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An Evaluation of Stakeholder Perception Differences in Forest Road Assessment Factors Using the Analytic Hierarchy Process (AHP)

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Abstract: Many factors, with differing priority ratios, need to be assessed in the evaluation of forest roads. Stakeholder perceptions differ in the road assessment process and this research addresses those differences between academic and practitioner groups. The focus was on four main forest road assessment factor groups (technical, economic, environmental, and social) within 23 sub-factors to determine the priority ratios using the Analytic Hierarchy Process (AHP) method. Stakeholder groups expressed different priority ratios, indicating varying perceptions of the importance of these factors: forest engineering academic staff identified technical specifications as the most important issue (with a ratio of 39.77%), while environmental issues were most important for forestry department academic staff, mechanical supply technical staff, and forest enterprise chiefs (with ratios of 41.79%, 39.95%, and 37.03%, respectively). Due to differences in stakeholder group perceptions, a participatory forest road assessment approach should be adopted.

Keywords: forest roads; stakeholder perceptions; assessment factors; Analytic Hierarchy Process (AHP)

1. Introduction

The planning of forest road networks is an important issue for sustainable management. Forest roads are also essential infrastructure in the protection and rehabilitation of mountainous areas. Roads are indispensable in providing access to forest harvesting. The efficiency of forest logging depends on an appropriate forest road network [1–4]. Decision making about road alignment, building, and maintenance or decommissioning is a complex process because of the many trade-offs involved [5]. Forest roads interact within many technical, economic, and environmental specifications to fulfil these tasks.

Enhancing forest infrastructure has always been a topic of interest among specialists charged with providing for forest accessibility in the context of sustainable forest management [6]. The economic feasibility of forest harvesting has served as the main goal in the establishment and maintenance of forest road networks for many years. However, recently, the utilisation of new techniques has paved the way for the evaluation of different factors. Transportation distance and costs, vehicle types and road categories, extraction distances and costs, road surfaces, road space, and road density values have been taken into consideration in these studies and related problems have been solved with various mathematical models [7–17]. The most appropriate solutions were realised for multiple objectives. An integrated and interdisciplinary evaluation study has not been conducted.

Although environmental sensitivity is a worldwide phenomenon that has important implications for ecological, economic, and human well-being, there is a limited understanding of how environmental managers perceive the problem [18]. Forest road network environmental issues can be classified as the fragmentation of wildlife habitat; mortality from road construction and collision with vehicles;

modification of animal behaviour; disruption of the physical environment; the spread of exotic species; and changes in human use of land and water [19,20].

The management of natural resources, especially forest conservation, is critical to achieving sustainable development. In this regard, forest road networks are considered as one of the main keys for economic, protective, and supportive forestry development plans and have an underlying role in plan organization [21].

The stakeholder perception assessment entails a subjective point of view, related to the experience and opinion of the people involved in the analysis [22]. Incorporating perceptions is essential for ensuring the successful formulation and implementation of any policy [23].

The forest road network planning begins with the forest road evaluations, and the appropriate ones will be included in the plan. The road evaluation studies are performed by an experienced planner. In Turkey, existing roads are evaluated for a new plan in the process of making or redesigning the forest road network plans. This is done in accordance with edict number 292, which was issued by the General Directorate of Forestry (GDF) [24]. This evaluation is performed according to the location, longitudinal gradient, road platform width, curve and bend standards, and so on. From the existing roads, those that meet the forest road standards with these features are included in the new road network plan, while the roads which cannot be improved even with major repairs, taking into account economy and environmental harm, are completely abandoned and omitted from the new plan. The aforementioned factors are generally assessed according to the legislation of the GDF, in spite of the fact that at the international level all environmental and influencing factors, including the slope, soil type, geology, hydrography, aspect, the volume of trees per hectare, tree type and elevation are used for forest road planning.

As a result of increased competition under globalisation, various parametrical and non-parametrical techniques are used both in the public and private sector to measure and increase efficiency and productivity [25,26]. Multi-criteria techniques are considered as a promising framework for evaluation because they clearly have the potential to take into account conflictual, multidimensional, incommensurable, and uncertain effects of decisions [27]. Flexibility, simplicity in computing, and option ranking feasibility are some of the advantages of the Analytic Hierarchy Process (AHP) method that can be an effective help to evaluate diverse situations and road locating in the forest [1].

The AHP method, which was first proposed by Myers and Alpert in 1968 [28] and developed by Saaty in 1977 [29], is a user-friendly, simple, and logical multi-criteria assessment method, which allows for stakeholder inclusion [30–33]. The AHP has been widely applied for preference analysis in complex, multi-attribute problems [27].

AHP uses various alternatives, such as choosing the best policy alternatives, determining requirements, allocating resources, predicting outcomes, measuring performance, designing systems, ensuring system stability and optimization, planning, resolving conflict, and assessing risk when setting priorities [34].

The aim of this study was to determine the perception differences among stakeholders that should be taken into consideration during the evaluation of forest roads for the implementation of standard forest road planning studies countrywide. As a result, the prospect of a participatory planning approach should emerge.

2. Materials and Methods

This study was conducted to identify differences among the perceptions of four different stakeholder groups, comprised of academic and practitioner groups, which were stakeholders in the evaluation of forest roads, using the AHP framework.

Technical, economic, environmental, and social factors have been identified through literature studies for the evaluation process. These are often accepted factor groups for the evaluation of forest roads and networks. Within these four groups, 23 sub-factors were considered. The sub-factors were selected from commonly based factors by evaluating previous studies on forest roads [1–17,19,35–40].

The factor groups and sub-factors are tabulated below (Table 1). The evaluation process was based on these sub-factors.

Table 1. The factor groups and sub-factors evaluated for forest road assessment.

Technical Specifications	Economic Features	Environmental Properties	Social Features
Longitudinal gradient (Transport quality and safety)	Transportation costs	Fire protection (possibilities of accessing and linking)	Suitability for forestry activities (opening-up rate percents)
Road upper-structure	Maintenance costs	Partition or destruction of valuable forest lands	Suitability for rural settler transportation
Necessity of drainage structures		Soil erosion and water quality problems	Suitable for agricultural use
Continuous access		Risk of landslides by high hillside slopes	Transit eligibility
Temporary access		Pressure on water courses	Usability for safety (civil and military use) purposes
Extraction distance		Partition or destruction of wildlife habitats	Possibility to use for hunting
			Tourism-recreational potential
			Sporting suitability for use
			Access to scientific research areas

People evaluate subjects from many different angles and prioritize what they care about most. A simultaneous comparison of all the factors makes it possible to understand what kind of mutual relationships are created by these combined factors. Doing this, however, requires that certain assumptions be made and adopted [41].

Stakeholder partnerships consist of representatives from private interest groups, local public agencies, and state or federal agencies, who convene as a group, periodically and indefinitely, to discuss or negotiate public policy within a broadly defined issue area [42]. All of the experts selected for this research were forest engineers. While expert groups were established, forest engineering and forestry issues were evaluated separately in the academic environment and forestry sector. Forestry department members, to my personal observation, have higher environmental sensitivity than forestry engineering department members. Planners and practitioners were evaluated as two separate groups in the forestry sector. The forest enterprise's chiefs, who form the practitioner group, have been evaluated as the direct use group of the forest roads.

The stakeholder groups in the study are academic staff from the forest engineering department (FEDAS); forestry department academic staff (FDAS); the technical staff of the Mechanical Supply Branch Offices (MSBTS) of provincial organizations of the General Directorate of Forestry; and the Chiefs of the Forest Enterprises (FEC).

The Analytic Hierarchy Process (AHP) combines all the factors in a hierarchical decomposition of the system, which represents the goals and functions in the higher and lower priorities. AHP specifies priorities among the alternatives and it also assigns the criteria necessary to expertly judge these alternatives [1].

A questionnaire was used to determine the perceptions of the stakeholder groups according to the AHP methodology. A total of 33 out of 50 (66%) questionnaires were received at the year 2009. The stakeholder group's experts were informed about the evaluation method in the questionnaire. The questionnaire contains a pairwise comparison of each of the sub-factors according to the priorities within each sub-factor. In the pairwise comparison method, criteria and alternatives can be presented in pairs of one or more referees (e.g., experts or decision makers) [43]. Each factor in rows is compared with other factors in columns. The comparison was done by grading them between 2 and 9, from low through high priority. A value of 1 is used when the priorities of the compared factors are considered to be equal. If the priority of the factor in the column is considered to be higher than in the row, the grading is given as 1/priority grade.

There are several methods employed in AHP for aggregating group opinions. The arithmetic mean method is one of the most common group preference aggregation methods in AHP [43]. In order to determine the stakeholder groups priorities, the arithmetic mean of the priority values that each stakeholder group experts have identified in the questionnaires were taken and pairwise comparison matrices of AHP methodology were established [44]. The consistency of expert comparison priorities should be tested at AHP. The Consistency Ratio (CR) has been calculated for priority ratios of each stakeholder group, taking into account the pairwise comparison matrix and priority ratios. The consistency ratio has to be lower than 0.1. The Random Consistency Index (RI) value used 1.6526 according to the 23-factors matrix at CR calculation [45].

The relative priorities of the 23 sub-factors under four main factor groups were scored by four stakeholder groups, and the perception differences were discussed according to the priority ratios.

3. Results and Discussion

Pairwise comparison matrices were tabulated for four stakeholder groups, using the average priority scores of compared factors of questionnaires filled in by group's experts. These priority scores are generally shown in the upper triangle of a pairwise comparison matrix. The comparison matrix of the FEDAS group experts is given in Table 2 as a sample. The rows and columns of the matrix consist of the same factors. The highest average score according to the row–column comparison was 7.18 between factors of continuous access and temporary access. The score 7 indicates that the first factor is "very strong or demonstrated" according to the factor compared. The scoring value of 3 means that the priority is "weak/moderate" where 5 is "essential or strong priority" and 9 is "absolute priority" [29]. The "absolute priority" is calculated as 0.11 (1/9) if the factor in the column is prioritized.

The priority ratio of each sub-factor was calculated using the priority scoring generated with the pairwise comparison matrices of each stakeholder group separately. The priority ratio of each sub-factor and the main factor groups' (technical, economic, environmental and social) priority ratios that contain the sum of each sub-factor ratio are given in Table 3. The stakeholders' perceptions about forest road evaluation factors were evaluated for main factor groups according to the priority ratios.

The Forest Engineering Department Academic Staff (FEDAS) ranked the technical specifications with the highest priority ratio (39.77%), which was rated second (35.09%) by the Forest Enterprises Chiefs (FEC). The lowest priority was given by by the Forestry Department's academic staff (FDAS) (32.57%). The priority ratio (33.4%) of the General Directorate of Forestry's (GDF) Mechanical Supply Branch Technical Staff (MSBTS), who carry out the planning of the forest road networks, was lower than the FEC, who were the practitioner stakeholders.

The highest priority ratio difference (7.2%) was between the FEDAS and FDAS groups regarding the technical specifications. It is very difficult to explain the reason for this perception difference, but it is possible to conclude that stakeholder faculty members do not work together at high levels. A similar situation exists among practitioner stakeholder groups. The chief's high priority over that of the planner technical staff reveals some problems in the GDF. The planning units of the GDF are generally perceived as secondary task positions. This can, therefore, prevent technical staff from concentrating on their work.

Environmental issues were found to be the most important factors with a priority ratio of 41.79% by the FDAS, while in contrast, FEDAS gave this the least importance with a 35.57% priority ratio. Environmental issues were assessed with a 39.95% priority ratio by MSBTS and 37.03% by FEC. The rankings indicate that the perception difference among academic staff was larger than the perception differences between the GDF personnel.

The highest priority rate differences (6.22%) were determined among FDAS and FEDAS in terms of environmental issues, as with technical specifications. However, this time, the priority perceptions were reversed. In fact, this result shows that the AHP method is consistent, indicating that the difference of perceptions among the academic community in the forestry education system should be eliminated through increased cooperation.

Table 2. Comparison matrix of average priority scores provided by questionaries' filled out by the forest engineering department academic staff stakeholder group experts.

Assessed Effective Factors	Longitudinal Gradient	Road Upper-Structure	Necessity of Drainage Structures	Continuous Access	Temporary Access	Extraction Distance	Maintenance Costs	Transportation Costs	Fire protection	Partition or dest. of Valuable Forest Lands	Soil erosion and Water Quality Problems	Risk of Landslides by High Hillside Slopes	Pressure on Water Courses	Partition or Dest. of Wildlife Habitats	Opening-Up Rate Percent	Suitability for Rural Settler Transportation	Suitable for Agricultural Use	Transit Eligibility	civil and Military Use	Possibility to Use for Hunting	Tourism-Recreational Potential	Sporting Suitability for Use	Access to Scientific Research Areas
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**	**(19)**	**(20)**	**(21)**	**(22)**	**(23)**
(1)	1.0	4.17	3.30	2.66	5.30	3.75	3.34	3.12	2.57	1.49	1.66	1.30	1.96	2.29	2.85	3.68	4.02	4.47	3.13	4.82	4.18	5.09	3.48
(2)		1.0	1.11	1.82	4.03	3.78	2.59	2.96	1.72	1.33	1.27	1.09	1.40	2.29	3.31	3.41	3.75	4.47	3.04	5.09	4.18	4.55	3.21
(3)			1.0	2.01	3.76	3.38	3.39	3.13	2.06	1.39	1.90	1.39	1.42	1.96	2.78	3.41	3.47	3.75	2.13	4.36	3.91	4.73	3.76
(4)				1.0	7.18	5.27	3.04	3.41	3.29	3.52	1.40	1.08	1.31	2.39	3.03	3.39	3.58	3.58	3.12	4.55	4.55	4.91	3.64
(5)					1.0	0.33	0.71	0.77	1.46	0.23	0.64	0.63	0.28	0.59	1.16	0.83	0.93	1.19	1.63	2.38	1.59	2.87	1.24
(6)						1.00	1.27	0.65	0.87	0.71	0.53	0.50	0.58	0.74	1.44	2.10	2.50	2.61	2.29	3.49	2.42	3.68	1.95
(7)							1.00	1.99	1.53	1.02	0.66	0.65	0.70	0.88	1.92	1.97	2.87	2.62	2.14	4.03	3.50	4.85	2.85
(8)								1.00	1.97	2.00	0.80	0.78	1.13	1.55	3.14	3.50	2.96	2.81	2.09	4.30	3.68	5.03	2.54
(9)									1.00	3.37	2.65	2.24	2.60	3.51	3.74	4.19	4.73	4.91	3.27	5.82	6.18	6.45	4.09
(10)										1.00	1.14	1.06	0.98	1.97	3.30	3.62	4.12	4.58	3.18	4.21	4.27	4.61	3.56
(11)											1.00	1.42	1.51	2.47	4.09	4.64	4.82	4.36	3.56	4.64	5.00	5.55	3.82
(12)												1.00	3.09	4.00	4.64	5.09	5.36	5.18	4.02	5.09	5.55	5.55	4.27
(13)													1.00	2.86	3.73	4.55	4.55	4.55	3.26	4.39	4.30	5.21	3.38
(14)														1.00	2.68	3.20	3.64	3.73	2.46	3.91	4.00	4.55	3.05
(15)															1.00	2.94	2.86	3.03	2.10	4.18	3.27	4.55	2.45
(16)																1.00	2.45	1.95	1.49	3.27	1.79	4.00	2.59
(17)																	1.00	2.09	1.25	2.49	2.13	3.79	2.08
(18)																		1.00	0.91	2.55	1.62	2.58	1.45
(19)																			1.00	3.56	2.62	3.75	2.38
(20)																				1.00	0.76	0.97	0.61
(21)																					1.00	3.18	1.32
(22)																						1.00	0.54
(23)																							1.00

Table 3. Priority ratio distributions of forest road evaluation sub-factors and main factor groups according to stakeholders' perceptions.

Evaluation Factors	Forest Engineering Department Academic Staff (%)	Forestry Department Academic Staff (%)	Mechanical Supply Branch Technical Staff (%)	Forest Enterprises Chiefs (%)
Technical Specifications	**39.77**	**32.57**	**33.4**	**35.09**
Longitudinal gradient	10.53	9.28	7.86	10.29
Road upper-structure	7.44	5.27	5.88	6.65
Necessity of drainage structures	7.61	5.02	7.32	5.43
Continuous access	8.30	5.92	6.72	6.29
Temporary access	2.45	3.29	2.51	3.11
Extraction distance	3.44	3.79	3.11	3.32
Economic features	**8.92**	**7.39**	**6.77**	**6.3**
Transportation costs	4.14	3.69	3.25	3.92
Maintenance costs	4.78	3.70	3.52	2.38
Environmental issues	**35.57**	**41.79**	**39.95**	**37.03**
Fire protection	7.19	8.41	7.96	8.46
Partition or destruction of val. for. lands	5.50	5.83	6.27	5.33
Soil erosion and water quality problems	6.17	7.26	7.36	7.87
Risk of landslides by high hillside slopes	7.33	6.79	7.46	6.95
Pressure on water courses	5.42	5.85	5.50	4.32
Part. or destruction of wildlife habitats	3.96	7.65	5.40	4.10
Social features	**15.73**	**18.23**	**19.85**	**23.71**
Opening-up rate percent's	2.89	3.29	3.18	4.38
Suitability for rural settler transportation	2.24	2.29	2.29	2.56
Suitable for agricultural use	1.92	1.68	2.32	2.10
Transit eligibility	1.60	1.39	1.73	2.08
Usability for safety purposes	2.19	3.45	4.75	3.13
Possibility to use for hunting	1.06	1.52	1.15	1.28
Tourism-recreational potential	1.37	1.63	1.38	2.40
Sporting suitability for use	0.95	1.17	1.12	1.40
Access to scientific research areas	1.51	1.81	1.93	2.24
Consistency Ratio (C.R.)	0.058	0.040	0.070	0.074

The highest perception differences among stakeholders were realized in social characteristics based on the priority rates (7.98%). FEC gave the highest priority rate to social features, while FEDAS gave this the lowest priority rate. It is thought that more contact with the people living in rural areas by the chiefs would affect this result. The fact that this was given the least importance by the FEDAS suggests that they are thinking with an engineering mentality.

All the stakeholders ranked the importance of economic features in last place. In addition to this, the rates of the four groups were shown to be very close. FEDAS gave the biggest rating. Despite this, economic features have a low priority rating in total. In fact, the priority ratio of each of the sub-factors of the economic features group was higher than other sub-factor priority ratios. The average priority ratio for transportation costs was 3.75% and the maintenance costs ratio was 3.60%. These two values were determined to be higher than the average priority of many other sub-factors. The economical features of forest roads that are accepted as general infrastructure were evaluated with the lowest priority ratio by the practitioners because they do not pay much attention to the costs of forest roads relative to their functions.

Forest managers have to be concerned with road network design and construction more than in the past because of the environmental impacts of forest roads and their cost [1]. The environmental issues were the most important factor with an average priority ratio of 38.59% across all groups. This was followed by technical features, social features, and economic features, the average priority rates of which are 35.21%, 19.38% and 7.35%, respectively.

The longitudinal gradient factor is the most important factor with 9.49% of the highest priority when evaluated as a sub-factor. The fire protection factor follows the longitudinal gradient factor with an 8.01% priority ratio. The lowest priority ratio was obtained for sports purposes (1.16%).

4. Conclusions

This study was conducted to identify differences in the perception of four different stakeholder groups, comprised of academic and practitioner groups, in the evaluation of forest roads.

The highest perception difference in terms of priority ratio (7.98%) among stakeholders was based on social features between FEC and FEDAS groups. The second highest difference was in terms of technical specifications between FEDAS and FDAS groups with a 7.2% priority ratio. Regarding environmental issues, the highest perception difference was between FDAS and FEDAS groups with a 6.22% priority ratio. The lowest perception difference was in economic characteristics at 2.15%.

FEDAS identified technical specifications as the most important factor with a priority ratio of 39.77%, while FDAS, MSBTS, and FEC identified the environmental issues as the most important factor with a ratio of 41.79%, 39.95%, and 37.03%, respectively among of the stakeholders. The academic members of the Forest Engineering Department placed environmental issues in second position with a ratio of 35.57%.

Environmental issues had the highest priority factor with an average priority ratio of 38.59% across all groups. This was followed by technical features, social features, and economic features, the average priority rates of which are 35.21%, 19.38%, and 7.35%, respectively. The longitudinal gradient is the most important factor with 9.49% of the highest priority when evaluated as a sub-factor. The fire protection factor follows the longitudinal gradient factor with an 8.01% priority ratio. The lowest priority ratio was obtained for sports purposes (1.16%). It was concluded that the priorities of the technical and economic features, which are traditional approaches in planning, should be re-considered, as environmental issues are of higher priority.

The results showed differences between the priority ratios of the factors among the stakeholder groups. Therefore, stakeholder assessments should be considered and participatory approaches should be adopted for forest road evaluation.

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