The Application of SWOT-AHP Analysis in the Design and Construction of Forest Road Network

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Abstract

The construction of a forest road is a very expensive project and for this reason the choice of the appropriate location is of major importance for the designer. When designing, certain criteria must be taken into account, either individually or in combination with each other. In the present work, the SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) was applied together with AHP (Analytic Hierarchy Process) for the design and construction of a forest road in order to have a concentrated and hierarchical weights of SWOT criteria that play an important role. in the decisions in order to have the least possible financial burden in terms of construction and as little as possible environmental and social impact on the implementation of the project. The results from the application of AHP showed that strengths gather 57.7%, followed by weaknesses with 18.1% and opportunities with 15.9%. Last of the criteria as a whole are threats with 8.2%. Regarding the sub-criteria / factors that have the highest priority, the possibility of evacuating an area through the forest road network (such as natural disasters) gathers 35.5% for strengths, for weaknesses ecosystem disturbance has the highest percentage with 11.1 %, for the opportunities the increase in the yield potential of forest area (extraction of wood) with 8.1% and for the threats the possibility of destruction of infrastructure from natural disasters with 4.2%. The study area was the forest road network of the city of Xanthi (Eastern Macedonia and Thrace, Greece).

Keywords

Design, construction, forest road, SWOT analysis, AHP

1. Introduction

Forest roads are the main foundation of forest infrastructure, but on the other hand they are high-cost constructions and can cause significant environmental damage to forests [1]. According to Picchio et al. [2] The forest road network is important for several functions, such as connecting forest areas with roads. However, the design of forest roads is not an easy task as it should fulfill multiple conflicting objectives [3]. Construction and maintenance costs can increase in unsuitable areas, so great care is required when designing forest roads [4]. But it should be taken into account not only the total road costs but also the environmental impacts caused by the construction and use of the roads [5]. On the other hand, the forest road network plays an important role in the rational management of forests, for this reason the best possible planning is necessary [6]. Roads also contribute to forest fire protection and therefore play an important role in environmental protection [7]. and they can be used as escape

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exits in case it is not easy to extinguish the fire [8]. Adaptation to climate change requires a different way of thinking when designing forest roads [9], because the rate of erosion depends on the intensity of precipitation [10] and the extreme phenomena caused (fires). Thus regular removal of forest biomass along forest roads is therefore essential for fire prevention [11,12]. Forest roads are the main structures for the development of timber harvesting operations. For this reason it must be ensured that they will be open at all times [13]. Even the collected biomass waste can also be transported through the forest road network for methane production if disposed in anaerobic digestion facilities [14]. Forest roads serve multiple purposes, from recreation to facilitating the transportation of timber products. Many of these designed roads can be used in all seasons [15]. They are also used to connect areas, serve the residents [16] and help the economic development of the areas [17]. Roads create thinnings in dense forests and this is bee-friendly [18], for the development of beekeeping. They can also protect an area from poaching through patrols [19]. But according to Skidmore [20] roads also facilitate poaching because they connect even the most remote areas. Also the increase in road coverage can lead to fires when the population increases in areas that are less populated [21]. According to Demir [22] forests must be used according to forestry techniques so as not to alter the structure of the forest. Tampekis et al. [23] evaluated the intensity of human impact on the forest ecosystem as well as the absorption of the ecosystem from the impacts caused by the construction of forest roads. It must therefore serve the interests of both accessibility and sustainability. For this reason, the construction of a forest road network must be carefully studied because it can damage the environment [24].

2. Study Area

The study area was the city of Xanthi and in particular the forest road network of the area Geraka - Xanthi - Kimmeria (Eastern Macedonia and Thrace). The forest road network of the area is 67.76 km and includes all categories.This location was chosen because the forest road network connects some villages with each other and the inhabitants of these villages are primarily engaged in logging and other forest-related occupations. So a well-planned forest road network serves the needs of the residents.

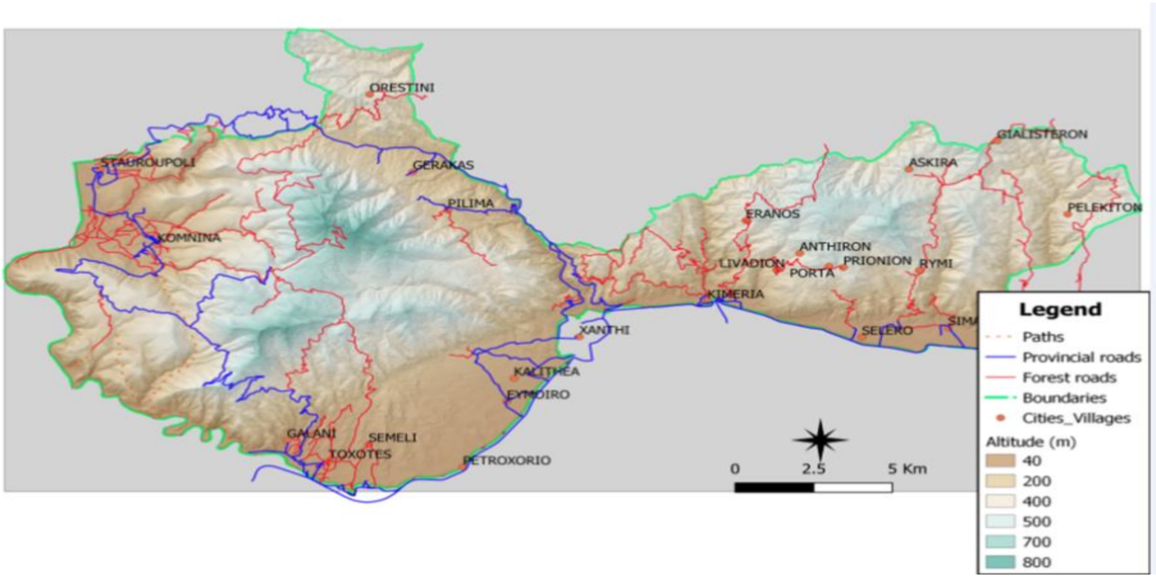

Figure 1: Study area of area Geraka - Xanthi - Kimmeria (Xanthi) [25].

3. Methodology

The association of AHP with SWOT contains detailed priorities for the factors included in the analysis and thus makes them comparable, with the aim of improving the quantitative database of strategic planning processes [26]. The answers were given by the authors who deal primarily with issues of forest road construction and forest economics.

The information derived from pairwise comparisons can be summarized in a table of weights, where the relative weight enters the table as an a_{ij} element and the inverse of the $1/a_{ji}$ preference ratio goes to the opposite side of the main diagonal.

$$A = (a_{ij}) = \begin{bmatrix} W_1/W_1 \; W_1/W_2 \; ... \; W_1/W_n \\ W_2/W_1 \; W_2/W_2 \; ... \; W_2/W_n \\ \cdots \\ \cdots \\ W_n/W_1 \; W_n/W_2 \; ... \; W_n/W_n \end{bmatrix} \tag{1}$$

When we multiply table A by the permutation of the vector of weights (w), we get the resulting vector nw

$$(A -)W = 0, \tag{2}$$

For consistency λmax = n otherwise λmax> n. Table A should therefore be checked for consistency with the formula:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)}, \tag{3}$$

The CI consistency index is determined by normalizing the following difference. The consistency index RI is the random index generated for a random order table n and CR is the consistency ratio [27]. The general rule is that CR must be CR≤0.1 for the table to be consistent

$$CR = \frac{CI}{RI}, \tag{4}$$

4. Results

Table 1 presents the Strengths, Weaknesses, Opportunities, Threats from ithe design and construction of Forest Road Network.

Table 1
SWOT analysis

Strengths	Weaknesses
S1:Ability to evacuate an area through the forest road network (such as natural disasters) S2: Protection of the forest from poaching S3: Fire protection S4: Connection of settlements	W1:Ecosystem disruption W2:High cost of construction - maintenance W3:Corrosion of the deck by the high movement of water on the road
Opportunities	**Threats**
O1:Increasing the efficiency of a forest area (wood extraction) O2:Increase of recreation O3:Development of various professions related to the forest and its functions (eg beekeeping) O4:Maximize the income of the inhabitants who live near the forests	T1:Possibility of destruction of infrastructure by natural disasters T2:Increased risk of fire due to increased mobility of the population T3:Burden of the environment by the mobility of the population T4:Increase in poaching after easy access to the forest environment

Table 2 shows the degree of importance after the pairwise comparison of (Strengths, Weaknesses, Opportunities, Threats). Positives occupy the largest percentage (57.7%), immediately after Weaknesses occupy 18.1%, followed by opportunities with 15.9% and threats have the smallest percentage (8.2%).

Table 2

Comparisons of SWOT group

SWOT group	Strengths	Weaknesses	Opportunities	Threats	Importance Degrees
Strengths	1.00	6.80	4.03	4.04	0.577
Weaknesses	0.15	1.00	2.09	2.58	0.181
Opportunities	0.25	0.48	1.00	3.20	0.159
Threats	0.25	0.39	0.31	1.00	0.082
CR = 0.09					

Table 3 shows the degree of significance after the pairwise comparison of Strengths. The Ability to evacuate an area through the forest road network (such as natural disasters) occupies a percentage (61.6%), followed by Fire protection with 18.4% and Protection of the forest from poaching with 10.8%. Last is Connection of settlements (9.2%).

Table 3

Comparisons of Strengths group

Strengths	S1	S2	S3	S4	Importance Degrees
S1:Ability to evacuate an area through the forest road network (such as natural disasters)	1.00	6.42	4.82	5.60	0.616
S2:Protection of the forest from poaching	0.16	1.00	1.16	0.77	0.108
S3:Fire protection	0.21	0.87	1.00	4.40	0.184
S4:Connection of settlements	0.18	1.30	0.23	1.00	0.092
CR = 0.07					

Table 4 shows the degree of significance after the pairwise comparison of Weaknesses. The criterion that is considered more important is Ecosystem disruption with 61.4% followed by High cost of construction – maintenance 27.9% and the least important is Corrosion of the deck by the high movement of water on the road with 10.7%.

Table 4

Comparisons of Weaknesses group

Weaknesses	W1	W2	W3	Importance Degrees
W1:Ecosystem disruption	1.00	3.10	4.40	0.614
W2:High cost of construction – maintenance	0.32	1.00	3.60	0.279
W3:Corrosion of the deck by the high movement of water on the road	0.23	0.28	1.00	0.107
CR = 0.08				

Table 5 shows the degree of significance after pairwise comparison of Opportunities. First in the ranking is Increasing the productivity of a forest area (extraction of wood) with 48.5%, second is Increasing recreation with 29.9%, third is the Development of various professions related to the forest and its functions (e.g. beekeeping) with 14.1% and finally Maximizing the income of residents living near forests with 7.6%.

Table 5
Comparisons of Opportunities group

Opportunities	O1	O2	O3	O4	Importance Degrees
O1:Increasing the efficiency of a forest area (wood extraction)	1.00	2.37	3.85	4.27	0.485
O2:Increase of recreation	0.42	1.00	2.87	4.64	0.299
O3:Development of various professions related to the forest and its functions (eg beekeeping)	0.26	0.35	1.00	2.71	0.141
O4:Maximize the income of the inhabitants who live near the forests	0.23	0.22	0.37	1.00	0.076
CR = 0.09					

Table 6 shows the degree of significance after pairwise comparison of Threats. The respondents ranked the Possibility of destruction of infrastructure by natural disasters first with a percentage of 51.2%, second place came the Increased risk of fire due to increased mobility of the population with a percentage of 27.0%. The third and fourth places were occupied by Burden of the environment by the mobility of the population (13.9%) and Increase in poaching after easy access to the forest environment (7.9%) respectively.

Table 6
Comparisons of Threats group

Threats	T1	T2	T3	T4	Importance Degrees
T1:Possibility of destruction of infrastructure by natural disasters	1.00	3.20	4.00	4.10	0.512
T2:Increased risk of fire due to increased mobility of the population	0.31	1.00	3.00	4.00	0.270
T3:Burden of the environment by the mobility of the population	0.25	0.33	1.00	2.67	0.139
T4:Increase in poaching after easy access to the forest environment	0.24	0.25	0.38	1.00	0.079
CR = 0.09					

Table 7 presents the overall priority scores of the SWOT factors as well as the priority of each factor.

Table 7
Total priority scores of the SWOT factors

SWOT group	Priory of group	SWOT factors	Priority factors within the Group	Overall priority of the factor
Strengths	0.577	S1:Ability to evacuate an area through the forest road network (such as natural disasters)	0.616	0.355
		S2:Protection of the forest from poaching	0.108	0.062
		S3:Fire protection	0.184	0.106
		S4:Connection of settlements	0.092	0.053
Weaknesses	0.181	W1:Ecosystem disruption	0.614	0.111
		W2:High cost of construction – maintenance	0.279	0.050
		W3:Corrosion of the deck by the high movement of water on the road	0.107	0.019
Opportunities	0.159	O1:Increasing the efficiency of a forest area (wood extraction)	0.512	0.081
		O2:Increase of leisure	0.270	0.043
		O3:Development of various professions related to the forest and its functions (eg beekeeping)	0.139	0.022
		O4:Maximize the income of the inhabitants who live near the forests	0.079	0.013
Threats	0.082	T1:Possibility of destruction of infrastructure by natural disasters	0.512	0.042
		T2:Increased risk of fire due to increased mobility of the population	0.270	0.022
		T3:Burden of the environment by the mobility of the population	0.139	0.011
		T4:Increase in poaching after easy access to the forest environment	0.079	0.006

5. Conclusions

In the present work, SWOT-AHP was applied for the construction of a forest road network. The results from the implementation of AHP showed that the strengths as a whole are superior by 57.7% compared to the other criteria. Following are the weaknesses with 18.1% and the opportunities with

15.9%. Last of the criteria as a whole are the threats (8.2%), that may exist during the construction of forest roads. Regarding the sub-criteria / factors that have the highest priority, the possibility of evacuating an area through the forest road network (such as natural disasters) gathers 35.5% for the strong points, for the weak points the ecosystem disturbance has the largest percentage with 11.1% , for the opportunities the increase of the efficiency possibility of a forest area (wood extraction) with 8.1% and for the threats the possibility of destruction of infrastructures from natural disasters with 4.2%. In conclusion, we would say that the construction of forest roads has positive benefits both for the protection of human life in case of evacuation of an area and for access to the forest in case of fire. It can also offer opportunities to increase the income of the inhabitants by engaging in professions that have direct contact with the forest. The disadvantages as well as the threats from the construction are small scale based on the answers.

For this reason SWOT-AHP can be a tool that can be used to make rational decisions taking into account all the factors that affect it. Thus, it can be used to solve issues related to the functions of the forest in general.

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