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Forest roads planning and construction in Iranian forestry

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The total length of Hyrcanian forest roads in Iran at the end of year 2009 was about 10000 km. Forest roads facilitate timber harvest and attainment of other multiple use objectives requires a high capital investment. A mistake in planning a road, such as ignoring the effects of environmental and other parameters leads not only to the waste of public investment but also to adverse environmental impacts and increase maintenance costs. In Iranian forestry system, road planning and building process can be partitioned into network planning, transferring network from the plan to the ground, mapping, data processing and sections design, right-of-way felling, pioneering, right-of-way logging, clearing and grubbing, excavation and embankment, subgrade finishing and surfacing. Nowadays the GIS techniques have been suggested to design the optimal forest road density in Northern forest of Iran. The GIS and computerized analyzing by AutoCAD and RoadEng softwares helps to economize time, costs and to minimize environmental damages.

Key words: Forest road, planning, building, computer softwares, Iran.

INTRODUCTION

The forest roads building for the Iranian forests to facilitate timber harvest and attainment of other multiple use objectives requires a high capital investment. A mistake in planning a road, such as ignoring the effects of environmental and other parameters, leads not only to the waste of public investment, but also to adverse environmental impacts and increase maintenance costs (Heralt, 2002). In previous, different formula were proposed by scientists for evaluating the alternatives of forest road network (Segebaden, 1964; Sundberg, 1976). Advances in personal computers (PCs) have increased interest in computer-based road-design systems to provide rapid evaluation of alternative alignments (Akay, 2006). LIDAR, one of the fastest growing systems in the field, can provide a high-resolution and accurate DEM. This system was applied for designing forest roads in Turkey (Akay, 2004). In the past years, the mixed integer mathematical programming and heuristic algorithms such as TIMBRI, NETWORK, TRANSHIP, MINCOST, NETCOST and NETWORK 2000 have been used to find the appropriate solution for certain fixed and variable cost problem (Ghaffarian and Sobhani, 2007). RoadEng software (Forest Engineer version, see www.softree.com) is a state-of-the-art designing tool which was used for detailed planning of road (Enache, 2009).

Iran government is the owner of almost all forests in Iran. Only northern forests of Iran or Hyrcanian forest zone are commercial and industrial. Therefore, for these areas forest roads need to be constructed such a way that forestry workers and machines can gain access to operational sites and carry out operations safely and efficiently. Northern forests of Iran are run by Government Forest Enterprises. For this reason planning, construction and maintenance of fixed type forest roads is the most important infrastructure establishment. The Iranian Government carries it out along with other forestry operations.

Forest roads should be planned consisted with the land structure involved, and during the planning of roads, the descents and ascents should be provided as to allow a minimum amount of excavation. Furthermore, dozers should in no case be used during the construction of roads, instead; excavators should be used (Parsakhoo et al., 2008). In recent years, excavator usage has become current in the Hyrcanian forests due to its environmental

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Table 1. History of forest roads construction in Hyrcanian zone based on reports of the technical office of Iranian forests and rangelands organization in 2010.

Construction period (Year)	1960 - 1978	1979 - 1988	1989 - 1992	1993 - 2000	2000 - 2009	Total
Forest road (Km)	1850	1600	1270	1280	4000	10000

aspects. Furthermore, the crawler bulldozers are the other machines which use in earth working operation. Approximately 80% of forest roads are constructed by bulldozer (Parsakhoo and Hosseini, 2009). One major factor preventing the more usage of excavators is their low productivity.

In mountain region of the Hyrcanian forests of Iran, road building is difficult due to larger quantities of stones and rocks. Thus at these regions, rock blasting is frequently performed by use of explosive agents with traditional methods of blasting such as dynamite and non-explosive demolition agents such as expansive chemical materials, rock cracker, CARDOX and rarely hydraulic hammer. Then the bulldozer and hydraulic excavator are used to remove broken stones. The detonation of non-explosive matters in the holes is for protection of the trees in adjacent zones, since it avoids the throwing around of rocks (Parsakhoo and Lotfalian, 2009).

The forest-road construction process can be partitioned into eleven main steps as follow: (1) network planning, (2) transferring network from the plan to the ground, (3) mapping, data processing and sections design, (4) right-of-way felling, (5) pioneering, (6) right-of-way logging, (7) clearing and grubbing, (8) excavation and embankment, (9) subgrade finishing and (10) surfacing. In this study we have focused on forest roads planning and building process in Iran forestry.

Network planning

The forest road network is planned first on the topographic map and then is established in the field by using a compass, clinometers, paint or flagging tapes. Following equations are used to calculate the optimum density of forest roads and networking percentage. In the northern forests of Iran, the case studies on selection cutting and skidding operations showed that optimal road density ranged from 9 to 28 m ha^{-1} for different areas (Mostafanejad, 1995; Lotfalian, 2001; Naghdi, 2004). Most of these studies used minimization of total cost of roading and skidding. This range of road is not adequate for managing northern forest of Iran. In Austria, the road density is 49.1 m ha^{-1} for small forests less than 200 ha (Ghaffarian et al., 2009), whereas in north of Iran the road density is 5.4 m ha^{-1} for 1850000 ha forest.

$$X_{opt} = \sqrt{\frac{khv}{m}} \quad [1]$$

$$R_{density} = \frac{R_{Length}}{A} \quad [2]$$

$$R_{spacing} = \frac{10000}{R_{density}} \quad [3]$$

$$T_{distance} = \frac{R_{spacing}}{2} \quad [4]$$

$$S_A = (R_{spacing} \times R_{Length}) - Cc \quad [5]$$

$$E = \frac{S_A}{A} \times 100 \quad [6]$$

Where X_{opt} is optimum density of roads (km/100 ha), k is transportation coefficient ($\cong$ 0.5), h is skidding cost for 1m^3/km, v is harvesting possibility in 100 ha (m^3), m is annual cost of road, $T_{distance}$ is transportation distance (m), S_A is skidding area (ha), Cc is common coverage, E is networking percentage, A is total area (ha), $R_{spacing}$ is distance between roads (m).

The total length of Hyrcanian forest roads in Iran at the end of year 2009 was about 10000 km (Table 1). Roads network planning and standard methods for their construction are performed according to principle of the bulletin No. 131 (Sarikhani and Majnonian, 1994) and 148 (Sarikhani and Majnonian, 1999), pub-lished by Plane and Budget Organization of Iran (PBOI). In Turkey, Forest road planning is conducted in accordance with the Commu-niqué no. 292 (OGM, 1984) by Directorate General of Forests in Turkey (Gumus, 2009).

Transferring network from the plan to the ground

Prior to the construction activity the design information has to be moved from the plan to the ground. This is accomplished by staking or painting with yellow color on trees trunk.

Mapping, data processing and sections design

The computer software and hardware is extensively and effectively used especially in the developed countries for the solutions of com-plex problems. The facilities offered by the computer technology are used to great extent in forestry also as in numerous other areas. AutoCAD and ROAD Eng softwares are used to design forest roads profiles and their calculations in the company of Mazandaran wood and paper industry. Vertical alignments refer to the lines that connect the surveyed points in a longitudinal profile in AutoCAD software. Line, Arc, Circle, Snap, Point style and Dimension commands are used to design curves in AutoCAD software. Cross sections and profiles can be extracted from AutoCAD software. Output can be directed to a printer or export to ROAD Eng software to calculate earth working volume.

Figure 1. Loading operation by HSM 904 skidder in Dales Kheil forest (Rafiei et al., 2009).

Figure 2. Clearing and grubbing by hydraulic excavator in Agha Mashhad forest of Hyrcanian zone.

Right-of-way felling

After designing cross sections and vertical alignments and calculating earthwork volume, the trees which have located in right-of-way limitation are marked and then are felled. In other words, right-of-way felling involves cutting down and bucking the trees in the right of-way. In addition hazardous snags and unsafe trees adjacent to the right-of way should also be felled at this time. The right of way is opened by chainsaw operator. According to Forest and rangeland organization of Iran the Clearing width should be 15 - 20 m.

Pioneering

Pioneering involves building a temporary construction access (pioneer road) along the route of the road project. The mean width of pioneer road in Hyrcanian forests of Iran is 4 m (Parsakhoo et al., 2009).

Right-of way logging

Right-of way logging involves removing merchantable logs from the right-of way. Once the trees have been felled within the clearing limits, road construction activities will start by log removal from the construction area. Often, a wheeled skidder is used to skid (transport) the logs to a landing. Loading operations can be done by this skidder on a truck (Figure 1). In some countries Log removal is done by means of chain attached to the bucket's hook of hydraulic excavator. Though using GMC machines imposes higher loading hourly costs, the production rate is lower as compared to the front grapple loader in wood loading operation in Hyrcanian zone of Iran (Sobhani et al., 2007).

Clearing and grubbing

One of the first steps in forest road construction is clearing and grubbing. The method of disposal of clearing debris is important to the future stability of the road. The clearing debris must be removed from the area of the road prism to eliminate the bridging effect that occurs when dirt is deposited against the debris (Figure 2). This also eliminates a safety hazard to anyone working below the road. Clearing and grubbing involve two separate operations: (a) clearing (removing un- merchantable logs, brush, and other debris from the right-of-way), and (b) grubbing (digging out and removing stumps from the right-of-way).

Excavation and embankment

Excavation and embankment involve construction of the subgrade. Excavated material is sidecast, drifted (pushed) a short distance, or end hauled. Fills also are compacted. In some of the important tree stands, marshy, hilly and stoniness terrain of the northern forests of Iran, using excavators not only replaced bulldozers in forest road construction but also improved the quality of roads while reducing environmental impacts of these complex engineering structures. The features and advantages of the hydraulic excavator in forest road construction are ability to build the drainage structures, excavation, digging, loading, dredging, stump grubbing, pipe laying, soil and stone materials side cast and breaking the stones and rock by hydraulic hammer. However, approximately 80% of forest roads are still constructed by bulldozer (Figure 3). One major factor preventing the more usage of excavators is their low productivity. In Hyrcanian Forests of Iran, The mean production rates for bulldozer Komatsu D60 in the slopes

Figure 3. Excavation by bulldozer in Khul Kheil forest of Hyrcanian zone.

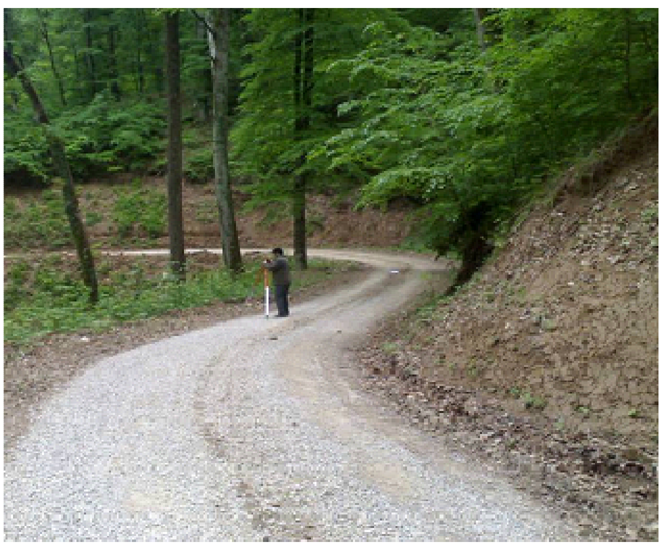

Figure 4. Balanced and prepared forest roads after subgrading and surfacing in Lat Talar forest.

30 - 70% in productive time are 144.92 m^3 h^{-1} and 22.87 m h^{-1} (Parsakhoo et al., 2009). Moreover, the mean production rates for the pc 220 Komatsu excavators are 60.13 m^3 h^{-1} and earthwork 14.76 m h^{-1} when the mean depth of excavation or cutting was 4.27 m^3m^{-1}, respectively (Parsakhoo et al., 2008). Ozturk et al. (2009) reported that the maximum length and minimum length of constructed fill slope by bulldozer was found to be 2 and 50 m on 10 and 80% slope gradient, respectively. So, the environmental damages of the forest roads constructed by the bulldozer are generally bigger. Damages are especially observed in steep terrain. In advance, these results were exactly detected by Parsakhoo (2008) in comparing the bulldozer and excavator performance for road construction in Hyrcanian Forests of Iran.

Subgrade finishing

Subgrade finishing includes installing ditches and culverts and shaping the road bed (in slope road, out slope road and crowned road). The condition of the subgrade is critical to the performance of the road surfacing.

Surfacing

Surfacing involves laying the base course (if needed) and surface course (rock or pavement). Once the gravel has been applied on the running surface the final shaping and smoothing will usually be provided by means of a grader. Finally, following up the grader is a vibration roller for proper compaction. Compaction is the process of increasing the density and the strength of the soil. The effectiveness of the compacting process will be affected by gradation of gravel material applied, its moisture content and the compact effort. Proper compaction of fill material is not only the key to a stable, balanced road design but also results in a significant reduction of maintenance cost and helps to prevent washing away of very loose silts and fine gravels when there is heavy rain (Figure 4).

Conclusion

Forest roads are the most important foundation for sustainable forestry operations. At the same time, forest roads are the first step in providing forest fire-protection in the shortest time and consequently they play an important role in the environmental protection. On the other hand, forest roads are at risk of road surface erosion and are subject to cut-and-fill slope failures. Therefore, it is important to design forest roads by considering not only cost efficiency but also the appropriate management of water and soil (Aruga et al., 2005). 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.

Some researchers applied the GIS techniques to design the optimal forest road density in northern forest of Iran (Rafetnia et al., 2006; Najafi et al., 2008; Abdi et al., 2009). They concluded that using GIS and computerized analyzing cause to economize in time, costs and to minimize environmentally damages. In this method the best area is selected to plan forest roads with overlaying effective factors such as maps of soil, slope, direction of slope, and bedrock and trees volume per hectare maps (Hosseini and Solaymani, 2006).

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