2015 5th International Conference on Environment Science and Engineering
Volume 83 of IPCBEE (2015)
DOI: 10.7763/IPCBEE. 2015. V83. 17

Implementation of environmentally forest road construction in sensitive Greek semi-mountainous forest

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Abstract. The environment-friendly construction of forest roads must incorporate not only technical and economic parameters, but also the (direct and indirect) effects of construction upon the natural and social environment.

The focus of this paper is on the opening-up of a sensitive Greek semi-mountainous forest. The environmental resources were identified, the impacts were evaluated and the criteria by which to estimate the impacts of the alternative solutions were set out following the grouping of the environmental resources. A form of cost benefit analysis was conducted to evaluate alternative solutions. Furthermore, an investigation was carried out in order to determine the environmental impacts of the construction work associated with the two alternative solutions identified.

From the results of the research it may be concluded that:

It is very useful to have alternative road construction solutions clearly mapped out for comparison before road construction begins. These solutions should be based on the newest planning technique and according to the aims of forest infrastructure development, the terrain conditions and the protection of the forest ecosystem.

In sensitive ecological systems such as Mediterranean forest areas it is very important, from a technical and an economic design perspective, to have a realistic concept, within the framework of an environmental impact assessment (E.I.A.)

It will very practical and useful for the assessment by the E.I.A. to have a list of serviceable criteria, and their weights to evaluate the absorption of road construction in order to make a profile form for every forest road.

Keywords: Implementation, environment, forest road construction, sensitive forests.

1. Introduction

By definition, a forest road is an artificial strip of land, which has taken shape from the viewpoint of geometrical features and quality of pavement to serve the demands of users for forest protection, which also obtaining the benefit of financial and social outputs as well as the demands of the natural environment [1]. However, the construction of forest roads can have negative impacts on the environment. These may be defined as changes of the environmental resources (natural and social), with a temporary or permanent character in respect to the time horizon within which these changes take place [1].

The forests of evergreen broad leaves are mainly grown in adverse soil, morphological and climatic conditions and perform a protective role (hydrological, climatic, soil etc.). This protective role of forests and in a broader sense their natural environment must not by disturbed by infrastructure works such as the construction of forest roads but it should be treated with the greatest environmental sensitivity.

The environment-friendly construction of forest roads must incorporate not only technical and economic parameters, but also the (direct and indirect) effects of construction upon the natural and social environment [2].

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When constructing environment-friendly forest roads in sensitive areas such one finds in large parts of southern Greece, the forester and the road builder are called upon to study the environmental resources of the area, to evaluate the impacts of the construction and to choose using rational estimation methods the friendliest (compatible) solution for the natural environment.

The focus of this paper is on the opening-up of a sensitive Greek semi-mountainous forest. The environmental resources were identified, the impacts were evaluated and the criteria by which to estimate the impacts of the alternative solutions were set out following the grouping of the environmental resources. A form of cost benefit analysis was conducted to evaluate alternative solutions. Furthermore, an investigation was carried out in order to determine the environmental impacts of the construction work associated with the two alternative solutions identified.

Another important objective of construction measures is to facilitate the supervision and protection of the area, allowing for timely intervention in the event of fire and also the development and utilisation of forest lands and abandoned fields.

2. Materials and Methods

2.1. Research area

The research area is the Pinakates - Milies - Vyzitsa of Pelion of Magnesia Prefecture. It lies between 370-1070 meters. Showing almost all aspects on the horizon, with the predominant S - SW, N - NW and E and the altitude ranges from 0-1466 meters (top Tsakos). The slopes are on average between 10-70%. The predominant species are sweet chestnut, common walnut tree, forest beech and downy oak (Fig. 1).

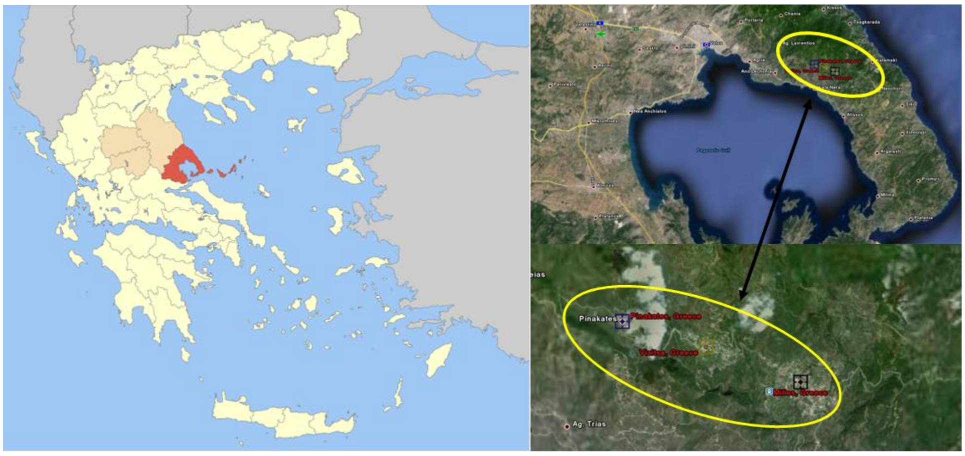

Fig. 1: Research area.

2.2. Methodology

The method as for the forest road network as for the alternative routes are assessed by quantitative and qualitative criteria. Where possible, a form of benefit-value analysis was used [3].

Stages of method application:

1. Two alternative routes were drawn (A and B). The A one has a total length of 3,600 m and the B one with a total length of 4,700 m.

2. The criteria used to estimate the effects of each route were set out and the values (Z) were calculated for each criterion and alternative solution.

Estimation criteria: Total costs of construction in € / ha, the forest landscape in m^2 / ha, the water saving in m^3 and the approximation of the area in running meters of forest road.

The forest landscape and the water saving (quality criteria) were estimated for the groups of environmental resources. The impacts of each proposed route evaluated using the studies [4], [5], [6], [7], [8].

Grouping prerequisites of environmental resources: The ability to measure with one quantity (quantity of expression, Z), with an index (expression index) and with a unit. To be independent among each other but not cover each other in respect to the estimation methodology.

The area's approximation criterion (quality criterion) was estimated based on the demand of the stakeholders for immediate access to the area in case of fire and was expressed with a length index of forest road and with units in running meters [9].

3. The importance of estimation criteria (weight, G) was calculated from a questionnaire sent to 60 respondents.

4. The fulfilment degree or transformation coefficient (E) was calculated using the formulas:

- For a decreasing direction of estimation E=B/Z (when the expression quantity (Z) increases then the benefit is decreased)
- For an increasing direction of estimation E=Z/B (when the expression quantity increases the benefit increases too).

Z = expression quantity (effect) of criterion

B = comparison size = average price of expression quantities of all criteria for each alternative solution.

Constraint $E_{min} > 0$ and $E_{max} \leqslant 2$.

The expression quantities (Z) of criteria are expressed in different units. In order for the estimation and shaping into comparable numbers of benefit value to be possible, it is required to transform them into a non-dimension scale. The transformed size is called fulfilment degree and is a non-dimension number [10], [11].

5. The partial values (G × E) were calculated for each criterion and alternative solution. The aggregate has provided the total benefit value for each alternative solution. The alternative solution with the biggest benefit value is the most advantageous.

Means: The data (matters) have resulted from a map with a scale 1:20,000, and field measures such as the length of the forest roads, the average hill slope (45%), the occupation zone in m^2/ha, the amounts of earth fills in m^3/ha for a road 6 m wide, the construction cost and the questionnaire.

Afterwards, the ability of absorption of the forest ecosystem of the forest road construction work impacts was studied. Specifically, the term absorption is defined by whether the impact effect will be absorbed from the forest ecosystem as time passes, as well as the number of impact receivers [1].

The absorbency criteria and their weight came from a questionnaire sent to specialist scientists [12]. The absorbency criteria are divided into 3 categories: 1st forestry criteria, 2nd topographical criteria and 3rd social criteria. The weights of the criteria are: three (3) for the forestry criteria, two (2) for the topographical criteria and one (1) for the social criteria.

The criteria were: 1. the kind of covering; 2. the forestry species; 3. the management form; 4. the forestry form (age); 5. The height of trees; 6. The site quality; 7. The productivity; 8. The cross ground slope; 9. The aspect; 10. The relief; 11. The distance from: 11.1. Tourist recreation area; l1.2. National road network; 11.3. Railway; 11.4. Archaeological site; 11.5. Adjacent big city; 11.6. Adjacent village; 11.7. European path; and 11.8. natural or artificial lake or river.

- As far as absorbency is concerned:

Criteria 1, 2, 8, 9 and 10 can be estimated digitally; criteria 3, 4, 5, 6 and 7 are set based on the management plan or terrestrial measurements by stepping out the area were conducted to determine the size of criteria, while criteria from 11.1 to 11.8 are assessed with special software, displaying on the P/C screen what is observed from a different DTM point.

The absorption (A) of the forest ecosystem is multiplied by respective weight coefficient (W_A) and is divided by the sum of the weight coefficient values with a view to extract the barycentric mean:

$$C_A = \sum(A \times W_A) / \sum W_A$$

where $\sum(I \times W_A)$ and are the sum of the absorption's estimate multiplied with the respective weight coefficient (W_A) and $\sum W_A$ the sum of the weight coefficient values, respectively, for matrix as size %.

3. Results and Discussion

From the research and investigation of the data of the research areas resulting the following environmental resources (components): the fauna, the flora, the water capacity (water resources, water saving), the soil, the disturbance of soil and rocky lands, the landscape-physiognomy and the acoustic environment.

Evaluation of impacts on the environmental resources:

Fauna: Local temporary disturbances are expected during the construction phase while during the working operation phase; no impacts on the forests roads are expected. Expression index is the occupation zone of forest roads in m^2/ha.

Flora: A permanent impact on the flora is expected during the construction phase due to loss of vegetation. The impact is expected to reduce over time due to the natural or artificial regrassing of the slopes on the forest roads but a small degree of vegetation loss is expected during the phase of the working operation of forest roads. Expression index is the occupation zone of forest roads in m^2/ha.

Water capacity (water resource): The construction of forest roads is not expected to have large effects on the aquatic environment. During construction, the interruption of the surface runoff is thought to have a temporary impact of small intensity while during the operational phase, the effect is considered as reversible with appropriate shaping of the pavement and the construction of draining works. Expression index is the volume of earth fills in m^3/ha.

Soil: A permanent loss of the soil layer is expected. The impact on the ground during the phase of operation is focused on the erosion of the body of the forest road which is supported by the big lengthwise axial gradients and the surface of the slopes on the forest road. The impact is expected to decrease over time and it will be of limited extent during the operation phase as long as the appropriate measures are taken. Expression index is the occupation zone of forest road in m^2/ha.

Balance of soil and rocky lands: It is expected that, during the construction phase, rocks may become temporarily unstable in the earth fill; the slopes will be of limited importance during this phase. Expression index is the volume of earth fills in m^3/ha in combination with the height and the gradient of slopes.

Landscape-physiognomy: The physiognomy and the harmony of the micro-landscape will be adversely affected during construction due to the removal of vegetation which will take place during the phase of operation of the forest road and the surface layout. The impact is expected to continue beyond the phase of construction into the operational phase of the forest road but is expected to be limited. This is due to a number of factors, inadequate organization and the implementation of restoration works, the regrassing of slopes, the gradual absorption of alterations by the broader landscape and the activity of natural processes. Expression index is the occupation zone in m^3/ha in combination with the created earth fills.

Acoustic environment: Noise from the explosions and from machinery will temporarily affect the local fauna during construction. During the phase of operation no impact is expected. Expression index is the volume of rocky masses and the type and number of machinery used for the implementation of the works.

Based on the expression index, the environmental resources were classified in two groups; those that are expressed by the occupation zone and with the criterion of the forest landscape, and those with the volumes of earth fills and with the criterion of water saving.

The following Tables 1 and 2 presents the estimation and hierarchy of alternative solutions and the percentage of absorbency criteria for the roads in the research area.

Table 1: Estimation and hierarchy of alternative solutions

Criteria	**Z**		**Expression**		**Weight**	**E = B / Z**		**E × G**	
	A	**B**	**Index**	**Unit**	**(G)**	**A**	**B**	**A**	**B**
Costs	117	153	Cost	€ / ha	30	2	2	60	60
Forest landscape	108	141	Occupation zone	m^2 / ha	20	2	2	40	40
Water Saving	29	38	Volume of earth- fills	m^3 / ha	15	2	2	30	30
Approximation	3600	4700	Length	m	35	0.3085	0.2363	10.8	8.3
Total Benefit Value								140.8	138.3
Hierarchy								1	2

Table 2: Estimation of absorption of the forest roads A and B in the forest area

ABSORBENCY						
			A		B	
	Criteria	**Weights**	**Grade %**	**Sum**	**Grade %**	**Sum**
1	2	3	4	5 = 3 ×4	6	7 = 3 ×6
	Terrain conditions					
1	Kind of covering	3	86	258	79	237
2	Forestry species	3	75	225	75	225
3	Management form	3	85	255	70	210
4	Forestry form (Age)	3	100	300	75	225
5	Tree height	3	75	225	75	225
6	Site quality	3	58	174	58	174
7	Forest productivity	3	25	75	25	75
8	Slope of ground	2	31.20	62.4	30	60
9	Aspect	2	85	170	80	160
10	Relief	2	75	150	50	100
Sum total		27		1894.4		1691
11	Distance from					
11.1	Tourist recreation area	1	30	30	30	30
11.2	National road network	1	50	50	50	50
11.3	Railway	1	10	10	10	10
11.4	Archaeological site	1	100	100	100	100
11.5	Adjacent big city	1	100	100	100	100
11.6	Adjacent village	1	70	70	70	70
11.7	European path	1	100	100	100	100
11.8	Natural or artificial lake or river	1	100	100	100	100
Sum total		8		620		620
Total		35		2454.4		2251
Absorption coefficient value $C_A = \sum(A \times W_A) / \sum W_A$				70.13%		64.31%

Table 1 shows the results of estimation and hierarchy of the alternative solutions (A and B). Solution (A) has the biggest benefit value (140.8) and is considered more advantageous than (B) with total benefit value (138.3). The selection of (A) is mainly due to its degree of fulfilment (transformation coefficient) (0.3085) which is bigger than (B).

Table 2 shows the estimated environmental impact of the two routes. The absorption coefficient (71.84%) of the solution (A) is bigger than (B) 6 unit about. This difference is due to kind of covering; management form; forestry form (Age) and relief. So because these differences and with regard to the differences in benefit-value analysis shown in table 2 we consider solution (A) more advantageous.

4. Conclusions

From the results of the research it may be concluded that:

- The estimation result of the alternative solutions and the selection of the A are in harmony with the willingness of the respondents (questionnaire) for a better approach to the area, with smaller costs and effects on the forest landscape. A small difference on the potential of absorption from the natural environment is shown by alternative B.
- The impacts from the forest road are not considered significant. The most significant effect is upon the forest landscape-physiognomy of the area, as a result of the removal of flora and the surface of slopes.
- The taking of suitable measures such as the regreasing of slopes, the avoidance of unnecessary earth fills and large axial gradients, the construction of ditches and draining gutters as well as the use of machinery

friendly to the environment (e.g. excavators) will reduce the impacts on the natural resources and will increase the rate of absorption of the proposed alternative solution.

- It is very useful to have alternative road construction solutions clearly mapped out for comparison before road construction begins. These solutions should be based on the newest planning technique and according to the aims of forest infrastructure development, the terrain conditions and the protection of the forest ecosystem.
- In sensitive ecological systems such as Mediterranean forest areas it is very important, from a technical and an economic design perspective, to have a realistic concept, within the framework of an environmental impact assessment (E.I.A.) or better ESCs (Environmental Standard Commitments).
- It will very practical and useful for the assessment by the E.S.Cs to have a list of serviceable criteria, and their weights to evaluate the absorption of road construction in order to make a profile form for every forest road.

5. Acknowledgements

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Thales. Investing in knowledge society through the European Social Fund.

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