FOREST ROADS LOCATING BASED ON AHP AND COPRAS-G METHODS: AN EMPIRICAL STUDY BASED ON IRAN

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Introduction

Land managers of different countries are often faced with how to optimize road networks in order to maintain all roads, trails and paths for the different purposes and reducing negative impacts on environment. Johnson *et al.* (2011) developed a spatial MCDM (Multiple criteria decision making) system to obtain weights of factors that had significant impacts on both economic and environment, combine GIS (Geographic information system) data layers, and derive a priority map of all the roads for being closed. Stakeholders aiming to survive the competition battle have to rethink the process of development and reconstruction of supply chains, and the process which may feature peculiarities, depending on the branch of industry. Jakimavicius and Burinskienė (2007) discussed problem o road network density assessment in regions and proposed GIS decision support system based on two calculation methods: TOPSIS (Technique for Order Preference by Similarity to Ideal Point) and SAW (Simple Additive Weighting). Strategy shaping of distribution network requires evaluation of number criteria, which influence the distribution system (Vasiliauskas *et al.* 2010). To increase the transportation effectiveness and quality, the interested parties (groups of people) should to coordinate their actions, cooperate with each other in solving the problems and exchange relevant information. Therefore, AHP (Analytic hierarchy process) methodology, based on pair wise comparisons of criteria, is relevant technique to determine criteria weights (significances) considering the data obtained from the respondents and experts (Sivilevicius 2011). The problem of selecting the most effective road investment projects is becoming more and more acute. Road investment project alternatives have to be apprised in an integer manner using mathematical models in addition to economic, social and environment criteria (Rudzianskaite-Kvaraciejiene *et al.* 2010). It should be noted that these aspects are interrelated and complementary, and therefore influence the appraisal of road investment projects. Rudzianskaite-Kvaraciejiene *et al.* (2010) for this purpose used expert and TOPSIS appraisal methods.

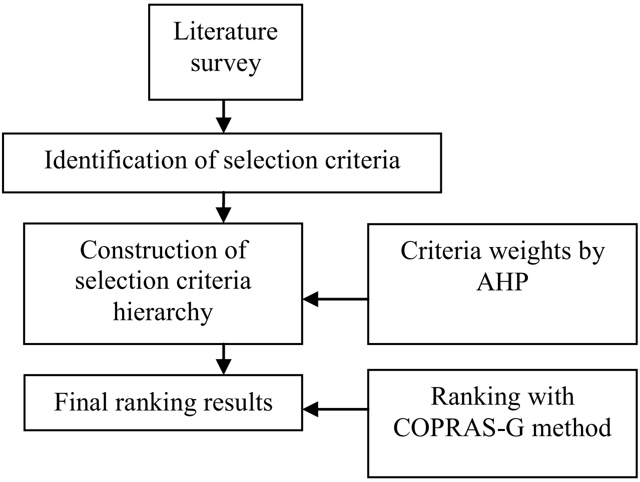
The Caspian Forest is located in the north of Iran. It covers the north facing slopes of the Alborz Mountain ranges and is classified as a temperate mountain forest. The majority of this forest is managed as an uneven aged forest (Naghdi *et al.* 2008). Forest roads are the most important infrastructural facilities to exploit forests that are renewable natural resources. Vehicles release large amount of heavy metals to environment (Mikalajūnė, Jakučionytė 2011).

Forest roads are generally planned and constructed by considering physical, economical, and environmental requirements (Naghdi, Mohammadi Limaei 2009). Tampère *et al.* (2009) presented modelling exercise aimed at ascertaining the effects of road pricing on a large road network. The main objective of this research is the maximization of social welfare gain. A road network that leads us to our goals needs to be established in order to plan forestry activities sustainably. In addition to forestry services, forest roads provide economic benefit for rural population by enabling them to market their products and help them meet their healthcare, education and other social needs. Valente and Vettorazzi (2008) presented model based on ordered weighting averaging method, integrated to a geographic information systems, in the definition of priority areas for forest conservation, also analytic hierarchy process (AHP) is used. Forest roads interact with many technical, economic, environmental and social factors to render these services. It is highly important to describe the capabilities of existing forest roads in terms o all functions assigned to them in line with forestry objectives and to define their conditions of utilization in future (Gumus 2009). At present, forests administrators are concerned with these issues and try to find suitable approaches to reduce the costs and increase the efficiency. On the other hand, not only cost of road and wood transportation and extraction must come down, but also environmental affect have to come down too. In fact, the cost of wood transportation and road constructing should be balanced by a technical forest road network that accesses the forest surface with the minimized road length (Naghdi, Babapour 2009). Manual road planning in mountainous forests, considering technical and environmental issues, is a difficult job. More recently, simultaneous information management with respect to the important factors in road planning and rapid assessment of the roads has been possible by using GIS capabilities (Naghdi, Babapour 2009; Raafatnia et al. 2006). For this purpose, more recently researchers have been using different methods such as linear programming method (Anderson, Nelson 2009), fuzzy logic (Tiryana 2005), Tabu search (Aruga 2005), genetic algorithm Keshtiarast et al. 2006) and using digital elevation model or DEM to analyze all kinds of data on forest road locating. Naghdi and Babapour (2009) prepared the stability map using soil texture and bed rock. Their results confirmed that using stability maps, GIS and AHP can be a useful method for the planning of forest road networks in mountain areas in Iran and is preferred to previous and traditional methods. In Mazandaran province that locating in the north of the Iran is so important to developed forest roads. The aim of this research is to select a location for forest road in Haraz region. After primary research three regions were selected for this research that including: Kelerd, Pelet Cheshme and Mangel. In this paper we use AHP method for calculating the weights of each criterion that shown in Table 3 and applied COPRAS-G (complex proportional assessment method with grey interval numbers) method for selecting the best place for construct the forest road.

1. Methodology

Over the past decades the complexity of economical decisions has increased rapidly, thus highlighting the importance of developing and implementing sophisticated and efficient quantitative analysis techniques for supporting and aiding economical decision-making (Zavadskas, Turskis 2011). Multiple criteria decision making (MCDM) is an advanced field of operations research, provides decision makers and analysts a wide range of methodologies, which are overviewed and well suited to the complexity of economical decision problems (Hwang, Yoon 1981; Zopounidis and Doumpos 2002; Figueira et. al. 2005). Multiple criteria analysis (MCA) provides a framework for breaking a problem into its constituent parts. MCA provides a means to investigate a number of alternatives in light of conflicting priorities.

Fig. 1: Process of Locating



Source: own

Over the last decade scientists and researchers have developed a set of new MCDM methods (Kaplinski, Tupenaite 2011; Kapliński, Tamosaitiene 2010, Tamosaitiene et al. 2010, Keršuliene et al. 2010). They modified methods and applied to solve practical and scientific problems.

Solving of modern decision making problems in most cases is based on integrated model of different approaches. Zavadskas et al. (2008b) provided a review on international and national practices in investment decision support tools in bridges and road management. Cost benefit analysis and multiple criteria analysis are principal methodologies or this reason. It is stated that multiple criteria analysis may be particularly helpful in early stages of project development, strategic planning. Cost benefit analysis is used most widely for project prioritization and selecting the final project from the set of alternatives. Brauers et al. (2008) demonstrated that the concept of multi-objective optimization of road design alternatives it is suitable tool to determine the best road design alternative from feasible discrete alternatives set.

For instance, Choi et al. (2009) applied a new raster-based GIS model that combines multiple criteria evaluation and least-cost path analysis to determine the optimal haulage routes of dump trucks in large scale open-pit mines. Vassou et al. (2006) stated that usually a subjective engineering judgment process is adopted for selecting new road alignment decisions, and so the need arose for a generic decision model to be developed to support engineers and decision-makers in selecting the optimal design. The AHP is usual tool for this reason. The association of South East Asian Nations has recently decided to develop a new highway network to connect countries in the association by roads to enhance cultural integration and economic growth of Asian countries. Priotization of investments for 32 road sections in the highway network construction was evaluated using a two-step hierarchical fuzzy multiple criteria decision making process (Lee *et al.* 2011). Erden and Coskun (2010) presented study which combines GIS and AHP to provide decision makers with a model to ensure optimal site location(s).

1.1 Analytic Hierarchy Process

Analytic hierarchy process, proposed by Thomas L. Saaty in 1971 (Saaty 1971, 1980), is able to solve the multiple criteria decision making problems. AHP utilize three principles to solve problems (Aydogan 2011):

1) structure of the hierarchy,
2) the matrix of pair wise comparison ratios, and
3) the method for calculating weights.

AHP can decompose any complex problem into several sub-problems in terms of hierarchical levels where each level represents a set of criteria or attributes relative to each sub-problem. During the past, there were 13 major conditions that have discovered to well fit the utilization of AHP such as setting priorities, generating a set of alternatives, choosing a best policy alternatives, determining requirements, allocating resources, predicting outcomes, measuring performance, designing system, ensuring system stability, optimization, planning, resolving conflict, and risk assessment. Besides, recent conditions encompass to reduce the influence of global climate change (Berrittella *et al.* 2007), to choose university faculty (Grandzol 2005), to decide the location of offshore manufacturing plants (Walailak, McCarthy 2002), to evaluate risk in conducting cross-country petroleum pipelines (Dey 2003), and to manage U.S. watersheds (De Steiguer *et al.* 2003) and so on.

It has been well utilized in several fields that require the chosen of alternatives and the weight exploration of evaluation criteria like business (Angelou, Economides 2009), industry (Chen, Wang 2010; Fouladgar *et al.* 2011), and healthcare (Liberatore, Nydickl 2008). Coultier *et al.* 2006 stated that the management of low-volume roads has transitioned from focusing on maintenance designed to protect a capital investment in road infrastructure to also include environmental effects. They used AHP method to solve this problem. Callaos *et al.* (2003) applied model based on AHP scale to select the route path. Forest and low-class roads substantially differ from main roads in terms of extensiveness, databank availability, and profitability, which stress the need for a sophisticated decision making mechanism for assessment, selection and maintenance programs (Khademi, Sheikholeslami 2010). Khademi and Sheikholeslami proposed for stakeholders to use preliminary procedures including the Conference and the Delphi survey to determine the list of specialists for the AHP and criteria which were then fed into AHP. The problem's solution results indi-

Tab. 1: The Ratio Scale and Definition of AHP

Intensity of importance	Definition	Description
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgment slightly favour one over the other.
5	Much more important	Experience and judgment strongly favour one over the other.
7	Very much more important	Experience and judgment very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate values	When compromise is needed

Source: Saaty 1990

cate the significant contrast between conventional individualistic decisions and those made through incorporating systemic specialist comments.

Based on its unique merit, this method is used in solving many sophisticated decision-making issues by different researchers (Dong *et al.* 2008, 2010; Lin *et al.* 2008; Wong, Li, 2008; Arunraj, Maiti, 2010; Plebankiewicz 2009; Lin 2010; Ulubeyli, Kazaz 2009; Medineckienė *et al.* 2010).

The recent applications of AHP method in shortly are listed below:

- Ananda and Herath (2008) AHP used to synthesise stakeholder preferences related to regional forest planning and to incorporate stakeholder preferences;
- Cebeci (2009) presented a fuzzy AHP approach to select a suitable enterprise resource planning system for textile industry;
- Wu *et al.* (2009) applied fuzzy AHP (FAHP) and the three MCDM analytical tools of SAW, TOPSIS, and VIKOR were respectively adopted to rank the banking performance and improve the gaps with three banks;
- Podvezko (2009) considered an application of AHP technique to more complicated cases;
- Colombo *et al.* (2009) proved that judicious use of AHP by experts can be used to represent citizen views;
- Maskeliūnaite *et al.* (2009) solved problem of quality of passenger carriage;
- Podvezko *et al.* (2010) ranked contracts;
- Štemberger *et al.* (2009) applied in business processes management;
- Sivilevičius and Maskeliūnaite (2010) solved problem of improving the quality for passenger transportation;
- Bojovic *et al.* (2010) applied it to determine of an optimal rail freight car fleet composition;
- Steuten *et al.* (2010) used AHP weights to fill missing gaps in Markov decision models;
- Hadi-Vencheh and Niazi-Motlagh (2011) presented an improved voting AHP-data envelopment analysis methodology for suppliers' selection;
- Yan *et al.* (2011) presented new developments and maintenances of the existing infrastructures under limited government budget and time.

The calculation of AHP is adopted ratio scale for developing pair-wise comparison matrix. It typically can be categorized into 5 sub-scales based on different levels of importance: Equal importance, somewhat more important, much more important, very much more important, and absolutely more important. There are still 4 sub-scales with each level of importance between above 5 major sub-scales. Therefore, there is an amount of nine sub-scales. The ratio values from 1 to 9 are given to each sub-scale as we summarized in Table 1.

The calculation steps of AHP are presented as follows (Saaty 1990):

Step 1. Establish the pair-wise comparison matrix A by using the ratio scale in Table 3-6:

Step 2. Let $C_1, C_2, \ldots, C_n$ denote the set of elements, while a_{ij} represents a quantified judgment on a pair of elements C_i, C_j. This yields an n-by-n matrix A as follows:

$$A=[a_{ij}]=\begin{matrix} & C_1 & C_2 & \cdots & C_n \\ C_1 & 1 & a_{12} & \cdots & a_{1n} \\ C_2 & & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C_N & \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{matrix}, \qquad (1)$$

where $a_{ii}=1$, $a_{ji}=\frac{1}{a_{ij}}$, $i=\overline{1,n}$ and $j=\overline{1,n}$

In matrix A, the problem becomes one of assigning to the n elements $C_1, C_2, \ldots, C_n$ a set of numerical weights (significances) $q_1, q_2, \ldots, q_n$ that reflects the recorded judgments. If A is a consistency matrix, the relations between weights q_i and judgments a_{ij} are simply given by $\frac{q_j}{q_i}=a_{ij}$ (for $i=\overline{1,n}$ and $j=\overline{1,n}$).

Saaty (1990) suggested that the largest eigenvalue λ_{max} would be

$$\lambda_{max}=\sum_{j=1}^{n} a_{ij}\frac{q_j}{q_i}. \qquad (2)$$

If A is a consistency matrix, eigenvector X can be calculated by

$$(A-\lambda_{max}I)X=0. \qquad (3)$$

Saaty proposed utilizing the consistency index (*C.I.*) and random index (*R.I.*) verify the consistency of the comparison matrix (consistency ratio, *C.R.*). *C.I.* and *C.R.* are defined as follows (Saaty, Vargas 1991):

$$C.I.=\frac{\lambda_{max}-n}{n-1}, \qquad (4)$$

$$C.R.=\frac{C.I.}{R.I.}, \qquad (5)$$

where the *R.I.* represents the average consistency index, which is also named as the random index, was computed by as the average consistency of square matrices of various orders n which he filled with random entries. Average consistency values of these matrices are given by Saaty and Vargas (1991) as provided in Table 2. If the $C.R. < 0.1$, the estimate is accepted; otherwise, a new comparison matrix is solicited until $C.R. < 0.1$.

1.2 COPRAS-G Method

In order to evaluate the overall efficiency of a project, it is necessary to identify selection criteria, to assess information, relating to these criteria, and to develop methods for evaluating the criteria to meet the participants' needs. Decision analysis is concerned with the situation in which a decision-maker has to choose among several alternatives by considering a particular set of criteria. For this reason Complex proportional assessment (COPRAS) method (Zavadskas, Kaklauskas 1996) can be applied. This method was applied to the solution of various problems in construction (Kaklauskas *et al.* 2006, Tupenaite *et al.* 2010) and assessment of road design solutions (Zavadskas *et al.* 2007). The most of alternatives under development always deals with future and values of criteria cannot be expressed exactly. This multi-criteria decision-making problem must be determined not with exact criteria values, but with fuzzy values or with values in some intervals.

Zavadskas *et al.* (2008a) presented the main ideas of complex proportional assessment method with grey interval numbers (COPRAS-G) method. The idea of COPRAS-G method with criterion values expressed in intervals is based on the real conditions of decision making and applications of the Grey systems theory (Deng 1982, 1988). The COPRAS-G method uses a stepwise ranking and evaluating procedure of the alternatives in terms of significance and utility degree.

The recent developments of decision making models based on COPRAS methods are listed below:

- Ginevičius and Podvezko (2008) evaluated of banks from the perspective of their reliability for clients;
- Datta et al. (2009) solved problem of determining compromise to selection of supervisor;
- Bindu Madhuri et al. (2010) presented model for selection of alternatives based on COPRAS-G and AHP methods;

Tab. 2: Values for R.I.

n	2	3	4	5	6	7	8
R.I.	0.00	0.52	0.90	1.12	1.24	1.32	1.41

Source: Saaty, Vargas 1991

- Uzsilaityte and Martinaitis (2010) investigated and compared different alternatives for the renovation of buildings taking into account energy, economic and environmental criteria while evaluating impact of renovation measures during their life cycle;
- Chatterjee et al. (2011) presented materials selection model based on COPRAS and EVAMIX methods;
- Karbassi et al. (2011) applied COPRAS method to solve effectiveness problem of energy using in buildings;
- Podvezko (2011) presented comparative analysis of MCDM methods (SAW and COPRAS).

The procedure of applying the COPRAS-G method consists in the following steps (Zavadskas *et al.* 2009):

1. Selecting the set of the most important criteria, describing the alternatives;
2. Constructing the decision-making matrix $\otimes X$:

$$\otimes X=\begin{bmatrix}[\otimes x_{11}][\otimes x_{12}]\dots[\otimes x_{1m}]\\ [\otimes x_{21}][\otimes x_{22}]\dots[\otimes x_{2m}]\\ \vdots \quad \vdots \quad \ddots \quad \vdots\\ [\otimes x_{n1}][\otimes x_{n2}]\dots[\otimes x_{nm}]\end{bmatrix}=$$

$$=\begin{bmatrix}[\underline{x}_{11};\overline{x}_{11}]\ [\underline{x}_{12};\overline{x}_{12}]\dots[\underline{x}_{1m};\overline{x}_{1m}]\\ [\underline{x}_{21};\overline{x}_{21}][\underline{x}_{22};\overline{x}_{22}]\dots[\underline{x}_{2m};\overline{x}_{2m}]\\ \vdots \quad \vdots \quad \ddots \quad \vdots\\ [\underline{x}_{n1};\overline{x}_{n1}][\underline{x}_{n2};\overline{x}_{n2}]\dots[\underline{x}_{nm};\overline{x}_{nm}]\end{bmatrix}; \tag{6}$$

$$i=\overline{1,m} \text{ and } j=\overline{1,n},$$

where $\otimes x_{ij}$ is determined by $\underline{x}_{ij}$ (the smallest value, the lower limit) and $\overline{x}_{ij}$ (the biggest value, the upper limit).

3. Determining significances (weights) of the criteria q_j.
4. Normalizing the decision-making matrix $\otimes X$:

$$\tilde{\underline{x}}_{ij}=\frac{\underline{x}_{ij}}{\frac{1}{2}\left(\sum_{i=1}^{m}\underline{x}_{ij}+\sum_{i=1}^{m}\overline{x}_{ij}\right)}=\frac{2\underline{x}_{ij}}{\sum_{i=1}^{m}\underline{x}_{ij}+\sum_{i=1}^{m}\overline{x}_{ij}};$$

$$\tilde{\overline{x}}_{ij}=\frac{\overline{x}_{ij}}{\frac{1}{2}\left(\sum_{i=1}^{m}\underline{x}_{ij}+\sum_{i=1}^{m}\overline{x}_{ij}\right)}=\frac{2\overline{x}_{ij}}{\sum_{i=1}^{m}(\underline{x}_{ij}+\overline{x}_{ij})}; \tag{7}$$

$$i=\overline{1,m} \text{ and } j=\overline{1,n}.$$

In formula (7) $\underline{x}_{ij}$ is the lower value of the j criterion in the alternative i of the solution; $\overline{x}_{ij}$ is the upper value of the criterion j in the alternative i of the solution; n is the number of criteria; m is the number of the alternatives compared.

Then, the decision-making matrix is normalized:

$$\otimes \tilde{X}=\begin{bmatrix}[\tilde{\underline{x}}_{11};\tilde{\overline{x}}_{11}]\ [\tilde{\underline{x}}_{12};\tilde{\overline{x}}_{12}]\dots[\tilde{\underline{x}}_{1m};\tilde{\overline{x}}_{1m}]\\ [\tilde{\underline{x}}_{21};\tilde{\overline{x}}_{21}][\tilde{\underline{x}}_{22};\tilde{\overline{x}}_{22}]\dots[\tilde{\underline{x}}_{2m};\tilde{\overline{x}}_{2m}]\\ \vdots \quad \vdots \quad \ddots \quad \vdots\\ [\tilde{\underline{x}}_{n1};\tilde{\overline{x}}_{n1}][\tilde{\underline{x}}_{n2};\tilde{\overline{x}}_{n2}]\dots[\tilde{\underline{x}}_{nm};\tilde{\overline{x}}_{nm}]\end{bmatrix}; \tag{8}$$

5. Calculating the weighted normalized decision matrix $\otimes\hat{X}$. The weighted normalized values $\otimes\hat{x}_{ij}$ are calculated as follows:

$$\otimes\hat{x}_{ij}=\otimes\tilde{x}_{ij}\cdot q_j \quad or \quad \hat{\underline{x}}_{ij}=\tilde{\underline{x}}_{ij}\cdot q_j \quad and \quad \hat{\overline{x}}_{ij}=\tilde{\overline{x}}_{ij}\cdot q_j. \tag{9}$$

In formula (9), q_j is the significance of the $j-th$ criterion.

Then, the normalized decision-making matrix is:

$$\otimes \hat{X}=\begin{bmatrix}[\otimes\hat{x}_{11}][\otimes\hat{x}_{12}]\dots[\otimes\hat{x}_{1m}]\\ [\otimes\hat{x}_{21}][\otimes\hat{x}_{22}]\dots[\otimes\hat{x}_{2m}]\\ \vdots \quad \vdots \quad \ddots \quad \vdots\\ [\otimes\hat{x}_{n1}][\otimes\hat{x}_{n2}]\dots[\otimes\hat{x}_{nm}]\end{bmatrix}=$$

$$=\begin{bmatrix}[\hat{\underline{x}}_{11};\hat{\overline{x}}_{11}]\ [\hat{\underline{x}}_{12};\hat{\overline{x}}_{12}]\dots[\hat{\underline{x}}_{1m};\hat{\overline{x}}_{1m}]\\ [\hat{\underline{x}}_{21};\hat{\overline{x}}_{21}][\hat{\underline{x}}_{22};\hat{\overline{x}}_{22}]\dots[\hat{\underline{x}}_{2m};\hat{\overline{x}}_{2m}]\\ \vdots \quad \vdots \quad \ddots \quad \vdots\\ [\hat{\underline{x}}_{n1};\hat{\overline{x}}_{n1}][\hat{\underline{x}}_{n2};\hat{\overline{x}}_{n2}]\dots[\hat{\underline{x}}_{nm};\hat{\overline{x}}_{nm}]\end{bmatrix}. \tag{10}$$

6. Calculating the sums P_i of criterion values, whose larger values are more preferable:

$$P_i=\frac{1}{2}\sum_{j=1}^{k}(\hat{\underline{x}}_{ij}+\hat{\overline{x}}_{ij}). \tag{11}$$

7. Calculating the sums R_i of criterion values, whose smaller values are more preferable:

$$R_i=\frac{1}{2}\sum_{j=k+1}^{n}(\hat{\underline{x}}_{ij}+\hat{\overline{x}}_{ij});\ j=\overline{k,m}. \tag{12}$$

In formula (12), $(m-k)$ is the number of criteria which must be minimized.

8. Determining the minimal value of R_i:

$$R_{min}=\min_i R_i;\ j=\overline{j,m}. \tag{13}$$

9. Calculating the relative significance of each alternative Q_i:

$$Q_i=P_i+\frac{\sum_{i=1}^{m}R_i}{R_i\sum_{i=1}^{m}\cdot\frac{1}{R_i}} \tag{14}$$

10. Determining the optimality criterion K:

$$K=\max_i Q_i;\ i=\overline{1,m}. \tag{15}$$

11. Determining the priority of the alternative.
12. Calculating the utility degree of each alternative:

$$N_i=\frac{Q_i}{Q_{max}}100\%, \tag{16}$$

where Q_i and Q_{max} are the significance of alternatives obtained from Eq. (14).

2. Forest Roads Locating Model Based on AHP and COPRAS-G Method

2.1 Classification Criteria and Hierarchical Structure

In this paper we classified important criteria for forest road locating in Haraz region, Mazandaran, Iran. We consider criteria and identify themselves sub-criteria. The criteria and sub-criteria are shown in Table 3.

The criteria are considered three regions: Kelerd (A_1), Pelet cheshme (A_2) and Mangel (A_3). Analytic Hierarchy Process is used to identify the weights of criteria of forest road locating (Table 1). Its' hierarchical structure is shown in Fig.1. This structure serves to prioritize criteria and sub-criteria, to choose best locations for forest road.

2.2 Prioritization Criteria and Sub-Criteria for Forest Road Locating

For pair wise comparison decision making, a group of experts were invited to be the decision makers, because they are experienced. Information about experts is shown in Table 4.

Paired comparison matrix of criteria is one of the matrices which were completed with information of experts is shown in Table 4 as an example. AHP method is then used for prioritizing.

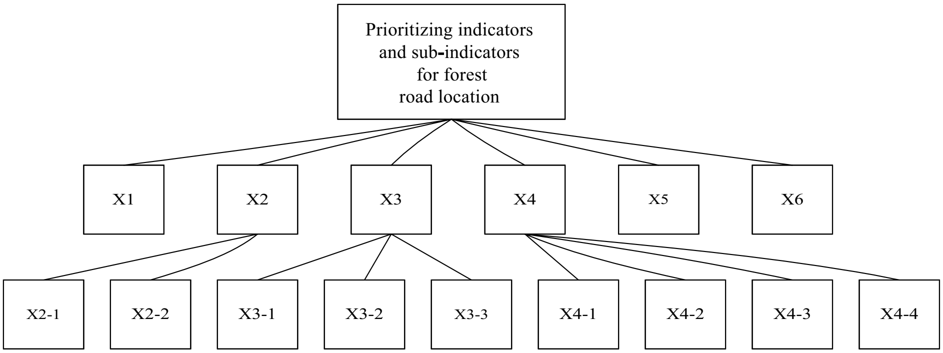
After all comparisons and weighing processes are done, the overall weight of each criterion and sub-criterion are obtained (Table 5). According the weights in Table 5, x_1, x_{3-1} and x_{3-2} were three of the most important considering criteria.

Tab. 3: Criteria and Sub-Criteria for Forest Road Location

Criterion	**Sub-criterion**		**References**
x_1	x_1	*Technical features*	(Gumus 2009), (Raafatnia 1988)
x_2		*Transportation*	
	x_{2-1}	*Traffic volume*	(Gumus 2009)
	x_{2-2}	*Quality & safety*	(Raafatnia 1988)
x_3		*Features*	
	x_{3-1}	*Environmental features*	(Raafatnia 1988)
	x_{3-2}	*Social features*	(Gumus 2009), (Raafatnia 1988)
	x_{3-3}	*Economical features*	(Gumus 2009), (Raafatnia 1988)
x_4		*Usage*	
	x_{4-1}	*Suitability for villagers*	(Raafatnia 1988)
	x_{4-2}	*For agricultural activities*	(Raafatnia 1988)
	x_{4-3}	*For security aimed usage*	(Gumus 2009), (Raafatnia 1988)
	x_{4-4}	*Progression to the mountainous areas*	(Gumus 2009)
x_5	x_5	*Road construction with minimal excavation*	(Gumus 2009)
x_6	x_6	*Destruction of wildlife habitats*	(Raafatnia 1988)

Source: own

Fig. 2: The Hierarchical Structure for Prioritizing Indicators and Sub-Indicators for Forest Road Locating



Source: own

Tab. 4: Background Information of Experts

Category	**Classification**	**No.**
Working background	Academic field	8
	Government unit	6
Education Level	Bachelor	1
	Master	5
	Ph.D.	8
Sex	Male	11
	Female	3

Source: own

Tab. 5: Criteria Paired Comparison Matrix

	Criteria							**Weights**
		x_1	x_2	x_3	x_4	x_5	x_6	
Criteria	x_1	1	6	1/3	4	8	6	0.271
	x_2	1/6	1	1/6	1/3	4	4	0.084
	x_3	3	6	1	5	9	8	0.434
	x_4	1/4	3	1/5	1	6	5	0.138
	x_5	1/8	1/4	1/9	1/6	1	1/3	0.027
	x_6	1/6	1/4	1/8	1/5	3	1	0.045
	C.I.=0.123				C.R.=C.I./R.I.= 0.10			

Source: own

2.3 Evaluation of Candidates for Forest Road Location

At this stage of the application, the group of experts evaluated each candidate according to each criterion and Table 4 developed. It indicates initial decision making matrix, with the criterion values described in intervals. For the weight (q_j) of criteria we used of weights in Table 6.

The initial decision making matrix (Table 7), has been normalized first as discussed in section 1.

The normalized decision making matrix is presented in Table 8. Using equations (7) to (12) for all the regions.

Tab. 6: Weights of Criteria and Sub-Criteria for Forest Road Locating

		Criteria						Sub-criteria weights q_j
		x_1	x_2	x_3	x_4	x_5	x_6	
Criteria weights		0.271	0.084	0.434	0.138	0.027	0.045	
Sub-criteria	x_1	1.000						0.271
	x_{2-1}		0.200					0.017
	x_{2-2}		0.800					0.067
	x_{3-1}			0.707				0.307
	x_{3-2}			0.201				0.087
	x_{3-3}			0.092				0.040
	x_{4-1}				0.348			0.048
	x_{4-2}				0.114			0.016
	x_{4-3}				0.477			0.066
	x_{4-4}				0.061			0.008
	x_5					1.000		0.027
	x_6						1.000	0.045

Source: own

Tab. 7: Initial Decision Making Matrix with the Criteria Values Described in Intervals

	$\otimes x_1$		$\otimes x_{2-1}$		$\otimes x_{2-2}$		$\otimes x_{3-1}$		$\otimes x_{3-2}$		$\otimes x_{3-3}$	
Opt.	max		min		max		max		max		max	
q_j	0.271		0.017		0.067		0.307		0.087		0.04	
Region	$\underline{x}_1$;	$\bar{x}_1$	$\underline{x}_{2-1}$;	$\bar{x}_{2-1}$;	$\underline{x}_{2-2}$;	$\bar{x}_{2-2}$;	$\underline{x}_{3-1}$;	$\bar{x}_{3-1}$	$\underline{x}_{3-2}$;	$\bar{x}_{3-2}$	$\underline{x}_{3-3}$;	$\bar{x}_{3-3}$
A_1	60	80	50	80	40	80	50	70	60	80	70	90
A_2	40	70	50	90	60	70	40	70	80	90	60	70
A_3	40	60	70	80	70	80	60	80	60	70	80	90

Source: own

Tab. 7 (continuation): Initial Decision Making Matrix with the Criteria Values Described in Intervals

	$\otimes x_{4-1}$		$\otimes x_{4-2}$		$\otimes x_{4-3}$		$\otimes x_{4-4}$		$\otimes x_5$		$\otimes x_6$	
Opt.	max		max		max		max		max		min	
q_j	0.048		0.016		0.066		0.008		0.027		0.045	
Region	$\underline{\hat{x}}_{4-1}$;	$\overline{x}_{4-1}$	$\underline{x}_{4-2}$;	$\overline{x}_{4-2}$	$\underline{x}_{4-3}$;	$\overline{x}_{4-3}$	$\underline{x}_{4-4}$;	$\overline{x}_{4-4}$	$\underline{x}_5$;	$\overline{x}_5$	$\underline{x}_6$;	$\overline{x}_6$
A_1	80	95	70	80	60	70	40	70	50	90	80	90
A_2	90	95	70	85	70	80	40	70	40	60	70	80
A_3	70	80	50	70	70	80	80	90	60	70	80	90

Source: own

Tab. 8: Normalized Weighted Decision Making Matrix

	$\otimes \hat{x}_1$		$\otimes \hat{x}_{2-1}$		$\otimes \hat{x}_{2-2}$		$\otimes \hat{x}_{3-1}$		$\otimes \hat{x}_{3-2}$		$\otimes \hat{x}_{3-3}$	
Opt.	max		min		max		max		max		max	
Region	$\underline{\hat{x}}_1$;	$\overline{\hat{x}}_1$	$\underline{\hat{x}}_{2-1}$;	$\overline{\hat{x}}_{2-1}$	$\underline{\hat{x}}_{2-2}$;	$\overline{\hat{x}}_{2-2}$	$\underline{\hat{x}}_{3-1}$;	$\overline{\hat{x}}_{3-1}$	$\underline{\hat{x}}_{3-2}$;	$\overline{\hat{x}}_{3-2}$	$\underline{\hat{x}}_{3-3}$;	$\overline{\hat{x}}_{3-3}$
A_1	0.093	0.124	0.004	0.006	0.013	0.027	0.083	0.116	0.024	0.032	0.012	0.016
A_2	0.062	0.108	0.004	0.007	0.020	0.023	0.066	0.116	0.032	0.036	0.010	0.012
A_3	0.062	0.093	0.006	0.006	0.023	0.027	0.100	0.133	0.024	0.028	0.014	0.016

Source: own

Tab. 8 (continuation): Normalized Weighted Decision Making Matrix

	$\otimes \hat{x}_{4-1}$		$\otimes \hat{x}_{4-2}$		$\otimes \hat{x}_{4-3}$		$\otimes \hat{x}_{4-4}$		$\otimes \hat{x}_5$		$\otimes \hat{x}_6$	
Opt.	max		max		max		max		max		min	
Region	$\underline{\hat{x}}_{4-1}$;	$\overline{\hat{x}}_{4-1}$	$\underline{\hat{x}}_{4-2}$;	$\overline{\hat{x}}_{4-2}$	$\underline{\hat{x}}_{4-3}$;	$\overline{\hat{x}}_{4-3}$	$\underline{\hat{x}}_{4-4}$;	$\overline{\hat{x}}_{4-4}$	$\underline{\hat{x}}_5$;	$\overline{\hat{x}}_5$	$\underline{\hat{x}}_6$;	$\overline{\hat{x}}_6$
A_1	0.015	0.018	0.005	0.006	0.018	0.021	0.002	0.003	0.007	0.013	0.015	0.017
A_2	0.017	0.018	0.005	0.006	0.021	0.025	0.002	0.003	0.006	0.009	0.013	0.015
A_3	0.013	0.015	0.004	0.005	0.021	0.000	0.003	0.004	0.009	0.012	0.015	0.017

Source: own

Tab. 9: Evaluation of Utility Degree

Region	P_i	R_i	Q_i	N_i
A1	0.324	0.021	0.345	100.00%
A2	0.299	0.019	0.321	93.11%
A3	0.303	0.022	0.322	93.49%

Source: own

Based on the results of Table 9, the ranking of the three regions is $A_1 > A_2 > A_3$.

Hybrid approach results indicate that A_1 is the best candidate with the highest degree and it is the best region for forest road in Haraz region.

Conclusions

It is very important that choose the best position for forest road, correct choice have a lot of advantages and it cause that the road work very good, be an effective project for region and improve the performance of region too. However where construction the roads is always a risky and complicated problem. Nevertheless, few applicable models have been addressed that concentrates on this problem. This paper presents a model for forest road locating in Haraz region that it can be used to improve the performance of forest roads. In this study, we proposed an effective model for forest road locating using both AHP and COPRAS-G methods. The AHP method was used to obtain the weights of the criteria and the COPRAS-G method used for the best position. COPRAS-G is a method for assessing the alternatives by multiple criteria values expressed in terms of intervals. This application has indicated that the model can be efficiently used in ranking candidates and another good point of this method is evaluating criteria in more details and experts can decision making less risky. Proposed model has significantly increased the efficiency of decision-making process in locating. In this study the result showed that with these indicators, the first region (Kelerd) is the best and is better for responsible of project that choose this region for forest road in the Haraz. COPRAS-G is an appropriate method for decision making; it can solve a wide range of problems associated with MCDM. This study can be considered as a framework for forest road locating in other regions according to differences in climate and etc.

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ABSTRACT

FOREST ROADS LOCATING BASED ON AHP AND COPRAS-G METHODS: AN EMPIRICAL STUDY BASED ON IRAN

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Forest roads have an important role in the forest management and economic of countries. The Caspian forest is the most important forests region in Iran. It's so important to construction of forest roads in the best place that can be useful. Haraz region is located in Mazandaran province that is near to Alborz Mountain. Selection the best place for construction of a road in forest is an important problem. For this research three place are considered for evaluating in Haraz region that including: Kelerd, Pelet Cheshme and Mangel. In this paper we applied hybrid MCDM methods for evaluating the regions. AHP applied for calculating the weight of each criterion and sub criterion and then COPRAS-G method applied for evaluating the places for selecting the best place for constructing the forest road. Result showed that Kelerd region in the best place for this work.

Key Words: *forests road, Caspian forest, AHP, COPRAS-G method.*

JEL Classification: *C02, C44, D81, L74.*