Developing Criteria and Indicator Set for Quality Assessment of Forest Roads

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Abstract:
The objectives of the study were; to identify the concept of road quality, to determine the components of the quality level, and to establish a set of criteria and indicators influencing the decision making process relevant to road quality level. Its aim was to improve the methodology of how to measure a roads level of quality by converting it into a 'checklist' of different aspects of the forest road. In this concept, it was firstly enumerated the expectations from a road segment or road network by taking into consideration the geometrical standards, objectives, functions, tasks, environmental impacts, and disadvantages of the forest roads to state the components of assessment set. A questionnaire was then developed and applied to interest groups and perceptions and expectations on them were identified. Thus, a decision support base was obtained for the criteria and indicators to facilitate in determining the quality level of a forest road with regard to technical, economical, ecological, and societal factors.

Keywords: Forest roads, road quality analysis, criteria and indicators for quality, road assessment, Turkey.

1 Introduction

Forest roads are the main infrastructure for opening-up forests to carry out personal to forest and products from forest. The roads have potential adversely impacts on forest ecosystem, as well. The forest roads are differantiated from other public road types in respect to geometrical and technical standards, construction techniques, and building cost. Furthermore, forest roads have various multidimensional attributes in terms of economical, ecological, social and institutional characteristics.

Forest roads are generally planned, projected, applied, and constructed according to their own unique conditions, rules, and standards. These building principles related to forest roads have to supply all functions and expectations from a road in the concept of sustainable forest management. Therefore, forest roads have to have a qualified structure. This illustrates that a forest road requires to be built in a certain quality level to sustain forest operations in the frame of technically reasonable, environmentally friendly, economically suitable, and societally acceptable. It means that a forest roads or road network should be planned, projected, and constructed according to the principles aimed at design, appropriateness, product, and service quality. In literature, generally, it is not run into "forest road quality" or "qualified forest road" phrase. However, there is uncertainty how the forest road quality is determined, measured, and evaluated. That is, there is no analysis methodology and criteria (and indicators) for definition quality of forest roads.

USDA (1999 and 2002) developed a forest road analysis method and applied it to various forest road networks on the basis watershed, forest or project level. Although these are a multicriteria analysis methodology, they don't need to evaluate or classify to forest road viewpoint of quality level. On the other hand, it is possible to encounter various analyses and assessment studies related to forest roads, which are economical, ecological and social based (Hutchinson et al., 2004; Potocnik et al., 2005; Hasmadi and Kamaruzaman, 2008). These studies devoted to road analysis have considered the potential benefits and risks of forest roads and has assessed the advantage and disadvantage by means of scientific

methods (Gucinski et al., 2000; USDA, 2002). Acar and Ünver (2007) developed an assessment methodlogy to grade and classify the actual condition of a forest road. They took into consideration the economical, ecological, technical attributes and visual structure. Gümüş (2009) improved an evaluating method and exposed that the geometrical features of a forest road could be criteria for assessment to a forest road. However, these evaluation criteria and assessment procedures were not applied to a real forest road in situ and didn't include a quality concept.

Forest roads, the most important infrastructural facility for forestry activities and they self-awaited technical, economical, ecological, and societal functions have to be able to meet the qualifications. This indicates that the development of the concept of a quality requirement for forest roads. Conversely, the quality is a relative concept and variable point of view, therefore, it is difficult to decide whether a forest road has good quality or not. Qualification of a forest road is a phenomenon related to meeting the expectations from a road. Therefore, it is difficult to determine what the quality principles are for forest road or uncertain which the flagger is to define quality level. However, it is possible to determine the quality degree of a forest road and forest road network by using the enhanced forest road quality assessment method (Eker, 2011; Ada, 2011) based on the using of descriptive criteria and indicators.

In this study it was aimed to develop a methodology to determine the quality level and conceptual framework for forest roads, to describe the components of road quality, to create the criteria and indicators sets that are effective on decision making on the quality of the forest road and how to decide if a road segment and network is quality or not by putting all these in a assessment list.

2 Material and Method

It was firstly developed a conceptual framework in order to be applied a quality analysis methodology on a forest road. By inspring of wellknown road analysis and assessment methodology used by USDA (1999), a quality analysis method (Eker, 2011) for forest roads was derived from. The quality analysis and assessment method developed for forest roads also includes these steps for criteria and indicators that are:

It was defined the components of a forest road segment or network. In this step, it was put forward which elements should be used when the quality of a forest road was determined. Ecological, economical and social dimension of a forest road was taken into consideration.

The benefits and risks of the forest roads were respectively enumerated. The steps aided to be understood the affirmative and adverse impacts of the roads. With the help of the step, it was arranged the expectations from a road segment or road network by taking into consideration the geometrical standards, objectives, functions, tasks, impacts, and disadvantages/unexpected aspects of the forest roads to state the components of assessment set.

The advantages and disadvantages were classified according to principles of sustainable forest management. In this step ecological, economical, and social dimensions of the roads were grouped into define a qualified forest road. At this step, descriptive main criteria for quality of forest road were decided with additional technical criterion. There were studied to find out for question of what should be required or not for high quality forest road. The main criteria were determined by common criteria of sustainable forestry.

A list symbolizing the main criteria (ecological, economical, social, and technical) was generated to define sub-criteria or seconder criteria. The sub-criteria have represented the main/primer criteria which attributes are to be required for qualified forest roads. To reveal the descriptive sub-criteria, the method was followed that the road quality concept was get in touch with logically significant questions which are related to the positive and negative effects of forest roads.

The representative indicators for each sub-criterion were developed by dividing of a sub-criterion into subset subjects related to forest road quality. At this step, it was benefited from regular questions on which potential factors were effective to describe the connected sub-criterion. To expose the potential

factors and make a question, the all aspects of forest roads were listed by means of SWOT analysis commonly used in case studies. It was assumed the hypothesis that the affirmative aspects of forest roads increase the quality level a forest road and adversely impacts decrease.

To intensify and support the indicators set, a questionnaire was then developed and applied to interest groups and whose perceptions and expectations relevant to forest road quality were identified. Thus, it was obtained a decision support base for criteria and indicators facilitating to determine the quality level of a forest road with regard to technical, economical, ecological, and social.

To describe and measure the indicators, the variables, which are generally geometrical-technical attributes of the forest roads, associated with indicators were used in as a parameter. It was interrogated how the measurable geometrical features of forest roads could affect the road quality, and then, it was decided that the relative variable could be used as a variable of connected indicator.

The next step includes the measurement strategies of the variables and, assessment and classification of the values with respect to road quality. In this study, these steps were not considered and it could be only clarified a criteria and indicator set for determining the level of quality of forest roads.

The criteria and indicators set for guality analysis of forest roads was developed for standardized B-Type Secondary Forest Road (GDF, 2008) in a project level manner (Table 1) (Ada, 2011), whose characteristics was the study material and objects. The main/primary forest roads, skidding or tractor roads, and other or unstandardized secondary roads were excluded from the evaluation.

Table 1: The geometrical standards of forest roads in Turkish Forestry

Forest Road Type	Unit	Main Forest Road	Secondary Forest Road Types				Tractor Road
			A-Type	B-Type			
				SBT	NBT	EBT	
Platform width	m	7	6	5	4	3	3.50
Strip number	piece	2	1	1	1	1	1
Maximum slope	%	8	10	9	12	12	20
Minimum curve radius	m	50	35	20	12	8	8
Strip width	m	3	3	3	3	3	3
Shoulder width	m	0.50	0.50	0.50	0.50	0.50	-
Ditch width	m	1.00	1.00	1.00	1.00	0.50	-
Superstructure width	m	6	5	4	3	3	-

SBT: Standards were increased NBT: Normal size EBT: Extreme size

3 Results

It was determined that four main criteria could be used in quality analysis for forest road at first level hierarchy (Table 2). The main criteria that were used in the assessment of road quality which were the criteria of sustainable forest management were economical, ecological, social-institutional and technical criteria that were added in this study. Economic main criterion has 2 sub-criteria, 5 indicators and 24 factors/variables; ecology main criteria has 4 sub-criteria, 13 indicators and 50 variables, social main criteria has 3 sub-criteria, 8 indicators and 17 variables, and technical main criteria has 3 sub-criteria, 6 indicators and 34 variables those depends on it (Table 3, 4, 5, 6).

Table 2: The criteria set for forest road quality analysis

Criteria (I. Level)	Sub-Criteria (II. Level)
1. Ecology	1.1. Hidrology
	1.2. Habitat conservation
	1.3. Losses of growing areas
	1.4. Forest fires
2. Economy	2.1. Good and service production
	2.2. Costs
3. Social	3.1. Impacts on historical, cultural, and valuable areas
	3.2. Aesthetic values of the forest road
	3.3. Accessibility for public transport
4. Technical	4.1. Geometrical attributes
	4.2. Safety
	4.3. Functionality

Table 3: Ecology criterion and indicators with their variables

Criteria	Subcriteria	Indicators	Variables
1. Ecology	1.1.Hidrology	1.1.1. Surface and groundwater hidrology	1.1.1.1. Road length
			1.1.1.2. Position on the hillside of the road
			1.1.1.3. Stream channel proximity
			1.1.1.3. Road-stream intersect number
			1.1.1.5. The number and density of state-of-the-arts
			1.1.1.6. Road aspects
		1.1.2. Erosion	1.1.2.1. Position on the hillside of the road
			1.1.2.2. Stream channel proximity
			1.1.2.3. Road-stream intersect number
			1.1.2.4. Slope class
			1.1.2.5. Ground type
			1.1.2.6. Road slope
			1.1.2.7. Superstructure type
			1.1.2.8. Erosion factor
			1.1.2.9. Road length on soil conservation area
		1.1.3.Sediment and Mass movement	1.1.3.1. Position on the hillside of the road
			1.1.3.2. Slope class
			1.1.3.3.The structure and functions of the ditches
			1.1.3.4. Stabilization of cutslope and fillslope
			1.1.3.5. Superstructure type
			1.1.3.6. Road width
			1.1.3.7. Hight of the cutslope
			1.1.3.8. Relationship ground type and cutslope
		1.1.4. Water quality and impacts on stream channels	1.1.4.1. Stream channel proximity
			1.1.4.2. Road-stream intersect number
			1.1.4.3. The number of state-of-the-arts and availability
			1.1.4.4. Road length on water conservation area
		1.1.5. Water pollution	1.1.5.1. Road-stream intersect number
			1.1.5.2. Protection of water resources
	1.2. Habitat conservation	1.2.1. Aquatic habitats	1.2.1.1. Stream channel proximity
			1.2.1.2. Road-stream intersect number
		1.2.2. Terrestrial habitats (animal and plant)	1.2.2.1. Nature conservation
			1.2.2.2. Road construction area width
			1.2.2.3. Road width
			1.2.2.4. Connected area by the forest roads
		1.2.3. Sensitive ecosystems	1.2.3.1. Road length on protected area
			1.2.3.2. Road length on wildlife conservation area
			1.2.3.3. Road length on sensitive ecosystem
		1.2.4. Rehabilitation	1.2.4.1. Road length in rehabilitation area
	1.3. Losses of growing areas	1.3.1. Losses of forest areas	1.3.1.1. Road construction area width
			1.3.1.2. Opening-up area (site index)
		1.3.2. Landslide areas	1.3.2.1.The number of landslide and slope flow
			1.3.2.2. Ground tpe
	1.4. Forest Fires	1.4.1. Fire prevention and fire fighting	1.4.1.1. Road length
			1.4.1.2. Opening-up area (length of fire hosepipe)
			1.4.1.3. Connection by firebreaks
			1.4.1.4. The fire strips on roadsides
		1.4.2. Fire risks	1.4.2.1. Connected areas by the forest road
			1.4.2.2. Opening-up areas
			1.4.2.3. Accessibility by road (Energy line, telephone line, etc)

Table 4: Economy criterion and indicators with their variables

Criteria	Subcriteria	Indicators	Variables
2. Economy	2.1. Production	2.1.1.Wood and nonwood production	2.1.1.1.Road length and opening-up area
			2.1.1.2.Accessibility in all season/trafficability
			2.1.1.3.Road length on conomical functions
		2.1.2. Service production (Recreation input)	2.1.2.1.Access to recreational areas
	2.2. Costs	2.2.1.Construction Costs	2.2.1.1.Position on the hillside of the road
			2.2.1.2.Slope class
			2.2.1.3.Ground type
			2.2.1.4.Superstructure type
			2.2.1.5.The number of state-of-the-arts andilability
			2.2.1.6.Road length
			2.2.1.7.Construction area width
		2.2.2. Maintenance and repair costs	2.2.2.1.Position on the hillside of the road
			2.2.2.2.Slope class
			2.2.2.3.Ground type
			2.2.2.4.Superstructure type
			2.2.2.5.The number of state-of-the-arts
		2.2.3. Transportation costs	2.2.3.1.Road slope
			2.2.3.2.Winding factor (horizontal)
			2.2.3.3.Sinousity factor (vertical)
			2.2.3.4.Reverse slope
			2.2.3.5.Vertical curve
			2.2.3.6.Density of horizontal curves
			2.2.3.7.Ground type
			2.2.3.8.Deformations on road surface

Table 5: Social criterion and indicators with their variables

Criteria	Subcriteria	Indicators	Variables
3. Social	3.1. Impacts on historical, etc. areas	3.1.1. Adverse impacts	3.1.1.1.Road length
		3.1.2. Openin-up of the areas	3.1.2.1.Road length on conservation areas
	3.2. Aesthetic values of the forest road	3.2.1. Driving pleasure	3.2.1.1.Diffrent tree species
			3.2.1.2.Variation on slope along the road
			3.2.1.3.Alteration on land use along the roadside
			3.2.1.4.Winding of road route
			3.2.1.5.Stabilization of cut and fillslopes
		3.2.2. Suitability of the road for forest structure	3.2.2.1.Visibility of road in forest composition
			3.2.2.2.Hight of cutslope
			3.2.2.3.Stabilization of cut and fillslopes
			3.2.2.4.Construction area width
			3.2.2.5.Roadbed position in elevation model
		3.2.3. Proximity to aesthetic area	3.2.3.1.Road length on aesthetic value areas
	3.3. Accessibility for public transport	3.3.1. Proximity to scientific area	3.3.1.1. oad length on scientific orientated area
		3.3.2.Accessibillity for villages	3.3.2.1.The number of village opened by roads
		3.3.3. Opening agricultural area	3.3.3. 1.Road length on agricultural areas

Table 6: Technical criterion and indicators with their variables

Criteria	Subcriteria	Indicators	Variables
4. Technical	4.1. Geometrical attributes (standards)	4.1.1. Geometrical standars of road prism	4.1.1.1.Road width
			4.1.1.2.Road slope
			4.1.1.3.Horizontal curve radius
			4.1.1.4.Strip width
			4.1.1.5.Shoulder width
			4.1.1.6.Ditch width
			4.1.1.7.Superstructure width
		4.1.2. Other technical features	4.1.2.1.Road breadthways slope
			4.1.2.2.Visibility distance (winding factor)
			4.1.2.3.Encounter-standstill placement
			4.1.2.4. Road length on positive cardinal points
			4.1.2.5.Existence caution signs along roadside
			4.1.2.6.Reverse slope
			4.1.2.7.The number of state-of-the-arts
	4.2. Safety	4.2.1. Traffic safety	4.2.1.1.Road width
			4.2.1.2.Road slope
			4.2.1.3.Vertical curve and sinousity
			4.2.1.4.Reverse slope
			4.2.1.5.Sharp and tight curves
			4.2.1.6.Visibility distance
		4.2.2. Building safety	4.2.2.1.Landslide and subsidence
			4.2.2.2.Holes, wheel tracks, ondulations on road
			4.2.2.3.Deterioration on hydraulic buildings
			4.2.2.4.Road aspects
			4.2.2.5.Superstructure type
			4.2.2.6.Distance between nearest tree and road
			4.2.2.7. Ground type
	4.3. Functionality	4.3.1. Opening-up of functional areas	4.3.1.1.Accessible managed forest types
			4.3.1.2.Functions of the road
			4.3.1.3.Existence of alternative road
			4.3.1.4.Connectivity other roads
		4.3.2. Accessibility	4.3.2.1.Superstructure type
			4.3.2.2.Permission of accessibility on road
			4.3.2.3. Landslide,rolling, etc potential on slope

4 Discussions

It is very difficult to define at once the concept of “forest road quality” or “qualified or good quality forest road” because the forest roads give an apportunity for all forestry function that are opposite direction with together. The multifunctionality and multiobjectivity get difficult to make a holistic definition for forest road quality. Because a forest road should be technically appropriate, economically bearable, ecologically friendly, and societally acceptable. However, quality is a flexible and relative concept and some adjectives are unsufficient to describe it (Merter, 2006). Therefore, it was determined that the “quality analysis methodology for forest road” could be a useful tool for definition of forest road quality in project and forest level (Eker, 2011). The metod was developed for analysis and assessment the characteristics of forest roads whether or not: they supply the objectives, functions, and services; the road is safety as technically; the road system is effectively managed; the adverse impacts of the roads are mitigated, etc. It appeared that the most important component or section of the analysis was constitution of criteria and indicator set for forest road quality. The set could enable an integrated quality assessment for forest road, which was supported by hierarchical cause-effect relationship.

It was accepted if a road is a good condition with respect to the criteria and indicators, then it is a good quality level. Therefore, it was found out very fitting the main criteria formed the base framework. It is expected that the criteria should have measurable through directly or indirectly with definitive characteristics (USDA, 1999; Durusoy, 2009). To measure directly the criteria, it was needed to determine the sub-criteria represent the main criteria. Each sub-criterion was also separated into relational indicators. The indicators were obtained by answering of investigative questions about relationship between road quality and sub-criteria. When asked how a criteria or sub-criteria might concern the forest road quality, then, the indicator set could be formed. According to some approaches, the indicators can called as tertiary criteria a subset of sub-criteria.

However, the indicators were still cloudily/fuzzy so that it can be measured and evaluated with scale or ordinal numbers for analysis. Therefore, it was revealed the effective factors belonging to road features on the each indicator by means of a relational analysis. The factors were enumerated as variables set that was supported by inquiry results realized with expert group. The variables that can easily be measured or counted via a real forest road segment or network and spatial attributes, reflects the features of forest road. It is possible to increase or decrease the variables to symbolize indicators or critera set. For example, Gümüş (2009) used a weighting strategy developed by Analytical Hierarchy Process to enumerate which variable is the most important to evaluate the road. Therefore, the variable set can be expanded or restricted according to situation of the road, assessment method, analyst, local conditions, etc. In order to be completed the assessment procedure with the criteria and indicator set, the values of the variables obtained by road attributes were grouped into for a scale developed to classify the values as very good, good, moderate, little bad, bad. If the variable's value is suitable for forest road quality that is if it is a desirable value, then it will be placed in very good or high quality class in terms of the variable. Thus, by means of qualitative assessment method, it is studied to determine the quality of forest road.

The usage of quality criteria and indicator set was tested on a planning unit in Turkey (Ağlasun Forest Planning Unit located in south of Turkey), having 206,550 km long and 61segments of B-Type forest roads. As a result of this study, it was found out that the roads in this planning unit has a middle quality level regard to economic, ecologic, social and technical aspects. Thus, it was proven the ability of the criteria and indicator set for road quality analysis (Eker, 2011; Ada, 2011).

In this way, the criteria and indicator set can be used for choosing the standard routes, determining the priority of road maintenance, supposing the potential risks and for developing a quality coefficient to estimate the transportation costs.

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