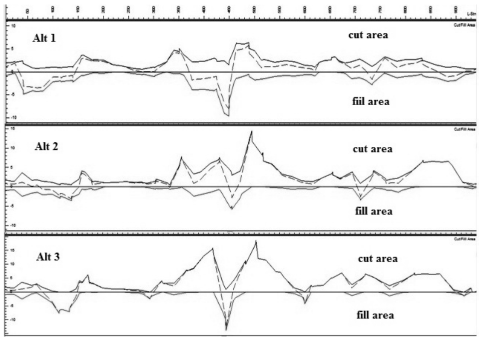

Fig. 6- Calculation of the earth working volume using Roadeng software

Table 3- Calculation of the earth working volume and construction cost

Cut & fill volume	Alt (1)	Alt (2)	Alt (3)
Total length (km)	4.3	3.6	4.8
Total cut volume (m3)	18679	17921	19231
Total fill volume (m3)	6838	4896	8125
Total excavation (Rials)	156903600	150536400	161540400
Total of soil filling (Rials)	57405600	41126400	68250000

Discussion

Forest road are a necessary part of forest management [21]. Road network provide access to the forest for harvests, fire protection and administration and non-timber uses such as grazing, mining and wildlife habitate [7-9]. Forest road planning is very important. According to the different roles of forest roads, incorrect plan of road causes to disturb nature balance of hydrologic network and secondary transportation of wood and vehicle traffic [29]. Many studies have been conducted to optimize and plane road network [1, 2, 3, 25]. In mentioned studies most attention was concentrated in accuracy of route planning, whereas the minimum attention was concentrated in technical and environmental issues. Rogers and Schiess [25], introduced the pegger software as guide software for forest road planning based on longitudinal slope. They reported that the road variants extracted from this software doesn't consider the environmental issues. In this study besides the accuracy in route planning, the technical issues such as stopping sight distance (in order to drivers safety), hydrologic network (water level) and minimum radius of horizontal curves (in order to prevent environmental damage) is considered in initial planning of route with software. In these routes which were planned with this method, the technical and environmental issues are considered. The quality of the plan is increased with increasing the accuracy of planning tools such as DTM. In addition the recent studies have proved this hypothesis [2, 3]. The use of the different alternatives and optimization during the initial planning of forest road has effective role on plan accuracy. In this study, two alternatives were planned and then optimum alternative was produced from the composition of two alternatives. Alternative 1 was planned to optimize alternative (2 and 3). In this alternative the operator with considering technical issues tried to decrease the passage of route from slopes more than 60 percent (as compared with alternative 2) after decreasing of the length of road (as compared with alternative 3) (Fig. 7). Increasing the cut and fill slope length increases the amount of environmental damages and sediment yield from cut and fill slopes area to ditch through soil creep, sheet wash and slumping [5, 27]. The road construction in slope gradient of more than 60 percent causes to increase construction, repair and maintenance cost [15, 19, 22]. In addition, the landslide and mass wasting may be occurred because of establishing road on unstable bedrock and floppy lands [14-28]. Landslides are frequent in the North and North West of Iran at Alborz fault zone and they are common during earthquakes, rainfall and as a result of road construction cutting the toe of the slopes [10]. So, the planners try to plan roads on gentle slopes to decrease the forest damage, construction, maintenance and repair cost of road [11]. The flow velocity of the stream increased with increasing of the slope gradient [12]. More cross drainage must be installed at the intersections of the hydrologic network and road to canalize water. This operations increase the construction cost of road and environmental damage[14].

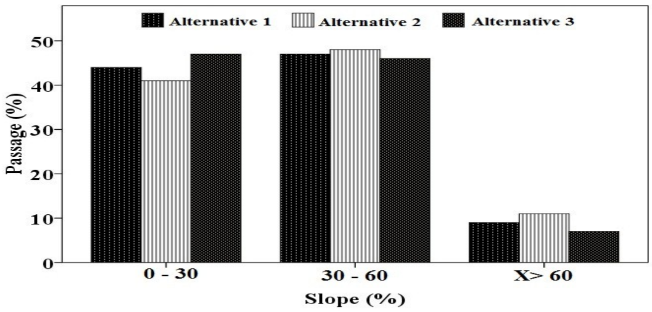

Fig. 7- Comparison of the road lengths (Alternatives) in different slope classes

Totally, the sunlight and warm which are received by southern slopes is two and/or three times more than northern slopes. So, the southern slopes have highest temperature because of the more radiation of sunlight in afternoon and drying soil [28]. Thus, the moisture on road surface constructed on southern slopes is low and consequently the construction and maintenance cost of drainage systems is low [29]. The selected alternative (alternative 1) of this study had good condition in passage point of view from sunny slopes (Fig 8).

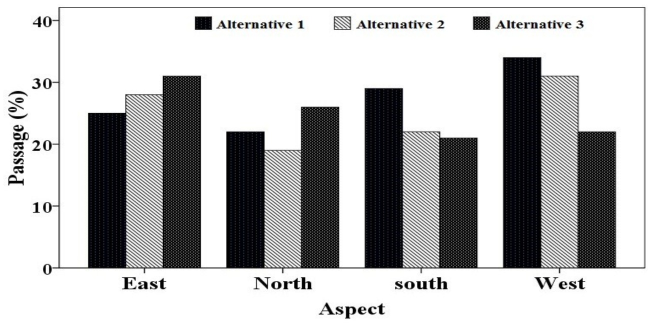

Fig. 8- Comparison of the road lengths (Alternatives) in different aspect direction

Optimization of the planned route with considering several alternatives causes to decrease environmental damage, earthworking volume and road construction cost [30]. In this study the length of road in alternative 1 increased as compared with alternative 2 to decrease passage of road from slopes more than 60 percent (Figure 9). This issue cause to increase road construction cost, whereas this road in future will have lower maintenance cost as compared to alternative 2.

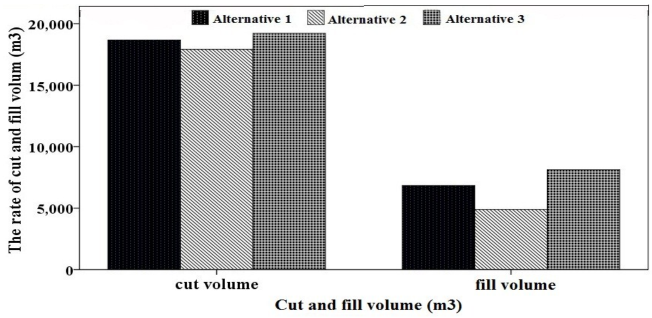

Fig. 9- Comparison of the earth working volume between the Alternatives

This software is not optimization software but it has high accuracy in planning after considering all effective factors. If the operator has sufficient experience, the planned route with this software will have high accuracy. For planning of route with this method high expert in computer and software sciences is need. The planner must be educated in programming languages to apply all effective factors in forest road planning. Of course, with providing of this software under open code and with replacing user formula through users this problem is solved.

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