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Formulation of the Truck Selection Process for Secondary Transportation in Hyrcanian Forests

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Abstract: This study evaluates different strategic courses of action concerning the secondary transportation sector in Hyrcanian forests of Iran. The decision support method Analytic Hierarchy Process (AHP) has been utilized in the assessment of different strategies in truck selection. The assessments are based on the opinions of a group of experts in Iranian forest industries. Results showed that the truck compatible with technical characteristics of road (W=0.558) is more important than transportation cost (W=0.122) and compatible with log size (W=0.320). In addition, the five axles truck (W=0.754) is cost effective than two (W=0.065) and three axles truck (W=0.181), but In Hyrcanian Forests of Iran, the curve radius and width of roads are low. So, the passage of five axles is difficult. The tire pressure and consequently road damages by two axles trucks is more than other trucks. Finally, the trucks were arranged as three axles > two axles > five axles according to priority. The optimum truck found by the formulation is the three axles truck (W=0.634).

Key words: Transportation . Truck selection . AHP . Forest road . Transportation cost . Log size

INTRODUCTION

In forestry several modes of transportation are used. All forest logs are carried by truck, train, ship and water either directly to customers or indirectly to storage locations [1]. Forest transportation activities in Hyrcanian zone of Iran include the logs extraction within the forest and transport by trucks on roads [2, 3]. Forest roads enable the transportation of wood, personnel and equipment and provide traffic facilities and recreation for forest visitors. Thus, roads create economical, social and cultural benefits [4, 5].

The largest vehicles in secondary transportation system are usually the log truck or tractor-trailer combination [6]. The tractor-trailer is used to transport road building and logging equipment in and out of road construction or logging project, whereas the log truck is used to transport harvested logs. Some roads are designated only for log trucks. Under normal road surface conditions, the ability of a loaded log truck to negotiate adverse grades must also be considered [7]. Maximum adverse grade with a loaded log truck can be 16%-20%. On compacted rock-surfaced roads, adverse grades up to approximately 12% are usually not a problem. At or below this grade, a log truck's tractor drive wheels will usually not spin out and a truck will usually not become stuck on the hill as it might on steeper grades [8, 9].

Forest roads should have a minimum road surface width that is added to a log truck or tractor-trailer's standard wheel width of approximately 2.4 m, because the truck driver should have a steering safety margin of 60 cm on each side of the truck's steering wheels. A forest road optimization model has been developed to design an optimal alignment that minimizes the sum of construction, maintenance and transportation costs, while considering design specifications, environmental requirements and driver safety [10]. The main geometric specifications considered in the model are maximum road gradient, minimum horizontal curve radius and minimum vertical curve length [11, 12].

In recent years, the forest sector in wood and paper industries of Mazandaran province and elsewhere has been moving away from a model of economical programs in secondary transportation towards maintenance programs that also consider the potential environmental impacts caused by trucks or trailers traffics [13]. So, selecting the best secondary transportation machines is necessary for scientific management in this company [14].

The analytical hierarchy processes (AHP) have already been applied in a wide variety of industries and programs including forest road maintenance and logs

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transportation systems. AHP is a method for formulating and analyzing decisions. The AHP can also be utilized to rank the importance of various alternatives [15]. The aims of this study are to evaluate the relative weights of effective factors on truck selection and to evaluate the formulated strategy alternatives of the forest transportation sector for the future of Hyrcanian forests.

MATERIALS AND METHODS

Site description: This study was conducted in forests which were under management of the company of wood and paper industries. This company with an area of 200000 hectare is located in south of sari city, Mazandaran province, Iran. Forest roads with total length of 1000 kilometer cover the forests of this company (Fig. 1). Roads network planning and standard methods for their construction are performed according to principle of the bulletin No. 131 and 148, published by Plane and Budget Organization of Iran (PBOI).

Analytical Hierarchy Process (AHP): The AHP is being used widely in corporate planning for resource allocation purposes and on international scale in the developing countries to determine priorities for transport, industrial and agricultural infrastructure [16]. The AHP is a method for breaking down a complex and unstructured situation into its component parts, then arranging those parts (or variables) into a hierarchical order. This method is based on the assignment of numerical values for subjective judgments on the relative importance of each variable, then synthesizing the judgments to determine which variables have the highest priority [17]. So this study attempts to offer a formulation method for truck selection in secondary transportation system within the framework of the analytical hierarchy process. The assessments are based on the opinions of a group of experts in Iranian forest industries in Hyrcanian zone [18].

Model the problem as a hierarchy: The first step in the Analytic Hierarchy Process is to model the problem as a hierarchy. In doing this, participants explore the aspects of the problem at levels from general to detailed, then express it in the multileveled way that the AHP requires [19]. As they work to build the hierarchy, they increase their understanding of the problem of its context and of each other's thoughts and feelings about both (Fig. 2). In Hyrcanian forests of Iran there are three alternatives of trucks for secondary transportation from forest depots to factory's yard. The schematic of this process is shown in Fig. 3.

AHP is based on determining the relative priorities (weighting) of the criteria by pairwise comparison. In pairwise comparison, the question is asked that "how many times is a criterion more important than another one?" and it is answered according to the scale in Table 1.

Relative priority of the criteria and alternatives: The calculation of the relative weights of the criteria such as cost, truck compatible with technical characteristics of

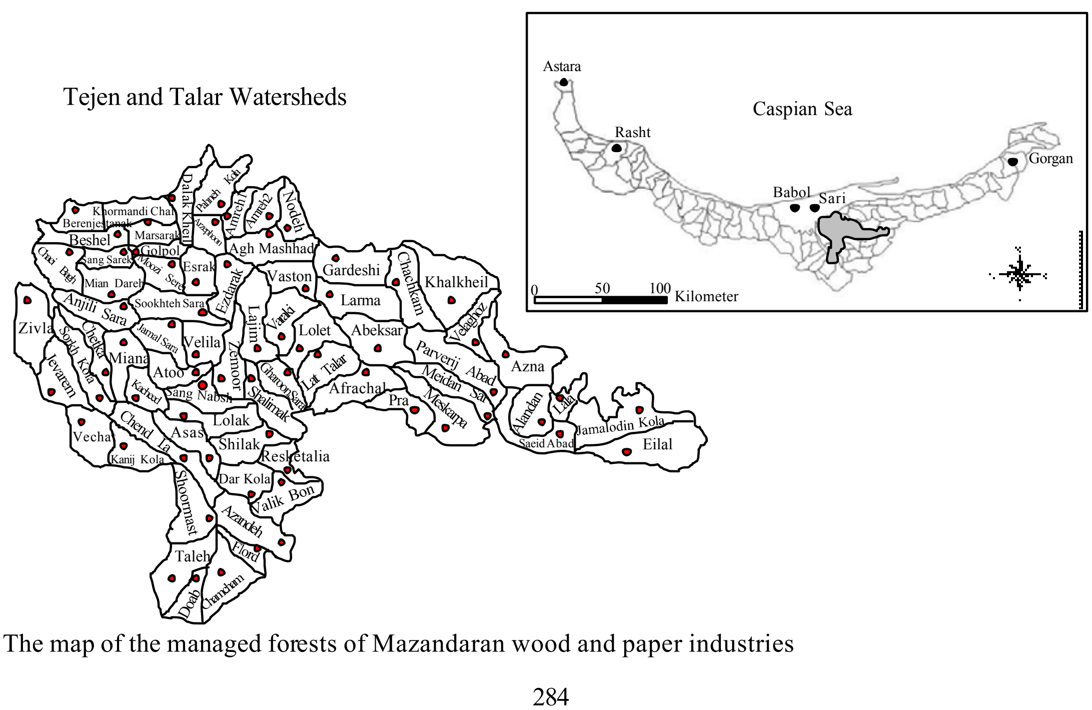

Fig. 1: The map of the managed forests of Mazandaran wood and paper industries

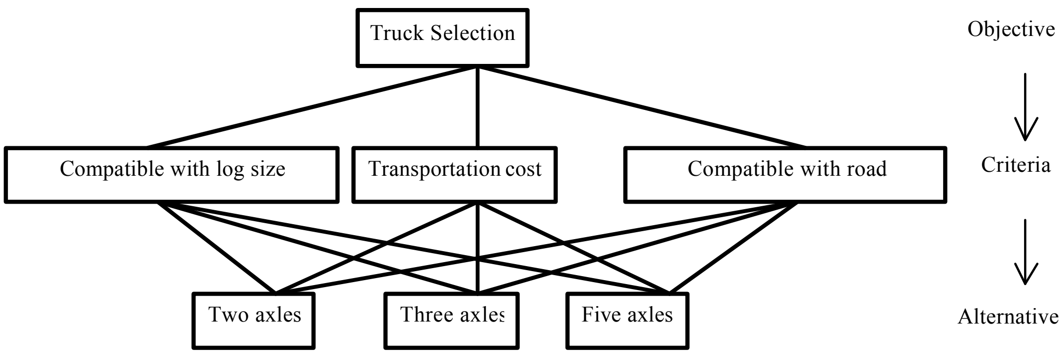

Fig. 2: Hierarchy used to select the best truck for secondary transportation

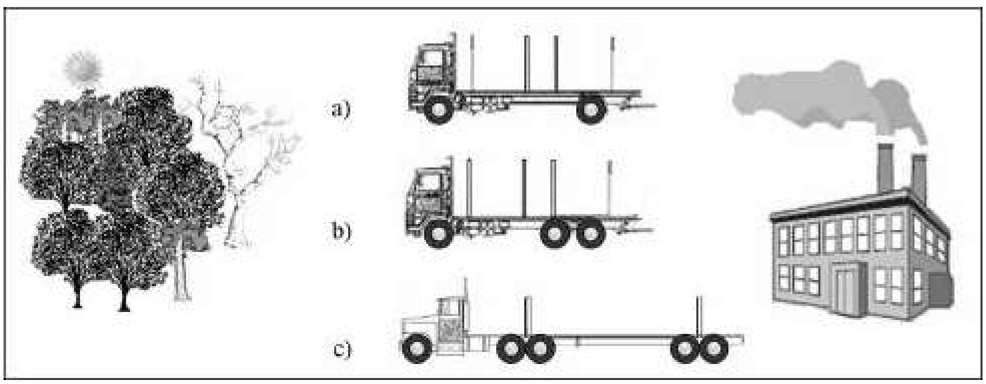

Fig. 3: (a) Two axle truck, (b) three axle truck and (c) five axle truck for secondary transportation

Table 1: Scale for pairwise comparison.

Definition	Degree of importance
Equal	1
Moderate	3
Strong	5
Very strong	7
Extreme	9

2, 4, 6 and 8 can also be used.

Hyrcanian forest roads and log size, which are relevant to the problem of truck selection, was down by geometric mean (Eq. 1).

$$G.M. = \left[\prod_{i=1}^{n} x_i\right]^{\frac{1}{n}} \qquad (1)$$

Where *G.M.* is geometric mean of matrix, X_i is matrix component and *n* is size of matrix.

Overall Priority of the Alternatives: The final weight of alternatives was calculated by equation (2).

$$Fj = \sum_{k=1}^{n}\sum_{i=1}^{m} W_k W_i (g_{ij}) \qquad (2)$$

Where *Fj* is the final weight of alternatives, W_k is the priority coefficient of criteria, W_i is the priority coefficient of sub criteria and g_{ij} is the priority coefficient of alternative in elation to criteria.

Estimation of consistency ratio: For controlling the consistency of comparison, the consistency index (*CI*) was determined as follows (Eq. 3):

$$CI = \frac{L - n}{n - 1} \qquad (3)$$

Where L is the maximum eigenvalue and *n* is the size of matrix. The L was obtained as below (Eq. 4):

$$L = \frac{1}{n}\left[\sum_{i=1}^{n} (AW_i / W_i)\right] \qquad (4)$$

Where AW_i was calculated by multiplying the matrix A by matrix W_i. The *n* is the number of matrix elements. The consistency ratio (*CR*) was determined by equation (5). Also, the random consistency index (*RI*) was extracted from Table 2.

$$CR = \frac{CI}{RI} \qquad (5)$$

Table 2: The random consistency index (R.I.) according to matrix size

n	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I	0	0.58	0.9	1.12	1.24	1.22	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.6

RESULTS AND DISCUSSION

Relative priority of the criteria and alternatives: Following matrix is the ranked results of pair-wise comparisons for the importance of criteria in the truck selection process. Results showed that the truck compatible with technical characteristics of Hyrcanian forest roads is more important than other criteria.

$$\text{G.M.} = \begin{matrix} \text{Cost} \\ \text{Road} \\ \text{Log} \end{matrix} \overset{\text{Cost} \quad \text{Road} \quad \text{Log}}{\begin{bmatrix} 1 & 1/4 & 1/3 \\ 4 & 1 & 2 \\ 3 & 1/2 & 1 \end{bmatrix}}$$

$$W_1 = \text{Transportation cost } = \sqrt[3]{(1)(1/4)(1/3)} = 0.437$$

$$W_2 = \text{Compatible with road } = \sqrt[3]{(4)(1)(2)} = 2$$

$$W_3 = \text{Compatible with log size } = \sqrt[3]{(3)(1/2)(1)} = 1.145$$

$$W_1 = \frac{0.437}{3.582} = 0.122 \quad W_2 = \frac{2}{3.582} = 0.558 \quad W_3 = \frac{1.145}{3.582} = 0.320$$

$$\text{G.M.} = \begin{matrix} \text{Cost} \\ \text{Road} \\ \text{Log} \end{matrix} \overset{\text{Cost} \quad \text{Road} \quad \text{Log}}{\begin{bmatrix} 1 & 1/4 & 1/3 \\ 4 & 1 & 2 \\ 3 & 1/2 & 1 \end{bmatrix}} = \begin{bmatrix} 0.122 \\ 0.558 \\ 0.320 \end{bmatrix}$$

Transportation cost: Forest transportation costs are the major cost component for many forest product supply chains. In order to minimize these costs, many organizations have turned to models make decisions that are extremely complex in nature. These models generally assume that input parameters are known with certainty, but in reality they are often associated with a high degree of uncertainty. One way of dealing with uncertainty is through AHP procedure [20]. In this study, the calculation of the relative weights of the alternatives comprising two (II), three (III) and five (V) axles trucks indicated that the five axles truck is cost effective than other alternatives.

$$\text{G.M.} = \begin{matrix} \text{II} \\ \text{III} \\ \text{V} \end{matrix} \overset{\text{II} \quad \text{III} \quad \text{V}}{\begin{bmatrix} 1 & 1/4 & 1/8 \\ 4 & 1 & 1/6 \\ 8 & 6 & 1 \end{bmatrix}} = \begin{cases} \sqrt[3]{1/32} = 0.315 \\ \sqrt[3]{4/6} = 0.873 \div 4.822 = \\ \sqrt[3]{48} = 3.634 \end{cases} \begin{matrix} \text{II} \\ \text{III} \\ \text{V} \end{matrix} \begin{bmatrix} 0.065 \\ 0.181 \\ 0.754 \end{bmatrix}$$

Compatible with technical characteristics of forest road: The required road width around curves on forest roads is largely determined by the difference in wheel paths between the inside front tractor wheel and the inside rear trailer wheel this difference known as off tracking is a function of the vehicle and road geometry [21]. In Hyrcanian broad leaved Forests of Iran, the horizontal curve radius (16 m) and road width (5.5 m) are low and the passage of truck with five axles is difficult [22]. So, according to following matrix, the trucks with three axles are more compatible with technical characteristics of Hyrcanian roads than the other alternatives.

$$\text{G.M.} = \begin{matrix} \text{II} \\ \text{III} \\ \text{V} \end{matrix} \overset{\text{II} \quad \text{III} \quad \text{V}}{\begin{bmatrix} 1 & 1/5 & 7 \\ 5 & 1 & 9 \\ 1/7 & 1/9 & 1 \end{bmatrix}} = \begin{cases} \sqrt[3]{7/5} = 1.119 \\ \sqrt[3]{45} = 3.557 \div 4.927 = \\ \sqrt[3]{1/63} = 0.251 \end{cases} \begin{matrix} \text{II} \\ \text{III} \\ \text{V} \end{matrix} \begin{bmatrix} 0.227 \\ 0.722 \\ 0.051 \end{bmatrix}$$

The tire pressure of two axles trucks on roadbed is high, because the weight of truck is transferred from six wheels (Maximum wheels) to ground, whereas in three axles trucks the weight of truck is transferred from ten wheels to ground. When the tire pressure on ground is high, the wheel rutting and consequently water erosion is occurred on road surface [23].

Compatible with log size and harvesting method: The silvicultural method in Hyrcanian forests is selection cutting, the harvesting method is long log tree system and the mean length of logs for beech is 5.20 m and for other species is 6.20 m So, the logs length in long log tree system is low as compared with coniferous logs length. For these reasons the five axles trucks is not suitable for log transportation in Hyrcanian forests.

$$\text{G.M.} = \begin{matrix} \text{II} \\ \text{III} \\ \text{V} \end{matrix} \overset{\text{II} \quad \text{III} \quad \text{V}}{\begin{bmatrix} 1 & 1/3 & 6 \\ 3 & 1 & 8 \\ 1/6 & 1/8 & 1 \end{bmatrix}} = \begin{cases} \sqrt[3]{2} = 1.260 \\ \sqrt[3]{24} = 2.884 \div 4.419 = \\ \sqrt[3]{1/48} = 0.275 \end{cases} \begin{matrix} \text{II} \\ \text{III} \\ \text{V} \end{matrix} \begin{bmatrix} 0.285 \\ 0.653 \\ 0.062 \end{bmatrix}$$

Overall priority of the alternatives: The results of this section states that the optimum truck found by the formulation is the three axles truck (W=0.6).

$$\text{Two} - \text{axle(Fj)} = 0.122 \times 0.065 + 0.558 \times 0.227 + 0.320 \times 0.285 = 0.226$$

$$\text{Three} - \text{axle(Fj)} = 0.122 \times 0.181 + 0.558 \times 0.722 + 0.320 \times 0.653 = 0.634$$

$$\text{Five} - \text{axle(Fj)} = 0.122 \times 0.754 + 0.558 \times 0.051 + 0.320 \times 0.062 = 0.140$$

Estimation of consistency ratio: For controlling the consistency of comparison, the consistency index was determined as follows:

$$AW_i = \begin{bmatrix} 1 & 1/4 & 1/3 \\ 4 & 1 & 2 \\ 3 & 1/2 & 1 \end{bmatrix} \times \begin{bmatrix} 0.122 \\ 0.558 \\ 0.320 \end{bmatrix} = \begin{bmatrix} 0.367 \\ 1.686 \\ 0.965 \end{bmatrix}$$

$$L = \frac{1}{3}\left[\frac{0.367}{0.122} + \frac{1.686}{0.558} + \frac{0.965}{0.320}\right] = 3.015$$

$$CI = \frac{3.015 - 3}{3 - 1} = 0.0075$$

If the *CR* is below 0.1 this shows the comparison is consistent.

$$CR = \frac{0.0075}{0.58} = 0.013$$

CONCLUSIONS

Timber harvest and transportation planning is necessary to assure cost-effective and environmentally sound harvests and to anticipate road access for future timber management. Transportation decisions in forestry appear in many planning situations and are often integrated with harvest planning as this step links supply with demand. At the same time, transportation corresponds to a large proportion of total operational costs and thus it is important to manage efficiently. In this study according to technical characteristics of forest roads, transportation cost and silvicultural and harvesting methods, the trucks with three axles must be selected for secondary transportation in forest because of lower damages to road structure, adequate load capacity and movement power.

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