Planning Forest Road Alignment Using a Shortest Path Algorithm

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Abstract:
This research attempts to build a framework for determination of optimal routes for timber transportation. The current paper presents an enhanced routing method which is based on Dijkstra''s algorithm and Analytical hierarchical processing. Five impendence factors, terrain slope, hydrology, geology formations, soil texture and road slope, which affect on forest road construction cost are found in cooperation with forest road experts. Analytical hierarchical processing is used to compared and analyze these five factors to determine the weight of factors/criteria. The Weighted linear combination (WLC) and The Analytical Hierarchy Process (AHP) were integrated with GIS to derive cost zoning map in ESRI Arc GIS 9.3. Two approaches, shortest path (SP) and an expert with 6 years hands-on experience in road design, were used to connect start point to end point. Two variants were delineated in field, and then the delineated roads were recorded by GPS Garmin 60C Sx. The results showed that the length and the cost of the map-base variant planned by SP were 55% and 65% lower than the path planned by the hands-on experience in road design, respectively. The results of the study also demonstrated that the length and the cost of field-base road by SP were 19% and 21% lower than the expert-based variants, respectively. This means the SP saved 45,800 USD. The results showed that using of the zoning map cost in combination with a shortest path algorithm can lead to a more favorite layout of the forest roads than traditional methods of planning.

Keywords: algorithm, Shortest Path, forest road, Analytical Hierarchy Process, Planning, construction cost.

1 Introduction

A great challenge for professional foresters is designing a road network that besides considering the low length of road, it can provide requirements for different silvicultural method and practices, fire supersession, help and rescue practices and vehicle recreation, as well (Anderson and Nelson, 2004). Forest road network designing to availability of forest area is a hard and time-consuming task (Murray, 1998). Forest road network designing requires to considering various physiographical and site factors. In conventional method, manual overlapping of information layers is used to integrate information, because of low speed and precision this method is not capable of utilizing large amount of information layers and special data, and for this reason it could not be compared all of the alternatives. For this reason in conventional designing necessary the alternatives would be reduced so that designing and assessment could be feasible and also it is possible that conventional method could not lead to road designing with low length and cost. The existence of these problems and failure in one hand, and change in forest management purposes and raising environmental and economic measures in other hand resulted to the concept of application of modern methods and methods with higher abilities and this led designers toward utilizing of computer, geographic information system (GIS) and various algorithms. Geographical Information System (GIS) can be used for finding this optimal path as well as for representing this valuable spatial information to end-users. This paper presents an enhanced routing method which is based on Dijkstra′s algorithm and Analytical hierarchical processing integrated with GIS. To assessment the application of used technique for zoning and the performance of Shortest Path Algorithm this method was conducted in an applied study in experimental forest of Tarbiat Modares University, and was compared to designated road by an skillful expert.

2 Material and methods

2.1 Study area

The study area is a part of district 3, 4 and 5 in Tarbiat Modares University's experimental forest where is located at catchment 46 in Mazandran province. This area is located at longitude 51˚ 41' 12"– 51˚ 48' 05" E and latitude 36˚ 29' 14" – 36˚ 33' 18" N. Elevation range of the study area is 118-2205 meter above sea level.

2.2 Research methodology

2.2.1 Shortest path algorithm

Dijkstra's algorithm, conceived by Dutch computer scientist Edsger Dijkstra in 1956 and published in 1959, is a graph search algorithm that solves the single-source shortest path problem for a graph with nonnegative edge path costs, producing a shortest path tree. This algorithm is often used in routing and as a subroutine in other graph algorithms.

2.2.2 Integrating of layers and path designing

Here five most effective factors on road construction cost, terrain slope, hydrology, geology formations, soil texture, (mohammadi samani et al., 2010) and road slope were selected. As for each factor constituting the hierarchy, priorities among them are determined and their relative importance weights are selected. In order to assess factor influence in detail, it is classified to many subclasses. Similar to factors, relative importance weights of them were determined.

In order to apply the analytic hierarchy process, this study draws a cost map of details and items. The map consist overall weights of subclasses. Then, road slope factor was calculated added to above mention data. In order to create cost map, Vector data should be converted into raster data. The size of the raster data constructed in this study is set and converted to 20m×20m.

Dijkstra"s algorithm is applied on cost map to get optimal path between predefined start and end points. In order to compare SP with conventional method, a path was designed by a skill expert who is familiar to study area. The cost map was classified to three classes: high cost, medium cost and law cost to calculate construction cost of designed paths by expert and also. The designed paths were delineated in field and all of the designed paths positions were recorded global position system (GPS). Ultimately, these last paths were compared from construction cost and the length of paths point of view.

3 Results

3.1 Zoning map of the road construction cost

Zoning map of the cost was prepared by integrating of five factors include terrain slope, hydrology, geology formations, soil texture and road slope in study area and these factors were weighted by expert. This map contains 60160 pixels and since values of these pixels were different, all of values were normalized between zero to one.

3.2 The map-base paths

Figure 1 shows the two paths. These paths were designed by SP and GIS and conventional method on the topographic map. Then, the length and construction cost of both of these paths were calculated using zoning map of cost (table 1). The length and construction cost of the path designed by the algorithm were 55% and 65% lower than the length and construction cost of the path designed by expert before correction in the field.

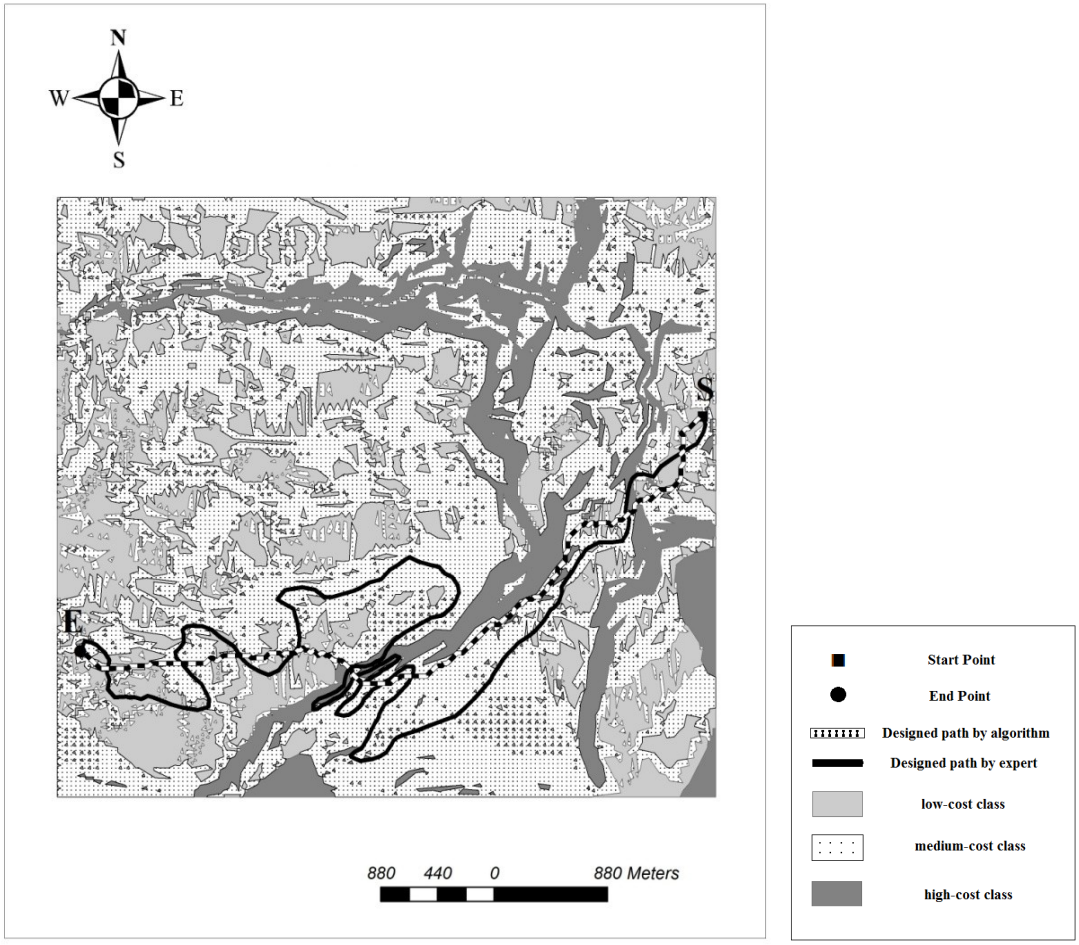

Figure 1: The map of designed paths from start point to end point before correction in the field

Table 1: Calculation the length and cost of the designed paths before correction in the field

	Road length (kilometer)	Estimated cost (Rial)
Designed road by expert	14.333	7044000000
Designed road by shortest path algorithm	6.547	2504000000

3.3 The field–base paths using

The real position of paths in the field from start point to end point is illustrated in figure 2. The result showed that the path designed by SP compared to expert design has lower length and construction cost and these differences are 1.753 km and 45800 USD, respectively (table 2). In other word, the length and construction cost of designed path using the algorithm from start point to end point and after correction in the field were 19% and 21% lower than designed by expert, respectively.

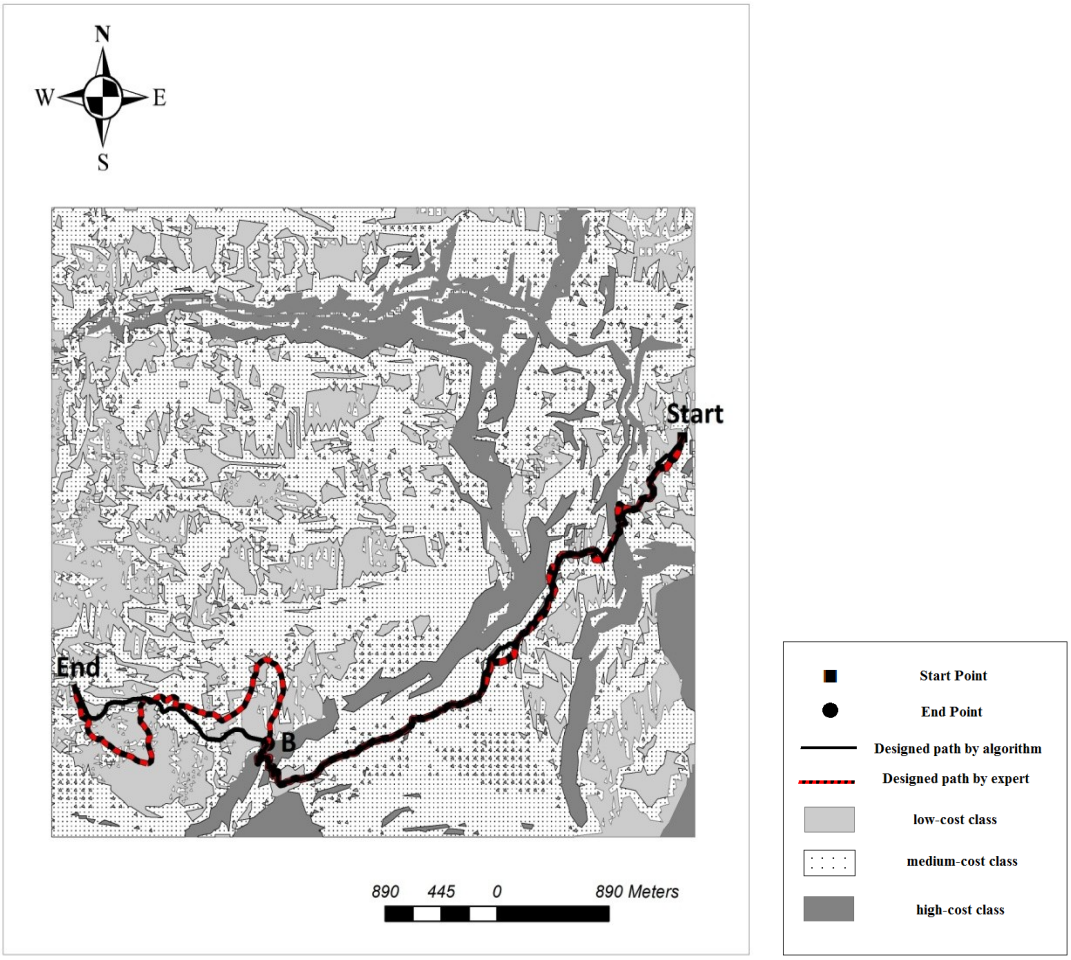

Figure 2: The map of designed paths from start point to end point after correction in the field

Table 2: Calculation the length and cost of the designed paths after correction in the field

	Road length (kilometer)	Estimated cost (Rial)
Designed road by expert after correction in the field	9.181	4442000000
Designed road by shortest path algorithm after correction in the field	7.428	3526000000

4 Discussion and conclusion

Assessment of the designed paths by shortest path algorithm and by expert before correction in the field

The reason of differences in respect to length and construction cost can be explained by the fact that since manual designing is conducted only with regard area slope. Usually, other effective maps are not taken in consideration , so that main part of path designed by expert was located in costly area. for example, if the path of designed road is located in 80 m margin of main river, this area is regarded as costly area because this lead to law stability of slopes and slop sliding, and also result in some environment effects. Thus the path designed by expert passed through from these areas and thereby we can see that this path passes

through the costly area. The characteristic of shortest path algorithm is that it selects the lowest weights with shortest distance. According to the obtained result, it can be state that shortest path algorithm passes through between two points that have the lowest weights and thereby have the lowest cost.

Assessment of the designed paths by the shortest path algorithm and by expert after correction in the field

It is noteworthy that in the areas that has limitations in respect to designing, the length and cost different between paths designed by the algorithm and by expert is negligible. Because in this situation, imposed condition lead to similarity between expert opinion and the algorithm. It can be suggested that that regarding to results of the present research, using shortest path algorithm to designing forest one can design paths with lower length and construction cost. The Results of this research also shows that combination of GIS and shortest path algorithm is feasible and despite low precision of data in the study area, one can uses this as a guide to select best path and this can be quickly implemented.

5 References

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