DECISION MAKING MODEL IN FOREST ROAD NETWORK MANAGEMENT*

Srđan H. Dimić[a], *Srđan* D. Ljubojević[b]
[a] University of Defence in Belgrade, Military Academy, Department of Logistics, Belgrade, Republic of Serbia
e-mail: srdjan.dimic@mod.gov.rs,
ORCID iD: http://orcid.org/0000-0003-0673-4710
[b] University of Defence in Belgrade, Military Academy, Department of Logistics, Belgrade, Republic of Serbia,
e-mail: srdjan.ljubojevic@va.mod.gov.rs,
ORCID iD: http://orcid.org/ 0000-0002-2696-3062

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Abstract:

Forest resource exploitation and the achievement of full forest potential depend on the density and quality of the forest road network. The forest road network has to fulfill multiple functions; it thus has strategic importance in forest management. When planning the forest road network development, decision makers have to consider various technological, economic, social, and environmental factors. A comprehensive and functional approach is needed. A hybrid methodological framework for the formulation of guidelines, within which the strategy for the development of the state-owned forest road network should be defined, is presented in this paper. A fuzzy modification of the A'WOT method is proposed. The model, named FDA'WOT model, is based on an idea to provide a conceptual framework for strategic option selection by combining the fuzzy Delphi technique, the fuzzy SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) and the Analytical Hierarchical Process (AHP). The FDA'WOT model overcomes the problems of a classical SWOT analysis related to the vagueness and uncertainties in assessment of the character, impact and relative importance of strategic factors. It is a frame for a multicriteria approach in decision making which allows analytical prioritization of alternative strategic options and selection of an optimal one. The proposed model is applied to a case study of the strategy selection for the forest road network development in the Republic of Serbia. The presented results have shown that the FDA'WOT model can successfully create conditions for sustainable strategy formulation.

Key words: forest road network, decision making, strategy, FDA'WOT model, fuzzy Delphi, fuzzy SWOT, AHP.

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Introduction

In the last few decades, the focus in forest management has been shifted from a dominant interest in timber harvesting to the so-called non-extractive uses, such as: recreational uses (hunting, fishing, hiking, camping), wildlife improvement, development of forests, environmental protection, etc. In the case of Serbia, decades of lagging in technical and technological development, numerous institutional weaknesses and slow adaptation to changes, as well as the applied forest management models, were the constraints in the forestry development (Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, 2006).

The development of the forest road network greatly impacts the achievement of the economic and ecological goals in forest management. Since forest roads are the most important foundation for sustainable forestry operations and represent one of the biggest investments in forest management, it is necessary to have an adequate strategy for the forest road network development for successful forest management. The strategy selection problem has a multidisciplinary character. In practice, the SWOT analysis is a common tool for solving the strategy selection problem, but the traditional SWOT analysis has some shortcomings such as subjectivity, the quantification of factors influences due to their uncertain nature, or the evaluation of strategic alternatives. To overcome these problems, in this paper, we propose a hybrid FDA'WOT model as an analytical approach to strategy formulation. The FDA'WOT model combines the fuzzy Delphi technique, the fuzzy SWOT analysis and the traditional AHP method.

The traditional SWOT analysis is often used in forestry studies. Hoang et al. (2015) used the SWOT analysis to assess the benefits and difficulties of forest management certification from the perspective of groups of smallholders in Vietnam. Hynynen et al. (2014) conducted the SWOT analysis to analyse Finnish forestry sector's operational environment and to define scenarios for the assessment of long-term impacts of alternative forest management strategies on potential resource use (Hynynen et al, 2015). Also, the SWOT analysis was used in the cases of forest management in the Czech Republic and Slovakia (Jarský et al, 2014), Algeria (Meddour-Sahar, 2015), Kyrgyzstan (Jalilova et al, 2012), Bulgaria (Winkel & Sotirov, 2011), Italia (Carbone & Savelli, 2009) and Austria (Rauch, 2007). Very rarely, the objects of the SWOT analysis were management issues regarding forest roads. In those cases, forest roads were analysed mainly from the wider perspective, as part of forest infrastructure (Meddour-Sahar, 2015), or from the investment perspective (Jarský et al, 2014), but not as a final aim of the SWOT analysis.

The Analytical Hierarchical Process, developed by Saaty (1980), is a multi-criteria decision-making method often used in forestry. For some examples and reviews of the AHP application in forest management issues, we refer the reader to Triantakonstantis et al. (2013) and Diaz-Balteiro and Romero (2008). In some studies, the AHP method was used to solve forest road design, planning and maintainance problems (Hayati et al, 2013), (Pellegrini et al, 2013).

In 2000, Kurttila et al. introduced a new, hybrid A'WOT method. In order to provide quantification and mutual comparison of the influences of the SWOT factors, they conducted the analytical prioritization of the SWOT factors by the AHP. The SWOT analysis, in the A'WOT approach, sets up a formal frame, while the AHP ensures the analytical support to the decision-making process (Kangas et al, 2001). The original or modified A'WOT method has found its application in many areas, especially in natural resources management. The SWOT and AHP combination in forestry management was also used by Stainback et al. (2012), Dwivedi and Alavalapati (2009), etc.

Gerasimov et al. (2013) identified, by the A'WOT, the strategic options for forest energy development and priorities in transferring the Nordic forest energy solutions to the Karelia region in Northwest Russia. Analysing the options, they noticed the forest road network as an important factor for forest energy development. In 2012, Kajanus et al. analysed the possibilities of combining the AHP, the SMART (Simple Multi-Attribute Rating Technique) and the SMAA-O (Stochastic Multicriteria Acceptability Analysis - Ordinal) methods with the SWOT analysis. They concluded, according to four case studies of natural resources management and strategic planning, that the ability to provide different levels of preference information and the required decision support are very important prerequisites for a successful application of hybrid decision-making models, because „too difficult is to consider comparisons of items from different dimensions" of the SWOT matrix. The importance of data for the classification of factors was underlined by Gerasimov et al. (2013), too.They demonstrated that, due to uncertainty and lack of information from the field, it is often not easy to differentiate and categorise identified factors into the given SWOT categories with no doubt. Information uncertainties and ambiguities, inherent to strategic problems, are usually treated with a fuzzy approach, established by Zadeh (1965). Fuzzy techniques have also been applied in forestry planning and forestry decision making (Zarekar et al, 2012), (Ochoa-Gaona et al, 2010), (Zadnik Stirn, 2006), (Mendoza & Prabhu, 2003).

The fuzzy approach in the application of the SWOT analysis, combined with other methods, such as the Analytical Hierarchical Process, or the Analytical Network Process can be found in areas other than forestry (for example, we refer to Dimić et al. (2016) and Ljubojević et al. (2014). In spite of numerous examples of separate applications of the SWOT and AHP methods in forestry and their more and more intensive combined applications, to the best of our knowledge, the fuzzified A'WOT combined with the fuzzzy Delphi technique has not been used in forest management.

Materials and methods

The proposed FDA'WOT model is a combination of the fuzzy Delphi technique, the fuzzy SWOT analysis and the AHP method. Expert opinions about the influences of the strategic factors are gathered and aggregated by the fuzzy Delphi technique, the strategic options are formulated through the fuzzy SWOT analysis and, finally, they are evaluated and prioritized in the AHP procedure.

As a tool for strategic decision making, the SWOT analysis is widely used, but besides many advantages it also has some disadvantages. The main disadvantages of the traditional SWOT analysis are (Ghazinoory et al, 2007): only qualitative analysis of factors; lack of objective (analytical) prioritization of different factors and strategies; difficult strategy selection in case a lot of factors are involved; and insensitivity to vagueness of the factor influences.

Quantification and prioritization problems can be overtaken by an AHP and SWOT combination. Accordingly, the A'WOT method, proposed by Kangas et al. (2001), solves the problems, but if a lot of factors are considered in the SWOT analysis, there appears a problem of consistency in AHP pairwise comparisons. Kurttila et al. (2000) and Saaty (1977) recommended limiting the number of SWOT factors to ten in order to increase the consistency. As it is axplained in Kurttila et al. (2000), the problem of pairwise comparisons consistency can be solved by grouping factors and introducing an additional level of hierarchy in the AHP model, or using specific techniques for data analysis.

However, the A'WOT model did not solve the problem of treatment and quantification of uncertain nature of the influences of strategic factors. The FDA'WOT model addresses that question. The model consists of six steps:

Step 1: Identify relevant internal and external strategic factors, and use a group of experts to assess the character and the influence of each factor on the forest road network. Do assessment by the fuzzy Delphi technique.

Step 2: Formulate alternative strategic options in the fuzzy SWOT process;

Step 3: Establish the hierarchical structure of the problem of choosing an optimal strategic option, according to the AHP approach;

Step 4: Conduct mutual pairwise comparisons of the factors within each SWOT group of factors (internal and external) and determine their relative priorities;

Step 5: Conduct mutual pairwise comparisons of the SWOT groups of the factors and determine the relative importance of the groups;

Step 6: Use the classic AHP method to evaluate alternatives, in relation to each SWOT group of factors, and to calculate the global priority of the alternatives in accordance with the established hierarchy of choice.

A need for the fuzzy approach in the evaluation of the strategic factors appears when a factor can be viewed as an opportunity and a threat, or a strength and a weakness, at the same time. For example, government support (if it is a strategic factor) is an advantage (opportunity) and a disadvantage (threat) simultaneously. It is an opportunity because of the possibility to use certain funds, but it is also a threat when the government support is denied or the funds are inefficiently used. An appropriate way to evaluate the character of a strategic factor such as this is to represent it as a fuzzy value. Thus, the estimation of the character and the importance of each strategic factor is expressed by a fuzzy number with a membership function which has a free form, in principle. Due to calculation simplicity, according to the recommendations given in (Ghazinoory et al, 2007), it is practical to use triangular fuzzy numbers $A=(a^l,a^m,a^u)$, where: a^l is a lower or pessimistic value, a^m is a medium or the most probable value and a^u is an upper or optimistic value of the factor. The task for the experts involved is to assess and linguistically express the influence of the factors. Their assessments are transformed into triangular fuzzy numbers, according to the adequate fuzzy scale (Figure 1). The average assessment of the group of experts $A_{sr}=(a^l_{sr},a^m_{sr},a^u_{sr})$, for each factor separately, is calculated by aggregating individual assessments into the average value of a set of fuzzy numbers given for a particular factor, according to Eq. (1).

$$A_{sr} = (a_{sr}^{l}, a_{sr}^{m}, a_{sr}^{u}) = (\frac{1}{N} \cdot \sum_{i=1}^{N} a_i^l, \frac{1}{N} \cdot \sum_{i=1}^{N} a_i^m, \frac{1}{N} \cdot \sum_{i=1}^{N} a_i^u) \qquad (1)$$

If some experts are more important, there is a possibility to use a weighted approach. In the assessment scale (Figure 1), a negative influence is related to threats or weaknesses, while a positive influence corresponds to opportunities or strengths.

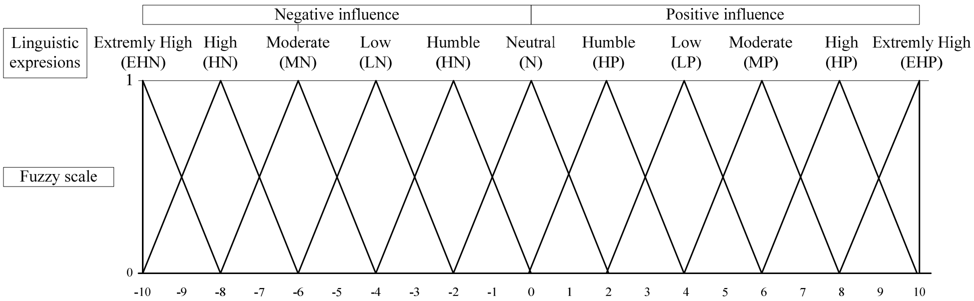

Figure 1 – Linguistic descriptors and a corresponding fuzzy scale for the assessment of the influence of the strategic factors

Рис. 1 – Лингвистические дескрипторы и соответствующая нечёткая шкала для оценки воздействия стратегических факторов

Слика 1 – Лингвистички дескриптори и одговарајућа fuzzy скала за процену утицаја стратегијских фактора

The next activity in the model is factor matching. It is an analysis of the mutual suitability of the factors. After that, the influences of the matched up factors should be mixed and projected into a domain of the adequate strategy type, according to the procedure explained by Ghazinoory et al. (2007). The aggregation and projection of factor influences result in potential ingredients of strategic options. Graphically, the factor combinations are presented as a set of pyramids, formed by a crossing mambership function (see the example in Figure 2).

The selection of factor combinations for the formulation of strategic options depends on the chosen α-cut (0 ≤ α ≤ 1) of the pyramids, the α-cuts projections onto the plane of the bases of the pyramids, and on the fulfillment of the selection criteria.

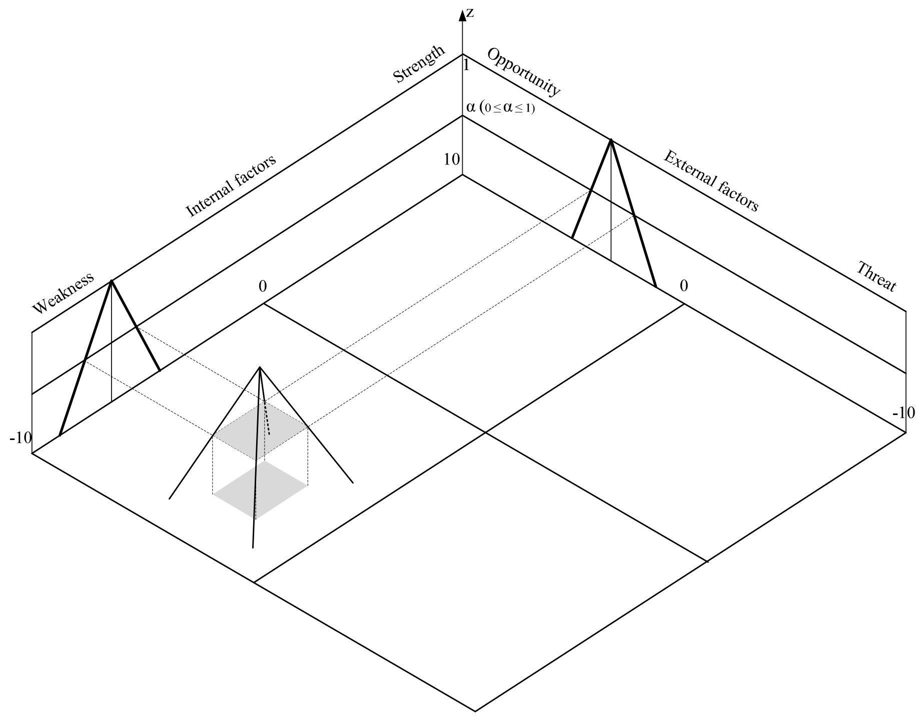

Figure 2 – Example of the aggregation of the membership functions of an internal and an external factor, their α-cut and its projection otno the base
Рис. 2 – Пример агрегации функций принадлежности с одним внутренним и одним внешним фактором, их α-сечения и его проекции на основании
Слика 2 – Пример агрегације функција припадности за један интерни и један екстерни фактор, њиховог α-пресека и његове пројекције на базу

As the selection criterion, Ghazinoory et al. (2007) recommended one of these:

- minimum of the Euklidean distance from the matrix vertices to the nearest edge of the projection area,
- minimum of the distance from the matrix vertices to the centre of gravity of the projection area, or
- maximum of the percentage of the projection area which belongs to a particular quadrant in the matrix.

The strategic options should be based on the combination of factors whose influences are connected and, in the same time, which satisfy the selection criterion. When the strategic options are defined, an AHP hierarchy is set up. Generally, a hierarchy of the selection model can be structured into four levels. At the top level, there is the selection goal –

the optimal strategic option for the forest roads network development. At the second level, there are two SWOT categories of factors - internal factors (strengths and weaknesses) and external factors (opportunities and threats). The identified strategic factors are at the third level while the defined strategic options are at the fourth level.

The presented model is applied to the problem of defining the strategic options in the development of the forest road network in Serbia. The existing forest road network in Serbia was constructed mainly with the view of timber harvest. Considering the contemporary needs of users, interests of stakeholders and forest management policy, an adequate strategy is one of the high priority prerequisites for the development of the forest road network. According to the Bulletin of Statistical Office of the Republic of Serbia (Statistical Office of the Republic of Serbia, 2015), the total length of the state-owned forest roads in Serbia is 25903 km, out of which 386 km are modern roads, 21190 km are rigid roads and 4 km are flexible roads. The assessed density of the forest road network in Serbia is 7.23 m/ha, or 5.24 m/ha if only forest roads paved with gravel are counted in (Danilović & Stojnić, 2014). Additionally, many of the forest roads are in unserviceable condition. A lot of them are unsurfaced „tractor“ roads. This state of the forest road network is not satisfactory. The development of the forest road network depends on many factors. Some of them are limiting. Because of that, a feasible and sustainable strategy should be balanced and based on an appropriate, scientific assessment of an uncertain nature of factors.

Results

Taking into account the contemporary conditions of the forest road network in the observed geographical area, actual management problems, incompleteness of law and management regulations (strategy, policy, development plans, etc.), contemporary and future social needs, as well as forestry needs, a set of internal and external factors with a strategic influence on the forest road network development has been formed. The characters of the identified factors are expressed by fuzzy values (Table 1), based on the expert oppinions gained in the fuzzy Delphy precedure presented in Bojadziev and Bojadziev (2007).

Expert oppinions were collected in 2015 through two rounds of questionnaires. Twenty one experts were involved in the survey (in the second round, 20 experts answered to the questionnaire). All of them are experienced, highly positioned managers in the Ministry of Agriculture, Forestry and Water Management or in the state enterprise „Srbijašume“, or are eminent professors at the Faculty of Forestry.

The average opinions of the group of experts on the characters of the influencing factors are presented by the triangular fuzzy number $A = (a_{sr}^{l}, a_{sr}^{m}, a_{sr}^{u})$, with the membership function:

$$\mu_A(x) = \begin{cases} 0; & x \le a_{sr}^{l} \\ \dfrac{x - a_{sr}^{l}}{a_{sr}^{m} - a_{sr}^{l}}; & a_{sr}^{l} < x \le a_{sr}^{m} \\ \dfrac{a_{sr}^{u} - x}{a_{sr}^{u} - a_{sr}^{m}}; & a_{sr}^{m} < x < a_{sr}^{u} \\ 0; & x \ge a_{sr}^{u} \end{cases} \tag{2}$$

Table 1 – The expert assessment of the nature of the strategic factors influencing the forest road network development
Таблица 1 – Экспертная оценка характера стратегических факторов, влияющих на развитие сети лесных дорог
Табела 1 – Експертска процена природе стратегијских фактора који утичу на развој мреже шумских путева

INTERNAL FACTORS (Int) - Strengths and Weaknesses		
Int1.	Renewed cooperation with educational institutions	(0, 1, 2)
Int2.	Current cooperation with local government and owners of private forests	(-2,-1, 2)
Int3.	Lack of strategy and policy in the forest road network management	(-1, 0, 2)
Int4.	Implemented Geographic Information System (GIS) provides a detailed map of the forest areas and insight into the existing network of forest roads.	(0, 2, 3)
Int5.	Cooperation with all sectors within the Ministry of Agriculture, Forestry and Water Management	(-2, 1, 2)
Int6.	Availability of the public transport network (rail and road networks)	(-3,-2,1)
Int7.	Density and quality of the existing forest road network	(-5,-4,-1)

EXTERNAL FACTORS (Ext) - Opportunities and Threats		
Ext1.	Legislation and support programs and projects	(0, 2, 3)
Ext2.	Cooperation within the Government of the Republic of Serbia (between different ministries: Ministry of Agriculture and Environmental Protection, Ministry of Civil Engineering, Transport and Infrastructure, etc.)	(0, 1, 3)
Ext3.	Growing interest in the aspects of the use of forests such as recreation, sports, tourism, etc. and potential secondary profit from the development of the forest road network	(1, 3, 5)
Ext4.	Undeveloped and non-standardized communication among stakeholders (administrative bodies, forest owners, transport companies, lumber industry, tourist organizations, etc.)	(-1, 0, 2)
Ext5.	Reconstruction and further development of the lumber industry	(-2, 0, 1)
Ext6.	Build-up rail and road communications on corridor 10 and corridor 11	(-1, 0, 1)
Ext7.	Lack of capital and small investments in the construction and maintenance of the existing forest roads	(-5,-4,0)

The formulation of strategic options for the development of the forest road network was carried out on the basis of the evaluation of the characters of the strategic factors, the correlation of their impacts, the chosen alpha-cut (α = 0.5) and the minimum affiliation percentage of the projection of the alpha-cut area to a particular „strategic“ quadrant as the criteria for selecting the factors based on which the strategic options will be formulated (Ghazinoory et al, 2007). The combinations whose projections of the alpha-cut belong to one of the strategic quadrants at least 75% of the total surface were considered as relevant combinations of the factors for the formulation of strategic options (Table 2). The combinations of the factors that also satisfy this condition (and which are indirectly linked through some other factor) are shown in Table 3.

Based on the basic types of the SWOT strategies (SO, ST, WO, and WT strategy) in general, the optimal strategic option is a combination of the characteristics of these types shaped by the impact of situational strategic factors.

In accordance with the combinations of the selected factors relevant for the formulation of strategic options (Figure 3), in the considered case, three strategic options for the development of the forest road network are extracted.

Table 2 – An overview of the combinations of the directly related factors which meet the established criterion
Таблица 2 – Обзор комбинаций непосредственно связанных факторов, которые соответствуют установленным критериям
Табела 2 – Преглед комбинација директно повезаних фактора, које задовољавају постављени критеријум

Factors combination	**Vertices Coordinates (x,y) of the projection surface**				**Percent of the projection surface which belongs to one of the strategic quadrants**
Int1 – Ext1	(0.5, 1)	(1.5, 1)	(1.5, 2.5)	(0.5, 2.5)	100 %
Int1 – Ext3	(0.5, 2)	(1.5, 2)	(1.5, 4)	(0.5, 4)	100 %
Int2 – Ext1	(-1.5, 1)	(0.5, 1)	(0.5, 2.5)	(-1.5, 2.5)	75 %
Int2 – Ext2	(-1.5, 0.5)	(0.5, 0.5)	(0.5, 2)	(-1.5, 2)	75 %
Int2 – Ext3	(-1.5, 2)	(0.5, 2)	(0.5, 4)	(-1.5, 4)	75 %
Int2 – Ext7	(-1.5, -4.5)	(0.5, -4.5)	(0.5, -2)	(-1.5, -2)	75 %
Int4 – Ext1	(1, 1)	(2.5, 1)	(2.5, 2.5)	(1, 2.5)	100 %
Int4 – Ext2	(1, 0.5)	(2.5, 0.5)	(2.5, 2)	(1, 2)	100 %
Int5 – Ext1	(-0.5, 1)	(1.5, 1)	(1.5, 2.5)	(-0.5, 2.5)	75 %
Int5 – Ext3	(-0.5, 2)	(1.5, 2)	(1.5, 4)	(-0.5, 4)	75 %
Int5 – Ext7	(-0.5, -4.5)	(1.5, -4.5)	(1.5, -2)	(-0.5, -2)	75 %
Int6 – Ext2	(-2.5, 0.5)	(-0.5, 0.5)	(-0.5, 2)	(-2.5, 2)	100 %
Int6 – Ext3	(-2.5, 2)	(-0.5, 2)	(-0.5, 4)	(-2.5, 4)	100 %
Int6 – Ext7	(-2.5, -4.5)	(-0.5, -4.5)	(-0.5, -2)	(-2.5, -2)	100 %
Int7 – Ext1	(-4.5, 1)	(-2.5, 1)	(-2.5, 2.5)	(-4.5, 2.5)	100 %
Int7 – Ext3	(-4.5, 2)	(-2.5, 2)	(-2.5, 4)	(-4.5, 4)	100 %
Int7 – Ext7	(-4.5, -4.5)	(-2.5, -4.5)	(-2.5, -2)	(-4.5, -2)	100 %

Tabela 3 – An overview of the combinations of the indirectly related factors which meet the established criterion
Таблица 3 – Обзор комбинаций косвенно связанных факторов, которые соответствуют установленным критериям
Табела 3 – Преглед комбинација индиректно повезаних фактора, које задовољавају постављени критеријум

Factors combination	**Vertices Coordinates (x,y) of the projection surface**				**Percent of the projection surface which belongs to one of the strategic quadrants**
Int1 – Ext2	(0.5, 0.5)	(1.5, 0.5)	(1.5, 2)	(0.5, 2)	100 %
Int1 – Ext7	(0.5, -4.5)	(1.5, -4.5)	(1.5, -2)	(0.5, -2)	100 %

Factors combination	Vertices Coordinates (x,y) of the projection surface				Percent of the projection surface which belongs to one of the strategic quadrants
Int4 – Ext3	(1, 2)	(2.5, 2)	(2.5, 4)	(1, 4)	100 %
Int4 – Ext7	(1, -4.5)	(2.5, -4.5)	(2.5, -2)	(1, -2)	100 %
Int5 – Ext2	(-0.5, 0.5)	(1.5, 0.5)	(1.5, 2)	(-0.5, 2)	75 %
Int6 – Ext1	(-2.5, 1)	(-0.5, 1)	(-0.5, 2.5)	(-2.5, 2.5)	100 %
Int7 – Ext2	(-4.5, 0.5)	(-2.5, 0.5)	(-2.5, 2)	(-4.5, 2)	100 %

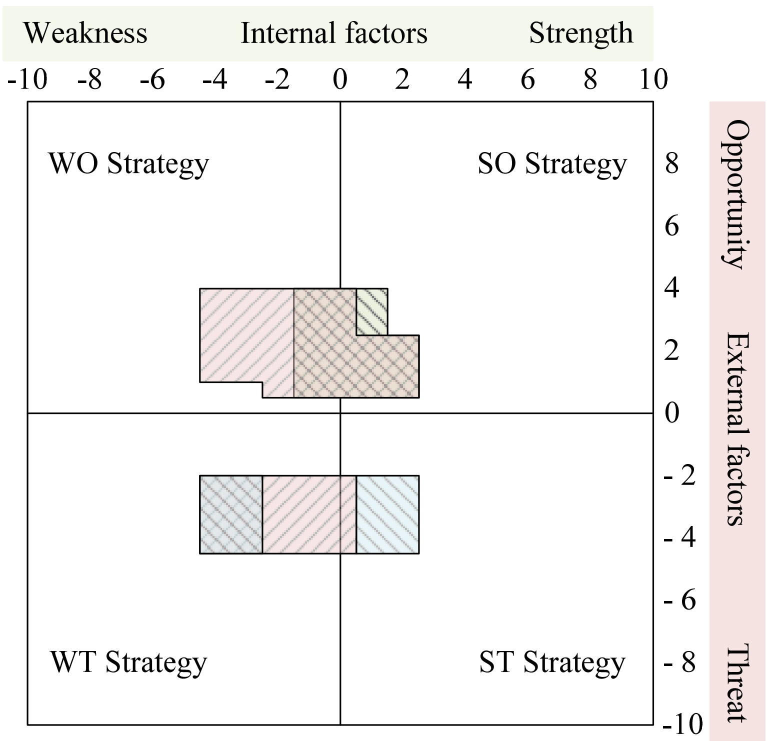

Figure 3 – Surfaces of the alpha-cut projections for the factors which shape the strategic options

Рис. 3 – Площадь α-сечения для факторов, которые образуют стратегические варианты

Слика 3 – Површине пројекција α-пресека за факторе који обликују стратегијске опције

Strategic option 1 is formed on the basis of the combinations of factors: Int 1 with Ext 1 and Ext 3; Int 2 with Ext 1, Ext 2 and Ext 3; and Int 4 with Ext 1 and Ext 2. It can be formulated as follows: *Through intensive cooperation with educational institutions, local government bodies, private forest owners and other stakeholders, based on the existing resources and possible support of the state, enable the efficient exploitation of the existing forest road network in order to achieve extended forest functions and reduce the gap between new needs and current abilities*.

Strategic option 2 is formed on the basis of the combinations of the factors: Int 2 with Ext 1, Ext 2, Ext 3 and Ext 7; Int 4 with Ext 1 and Ext 2; Int 6 with Ext 2, Ext 3 and Ext 7; and Int 7 with Ext 1, Ext 3 and Ext 7. It contains the elements of all four types of strategies (WO-WT-OS-ST). The formulation of strategic option 2 is: *Exploiting the opportunities offered by the programs and support projects to provide funds for the construction of new and maintenance of the existing forest roads, and based on the existing legislation and growing interest of the society for unconventional aspects of forest use, involving all stakeholders and synergistic action at all levels, as well as the achievement of a potential „secondary" profit from forests, establish a sustainable model for the management of the forest road network.*

Strategic option 3 is based on a combination of Factor Int 7 with Factor Ext 7, as well as indirectly linked factors Int 1 and Int 4 with Ext 7. As a mix of the WT and ST strategies, Option 3 can be formulated as: *Due to the lack of capital and insufficient investments, with the help of educational institutions, prepare a framework for analysis, maintenance and (re)construction of the forest roads, determine the priorities for maintenance and (re)construction and create preconditions for preserving the functionality of the existing forest road network*.

After selecting the factors and defining the alternatives, the A'WOT hierarchical model of choosing the guidelines for the long-term development of the forest road network is formed. The model is structured in four levels (Figure 4). The first level represents the selection goal - an optimal strategic option for the development of the forest road network. At the second level, there are two groups of the SWOT factors (internal factors and external factors). Each SWOT group contains perceived strategic factors which make up the third level of the hierarchy, while at the fourth level there are three defined alternatives - strategic options.

In the AHP procedure, by Saaty's scale (Saaty, 1980), decision makers express their own preferences. Transforming the preferences, according to the procedure described by Saaty (Saaty, 1980), the weighting coefficients of the elements in all hierarchical levels are determined. At the end of the procedure, a decision maker has two important pieces of information: 1) information about the significance of the alternatives, and 2) information about the ranking of the alternatives. In the presented case study, the AHP procedure is conducted using the Expert choice 11 software. Based on the pairwise comparison of the factors (the example of factors Ext 6 and Ext 7 is shown in Figure 5) and the pairwise comparison of the alternatives (the example of Strategic option 1 and Strategic option 2 is shown in Figure 6), priorities are defined and the optimal strategic option for the forest road network development is selected.

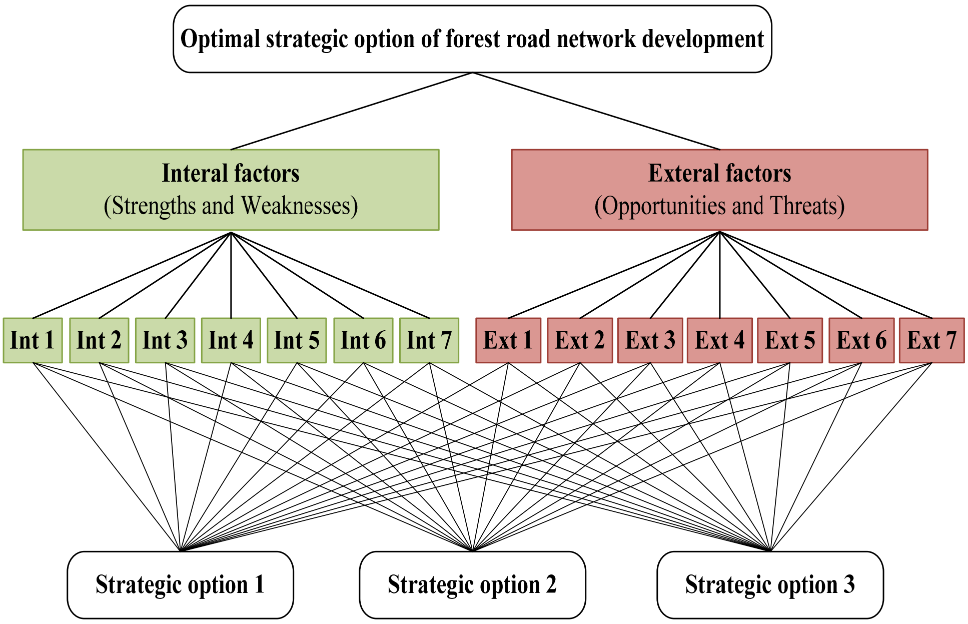

Figure 4 – A'WOT hierarchical model for the selection of the optimal development strategy
Рис. 4 – A'WOT иерархическая модель выбора оптимальной стратегии развития
Слика 4 – A'WOT хијерархијски модел избора оптималне стратегије развоја

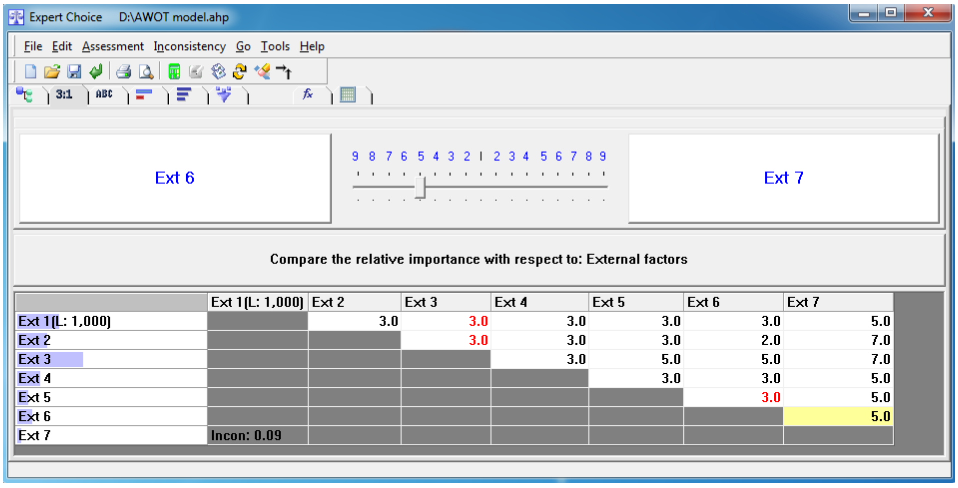

Figure 5 – Pairwise comparison of factors Ext 6 and Ext 7 and the priorities of the external factors
Рис. 5 – Сравнение факторов Ext 6 и Ext 7 и приоритеты внешних факторов
Слика 5 – Међусобно поређење фактора Ext 6 и Ext 7 и приоритети спољашњих фактора

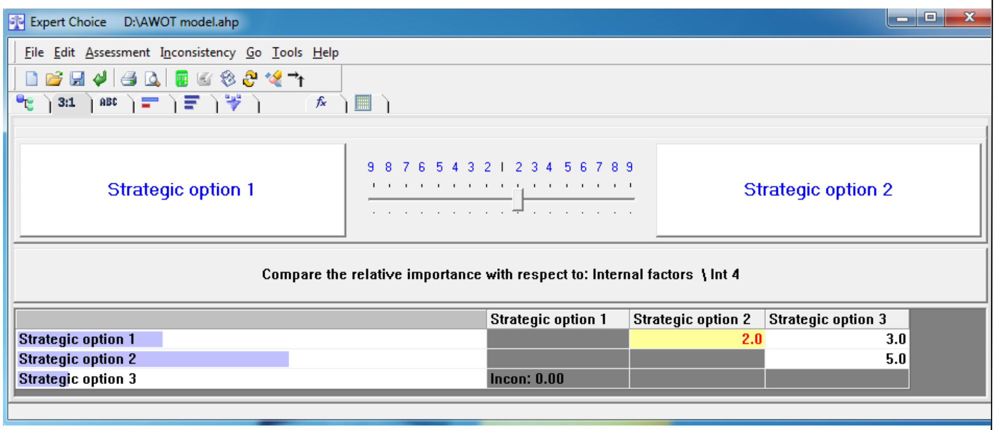

Figure 6 – Pairwise comparison of the alternatives and the relative importance of the alternatives
Рис. 6 – Парное сравнение и относительная важность альтернатив
Слика 6 – Међусобно поређење и релативна важност алтернатива

The final result of ranking the strategic options is shown in Figure 7. According to the results, in the context of the identified internal and external factors, strategic option 2 has the highest priority (its relative importance is the highest - 0.423).

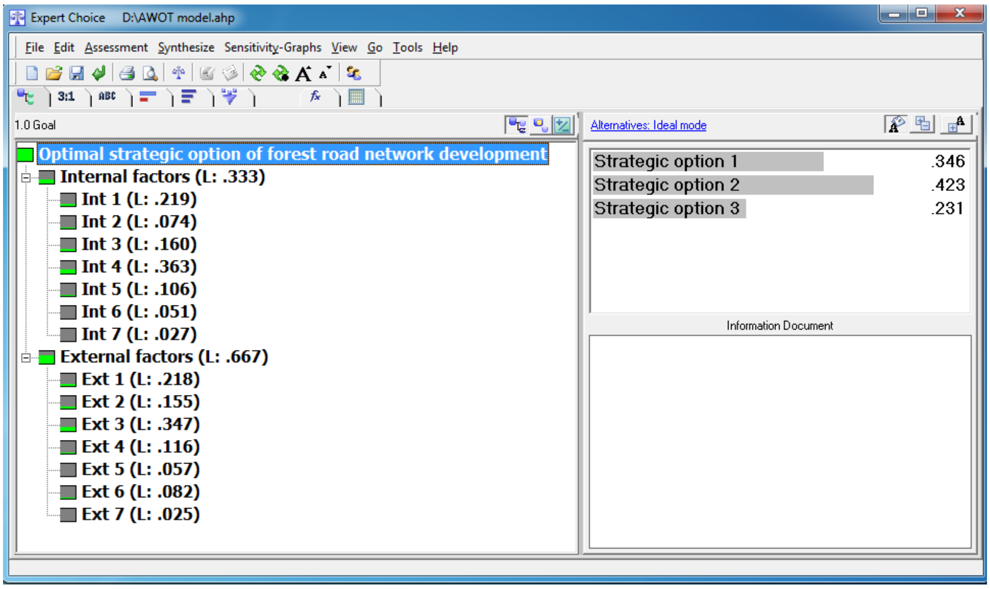

Figure 7 – The strategic options ranking results
Рис. 7 – Результаты ранжирования стратегических вариантов
Слика 7 – Резултати рангирања стратегијских опција

To test the reliability of the results and the sensitivity of the FDA'WOT model, a sensitivity analysis has been conducted. The Expert choice 11 software package enables five types of sensitivity analyses: Dynamic, Performance, Gradient, Head to Head and Two-Dimensional (2D Plot). In this paper, the Performance analysis has been chosen (Figure 8).

The sensitivity analysis is aimed at understanding the changes in the ranking order caused by the changes in the factor weighting coefficients. The procedures introduce intentional changes in the factor weighting coefficients to monitor the preferences of the alternatives in a „what-if" manner.

In this case study, the sensitivity analysis has been conducted through four scenarios: *Scenario 1* - Equal importance of the internal and external strategic factors; *Scenario 2* - Internal factors are more important than the external factors; *Scenario 3* - Internal factors are significantly more important than the external factors, and *Scenario 4* - External factors are significantly more important than the internal factors.

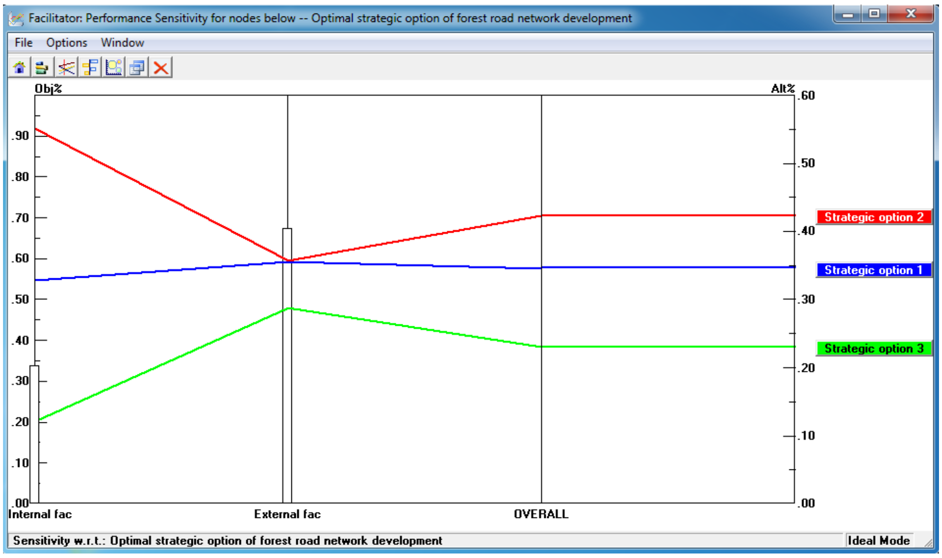

Figure 8 – Sensitivity analysis of the results (Performance analysis screen shot in the case of the dominance of the external factors)
Рис. 8 – Анализ чувствительности (скриншот "Анализ эффективности" в случае преобладания внешних факторов)
Слика 8 – Анализа осетљивости резултата (снимак екрана „Анализе перформанси" у случају доминације екстерних фактора)

The derived conclusions show the stability in the ranks of the alternatives (the ranks stay unchanged and the gaps between the preferences of the alternatives increase) for the first three scenarios. In the fourth scenario, the gaps between the preferences decrease until reaching the equality of strategic option 2 and strategic option 1. Accordingly, the model is sensitive and strategic option 2 is steadily the best option.

Discussion and conclusions

The presented hybrid FDA'WOT model is aimed to set up the guidelines for the selection of a sustainable strategy. The chosen strategy should be based on the current situation analysis and should forecast future trends. The concept of the model consists of the identification of the character of the strategic factors, the strategic options formulation based on the most influential factors, and the evaluation and prioritization of the strategic options in the process of pairwise comparison according to the AHP procedure. Thereby, unlike the classic qualitative approach, fuzzy logic provides a more objective treatment of imprecise, uncertain and subjective information. Also, in the AHP procedure, factors with indefinite influence are taken into account. It improves the information basis of decision making and quantifies the selection problem.

In the case study, the proposed FA'WOT method was applied to the problem of strategy selection for the development of the forest road network in Serbia.The chosen option provides long-term guidelines for an important aspect of forest management. The strategy defined on this concept should ensure that the road network meets both current and future forest management objectives, and responds to the needs of society, environmental protection requirements, safety requirements, etc. In addition, except for the forest road network long-term planning problem, the FA'WOT method is applicable to any problem of strategic planning.

The areas of possible improvement of the FA'WOT model are: quantification of the involvement of the factors whose influence has a dual character, in different strategic options; selection of the shape of the fuzzy membership functions which, in the most appropriate way, represents the characters of the factors; quantification of the relationships among the factors in order to select ingredients in the strategic options; expansion of the areas of the sensitivity analysis deeper into the model (to analyse the sensitivity of the result when the α value changes, $0 \leq \alpha \leq 1$, to analyse the sensitivity of the result when the selection criteria of factors relevance change, etc.).

References

Bojadziev, G., & Bojadziev, M. 2007. *Fuzzy Logic for Business, Finance and Management*.Singapore: Hackensack. NJ: Word Scientific, pp.71-72.

Carbone, F., & Savelli, S. 2009. Forestry programmes and the contribution of the forestry research community to the Italy experience. *Forest Policy and Economics,* 11(7), pp.508-515. Available at: https://doi.org/10.1016/j.forpol.2009.06.001.

Danilović, M., & Stojnić, D. 2014. Assessment of the state of a forest road network as a basis for making a program of forest management unit opening. *Bulletin of the Faculty of Forestry,* 110, pp.59-71. Available at: https://doi.org/10.2298/gsf1410059d.

Diaz-Balteiro, L., & Romero, C. 2008. Making forestry decisions with multiple criteria: A review and an assessment. *Forest Ecology and Management,* 255(8-9), pp.3222-3241. Available at: https://doi.org/10.1016/j.foreco.2008.01.038.

Dimić, S., Pamučar, D., Ljubojević, S., & Đorović, B. 2016. Strategic Transport Management Models—The Case Study of an Oil Industry. *Sustainability,* 8(9), p.954. Available at: https://doi.org/10.3390/su8090954.

Dwivedi, P., & Alavalapati, J.R.R. 2009. Stakeholders' perceptions on forest biomass-based bioenergy development in the southern US. *Energy Policy,* 37(5), pp.1999-2007. Available at: https://doi.org/10.1016/j.enpol.2009.02.004.

Gerasimov, Y., Senko, S., & Karjalainen, T. 2013. Nordic Forest Energy Solutions in the Republic of Karelia. *Forests,* 4(4), pp.945-967. Available at: https://doi.org/10.3390/f4040945.

Ghazinoory, S., Zadeh, A.E., & Memariani, A. 2007. Fuzzy SWOT analysis. *Journal of Intelligent and Fuzzy Systems,* 18(1), pp.99-108.

Hayati, E., Majnounian, B., Abdi, E., Sessions, J., & Makhdoum, M. 2013. An expert-based approach to forest road network planning by combining Delphi and spatial multi-criteria evaluation. *Environmental Monitoring and Assessment,* 185(2), pp.1767-1776. Available at: https://doi.org/10.1007/s10661-012-2666-1.

Hoang, H.T.N., Hoshino, S., & Hashimoto, S. 2015. Forest stewardship council certificate for a group of planters in Vietnam: SWOT analysis and implications. *Journal of Forest Research,* 20(1), pp.35-42. Available at: https://doi.org/10.1007/s10310-014-0472-z.

Hynynen, J., Salminen, H., Ahtikoski, A., Huuskonen, S., Ojansuu, R., Siipilehto, J., . . . Eerikäinen, K. 2015. Long-term impacts of forest management on biomass supply and forest resource development: a scenario analysis for Finland. *European Journal of Forest Research,* 134(3), pp.415-431. Available at: https://doi.org/10.1007/s10342-014-0860-0.

Hynynen, J., Salminen, H., Huuskonen, S., Ahtikoski, A., Ojansuu, R., Siipilehto, J., . . . Eerikainen, K. 2014. Scenario analysis for the biomass supply potential and the future development of Finnish forest resources. *Working Papers of the Finnish Forest Research Institute,* 302, ISBN 978-951-40-2487-0.

Jalilova, G., Khadka, C., & Vacik, H. 2012. Developing criteria and indicators for evaluating sustainable forest management: A case study in Kyrgyzstan. *Forest Policy and Economics,* 21, pp.32-43. Available at: https://doi.org/10.1016/j.forpol.2012.01.010.

Jarský, V., Sarvašová, Z., Dobšinská, Z., Ventrubová, K., & Sarvaš, M. 2014. Public support for forestry from EU funds – Cases of Czech Republic and Slovak Republic. *Journal of Forest Economics,* 20(4), pp.380-395. Available at: https://doi.org/10.1016/j.jfe.2014.10.004.

Kajanus, M., Leskinen, P., Kurttila, M., & Kangas, J. 2012. Making use of MCDS methods in SWOT analysis—Lessons learnt in strategic natural resources management. *Forest Policy and Economics,* 20, pp.1-9. Available at: https://doi.org/10.1016/j.forpol.2012.03.005.

Kangas, J., Pesonen, M., Kurttila, M., & Kajanus, M. 2001. A'WOT: Integrating the AHP with SWOT Analysis. In *Proceedings of the 6th International Symposium on the Analytic Hierarchy Process - ISAHP 2001.*Bern,Switzerland, pp.189-198.

Kurttila, M., Pesonen, M., Kangas, J., & Kajanus, M. 2000. Utilizing the analytic hierarchy process (AHP) in SWOT analysis — a hybrid method and its application to a forest-certification case. *Forest Policy and Economics,* 1(1), pp.41-52. Available at: https://doi.org/10.1016/s1389-9341(99)00004-0.

Ljubojević, S., Dimić, S., & Luković, N. 2014. An analytical approach to defining strategic options in a case of developing multimodal transport in the Army of Serbia. *Vojnotehnički glasnik / Military Technical Coourier,* 62(2), pp.74-95. Available at: https://doi.org/10.5937/vojtehg62-2068.

Meddour-Sahar, O. 2015. Wildfires in Algeria: problems and challenges. *iForest - Biogeosciences and Forestry,* 8(6), pp.818-826. Available at: https://doi.org/10.3832/ifor1279-007.

Mendoza, G.A., & Prabhu, R. 2004. Fuzzy methods for assessing criteria and indicators of sustainable forest management. *Ecological Indicators,* 3(4), pp.227-236. Available at: https://doi.org/10.1016/j.ecolind.2003.08.001.

-Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, Directorate for Forests. 2006*. Strategija razvoja šumarstva Republike Srbije.* Belgrade: Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia (in Serbian).

Ochoa-Gaona, S., Kampichler, C., de Jong, B.H.J., Hernández, S., Geissen, V., & Huerta, E. 2010. A multi-criterion index for the evaluation of local tropical forest conditions in Mexico. *Forest Ecology and Management,* 260(5), pp.618-627. Available at: https://doi.org/10.1016/j.foreco.2010.05.018.

Pellegrini, M., Grigolato, S., & Cavalli, R. 2013. Spatial Multi-Criteria Decision Process to Define Maintenance Priorities of Forest Road Network: an Application in the Italian Alpine Region. *Croatian Journal of Forest Engineering,* 34(1), pp.31-42.

Rauch, P. 2007. SWOT analyses and SWOT strategy formulation for forest owner cooperations in Austria. *European Journal of Forest Research,* 126(3), pp.413-420. Available at: https://doi.org/10.1007/s10342-006-0162-2.

Saaty, T.L. 1980. *The Analytic Hierarchy Process*.New York: McGraw-Hill.

Saaty, T.L. 1977. A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology,* 15(3), pp.234-281. Available at: https://doi.org/10.1016/0022-2496(77)90033-5.

Stainback, G.A., Masozera, M., Mukuralinda, A., & Dwivedi, P. 2012. Smallholder Agroforestry in Rwanda: A SWOT-AHP Analysis. *Small-scale Forestry,* 11(3), pp.285-300. Available at: https://doi.org/10.1007/s11842-011-9184-9.

-Statistical Office of the Republic of Serbia. 2015. *Šumarstvo u Republici Srbiji, 2014.Bilten,* 596/2015.Belgrade: Statistical Office of the Republic of Serbia (in Serbian).

Triantakonstantis, D.P., Kalivas, D.P., & Kollias, V.J. 2013. Autologistic regression and multicriteria evaluation models for the prediction of forest expansion. *New Forests,* 44(2), pp.163-181. Available at: https://doi.org/10.1007/s11056-012-9308-x.

Zadnik Stirn, L. 2006. Integrating the fuzzy analytic hierarchy process with dynamic programming approach for determining the optimal forest management decisions. *Ecological Modelling,* 194(1-3), pp.296-305. Available at: https://doi.org/10.1016/j.ecolmodel.2005.10.023.

Winkel, G., & Sotirov, M. 2011. An obituary for national forest programmes? Analyzing and learning from the strategic use of “new modes of governance” in Germany and Bulgaria. *Forest Policy and Economics,* 13(2), pp.143-154. Available at: https://doi.org/10.1016/j.forpol.2010.06.005.

Zadeh, L.A. 1965. Fuzzy sets. *Information and Control,* 8(3), pp.338-353. Available at: https://doi.org/10.1016/s0019-9958(65)90241-x.

Zarekar, A., Vahidi, H., Zamani, K.B., Ghorbani, S., & Jafari, H. 2012. Forest Fire Hazard Mapping Using Fuzzy AHP and GIS study area: Gilan province of Iran. *International Journal on Technical and Physical Problems of Engineering,* 12(4), pp.47-55.

МОДЕЛЬ ПРИНЯТИЯ РЕШЕНИЙ В УПРАВЛЕНИИ СЕТЬЮ ЛЕСНЫХ ДОРОГ

Срджан Х. Димич, *Срджан* Д. Любоевич
Университет обороны в г.Белград, Военная академия, Департамент по логистике, г. Белград, Республика Сербия

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ВИД СТАТЬИ: обзорная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Эксплуатация лесных ресурсов и достижение полного потенциала лесного хозяйства зависят от плотности и качества сети лесных дорог. Поскольку сети лесных дорог выполняют не одну, а несколько функций, то их с правом можно считать чрезвычайно значимым стратегическим фактором в управлении лесным хозяйством. При планировании развития сети лесных дорог лица, принимающие решения, должны учитывать многочисленные технологические, экономические, социальные и природно-экологические факторы. При этом необходимо придерживаться комплексного и функционального подхода. В настоящей статье представлена гибридная методологическая основа для разработки принципов, которые помогут определить стратегию развития государственной сети лесных дорог. В данной связи предлагается нечёткая модификация метода A'WOT. Предложенная модель, названная моделью FDA'WOT, основана на идее сочетания нечёткого анализа дельфи, нечёткого SWOT анализа (Силы - Strengths, Слабости - Weaknesses, Шансы - Opportunities, Угрозы - Threats) и Аналитического Иерархического Процесса (AHP), которое формирует концептуальные рамки для *выбора оптимального стратегического варианта. Модель FDA'WOT поможет преодолеть проблему классического SWOT-анализа, связанную с нечёткостью и неопределенностью в оценке характера, воздействия и относительной важности стратегических факторов. Эта модель представляет собой формальную основу для принятия многокритериальных решений, которая позволяет аналитическим способом определить приоритет альтернативных стратегических вариантов и выбрать лучший из них. Предлагаемая модель разработана на примере выбора стратегического варианта при развитии сети лесных дорог в Республике Сербия. Представленные результаты показывают, что модель FDA'WOT создает условия для разработки устойчивой стратегии.*

Ключевые слова: сеть лесных дорог, принятие решений, стратегия, модель FDA'WOT, нечёткий метод дельфи, нечёткий SWOT, AHP.

МОДЕЛ ОДЛУЧИВАЊА ПРИ УПРАВЉАЊУ МРЕЖОМ ШУМСКИХ ПУТЕВА

Срђан Х. Димић, *Срђан* Д. Љубојевић
Универзитет одбране у Београду, Војна академија, Катедра логистике, Београд, Република Србија

ОБЛАСТ: саобраћај и транспорт
ВРСТА ЧЛАНКА: прегледни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Експлоатација шумских ресурса и остварење пуног потенцијала шума зависе од густине и квалитета мреже шумских путева. Како треба да задовољи више функција, она има стратегијски значај у управљању шумама. При планирању развоја мреже шумских путева, доносиоци одлука морају да узму у обзир бројне технолошке, економске, друштвене и природне – еколошке факторе, што значи да је неопходан свеобухватан и функционалан приступ. У овом раду приказан је хибридни методолошки оквир за формулисање смерница на којима треба дефинисати стретегију развоја државне мреже шумских путева. У ту сврху предложена је fuzzy модификација A'WOT методе. Предложени модел, назван FDA'WOT модел, заснован је на идеји да се кроз комбинацију fuzzy делфи технике, fuzzy SWOT (снаге – Strenghts, слабости – Weaknesses, шансе – Opportunities, претње – Threats) анализе и аналитичког хијерархијског процеса (AHP) обезбеди концептуални оквир за избор оптималне стратегијске опције. FDA'WOT модел омогућава превазилажење проблема класичне SWOT анализе који *се односе на неодређености и неизвесности приликом процене карактера, утицаја и релативне важности стратегијских фактора. Он представља формални оквир за вишекритеријумско одлучивање, који омогућава да се на аналитичан начин одреди приоритет алтернативних стратегијских опција и изабере оптимална. Предложени модел примењен је на примеру избора стратегијске опције развоја мреже шумских путева у Републици Србији, а презентовани резултати показују да FDA'WOT модел ствара услове за формулацију одрживе стратегије.*

Кључне речи: мрежа шумских путева, одлучивање, стратегија, FDA'WOT модел, fuzzy делфи, fuzzy SWOT, AHP.

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