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# VREDNOVANJE I OPTIMALNI IZBOR LOKACIJE ZA IZGRADNJU MINI HIDROELEKTRANE NA RIJECI VRBAS

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***Sažetak:***

Predstavljeni rad je dio šireg istraživanja vezanog za primjenu vode, kao obnovljivog izvora, koji je rađen u sklopu master programa sa temom energetske efikasniosti. Rad analizira aspekte izgradnje mini hidroelektrane (sa instaliranom snagom od 0.5 MW) za energetsko-ekološki razvoj ruralnog područja i primjenu obnovljivih izvora energije bez negativnog uticaja na životnu sredinu. Izvršena je analiza 3 različite lokacije na rijeci Vrbas sa pritokama, pomoću AHP metode i izvršen je izbor one koja je najadekvatnija za izgradnju ovog tipa objekta. Na početku rada opisan je značaj mini hidrocentrale u odnosu na veliki, a kasnije i potencijal za izgradnju objekata ove vrste u širem regionu Republike Srpske i BiH. Cilj rada je da pokaže značaj proizvodnje električne energije korišćenjem vode kao obnovljivog izvora energije i optimalan izbor lokacije primjenom AHP metode.

*Ključne riječi: Mini hidroelektrana, obnovljivi izvori energije, AHP metoda*

# EVALUATION AND OPTIMAL LOCATION'S SELECTION FOR MINI HIDRO POWER PLANT'S CONSTRUCTION ON RIVER VRBAS

***Abstract:***

The presented paper is part of a wider research related to the application of water, as a renewable source, which was made in the frame of master program with energy efficiency's topic. This paper analyzes aspects of the mini hydro power plant's construction (with installed power of 0.5 MW) for the energy-ecological development of the rural area and the application of renewable energy sources without negative impact on the environment. An analysis of 3 different locations on river Vrbas was performed using the AHP method and a selection of the most suitable location for the construction of this type of facility was made. At the beginning of the paper, the significance of the mini hydroelectric power plant is described in relation to the large, and later, the potential for the construction of facilities of this type in the wider region of the Republic of Srpska and BiH. The aim of paper is to show the importance of producing electricity using water as a renewable energy source and optimal location selection using the AHP method.

*Key words: mini hydro power plant, renewable energy sources, AHP method*

## 1. INTRODUCTION

The construction of a mini hydro power plant (MHPP), a flow character, with a centralized electromagnetic network, achieves the production of electricity by using water as a renewable source with a higher degree of environmental protection than large hydroelectric power plants [1],[2]. In addition to the production of el. energy, the goal of the project is the development of a rural environment near Banja Luka, famous for its natural resources. The notion rural development refers to the new modern concept of electric energy, which has not yet been developed in our region. One household, who by constructing such an object, becomes the owner of the energy factory, repays the construction costs and gets free electricity. Households sell electricity to electricity distribution, connect to their network, and forward surplus energy produced. By saving energy costs and earnings from selling assets, they are refunded over a certain period of time. At the end of the household / factory, as an investor, he earns a bonus and earnings. The offered MHPP technology is becoming innovative, because our market is not saturated with such types of projects, thus the technological and design solution is inherently attractive and raises the marking and mapping of the site as important in the environment. The construction of a mini hydroelectric power plant, besides economic characteristics, aims at protecting the environment, reducing fossil fuel emissions, protecting bio systems and microclimate, since the selected flow type of the mini hydro power plant has the least impact on the living world from other types of hydro power plants. In addition, the advantages of building mini hydropower plants are [3]:

- supply of electricity from renewable energy sources,
- water supply,
- watercourse arrangement (regulation of torrents, prevention of deposits, etc.),
- irrigation,
- sports and commercial fishing, and recreation of sports recreation zones.

*Figure 1. Appearance of a flow-through mini hydro electric power plant, [3]*

Mini hydro power plants has much less harmful impacts on the environment than large hydro power plants. While large hydroelectric power plants influence the change in the micro climate, water flow, fish migration and impact on the biological composition of water, small hydro power plants, especially those of the flowing type (Figure 1), minimize

the migration of fish, the environment and its aspects, as it is not necessary to make artificial accumulation, but use a natural fall. There is noise and vibration, but low intensity. A key advantage of mini hydroelectric power plants is the reduction or completely eliminated of greenhouse gas emissions. The main reason for this is that fossil fuels do not use as a turbine engineer or electric generator. Thus, the electricity produced in hydro power plants becomes more viable, and independent of the price and supply of fossil fuels on the market [2], [4].
In the continuation of work are shown: Criteria, which are important for MHPP's construction, locations suggestions based on criteria and preliminary research, their evaluation and selection of the most adequate solution.

## 2. DESCRIPTION OF THE CRITERIA FOR MHPP CONSTRUCTION

Criteria, analyzed in paper, are related to the requirements that are necessary for smooth functioning of MHPP. They are defined by urban and technical conditions and law of water use [6], [7]. Urban criteria are related to macro location analysis, e.g. its connection with environment, the distribution and density of population, distance of the existing plants - appearance of competitiveness and distance from urban environment. They are technically most related to micro location and relate to function of plant itself. The criteria on which locations was analyzed are [5], [6]:

- C1 - distance of existing MHP plants from proposed construction sites (greater distance, more favorable option);
- C2 - the existence of a transport infrastructure (this criterion is significant for possibility of access to plant during construction and exploitation, and for a better urban solution that is essential for obtaining a permit);
- C3 - the distance of traffic access from proposed locations (which has closer traffic access to location gets significant);
- C4 - the immediate distance of proposed sites for construction from urban environment (since it is a rural development of a home, the distance from urban environment is desirable, since the construction of such an object is not appropriate for the city environment);
- C5 - the existing quality of household electricity supply at observed sites;
- C6 - development of environment (for development of MHP plants of rural areas, good development of environment is not required, lower development is desirable);
- C7 - population density (a lower population density is desired, but with a concentrated type of object construction, rather than dissolved ones);
- C8 - the velocity of Vrbas River flow (for the MHPP operation it is necessary that the terrain has a fall from 2 to 40m and therefore a higher flow and speed);
- C9 - the distance of planned plant from connection to the mains network (the closer location connection gets to the significance);
- C10 - the consumer's distance from MHP plant (the consumer / investor who builds such an object and supplies electricity is desirable to be in close proximity).

In the wider region of Republic of Srpska, the potential for the development of mini hydroelectric power plants has basins: Vrbas, Trebišnjica, Drina, Bosna, Una and their tributaries [6]. Entity government of the Republic of Srpska has awarded 107 concessions for the construction of similar hydroelectric power plants since 2005, of which 28 contracts have been terminated and seven facilities have been put into operation so far. Of the aforementioned concessions, only one hydroelectric power plant Divič on the Vrbanja River (in 2006) with installed power of 1.4 MW and an average annual 0.25 GWh was built and put into operation [8]. In the Republic of Srpska, there are 7 mini hydro power plants with an installed power of more than 16, 95 MW and an average production of electricity of 68, 14 GWh. At the construction stage, there are two more hydroelectric power plants, while the remaining projects are in the process of preparation or at lower levels of the legal procedure in the process of obtaining the necessary permits and approvals [6], [8].
The main problem for building such facilities is lack of money, insufficient research and problems with local communities. The commission for concessions says that the spatial plans of the municipalities are not harmonized with the entity, so the site is intended for a mini hydroelectric power plant, often a protected area or a planned nature park [7]. Considering that the Vrbas river with its tributaries is characterized as a river with high potentials, which have not been used sufficiently and there are no mini hydroelectric power plants built near Banja Luka municipality, we decided to analyze this catchment in rural city's environment.

## 3. ANALYSIS OF LOCATION FOR MHPP'S CONSTRUCTION

During the selection of location for mini hydro power plant's construction on the Vrbas and Vrbanja, the criteria set out in the previous chapter have been used. The proposed locations for the construction of a new hydroelectric power plant on the Vrbas river basin are: Rekavice, Vrbanja and Karanovac (Figure 2). It is important to emphasize that our market is not saturated with this solution, and this type of project should not be considered as a competition, since the aim is to increase regional production of electric energy, while using a rational use of natural resources without environment's disturbing. In the territory of municipality of Banja Luka, in Vrbas basin, north of the HPP Bočac, there are no existing projects, while in the southern part of the municipality of Mrkonjic Grad, the project of mini HPP "Medna" is currently being implemented [9].

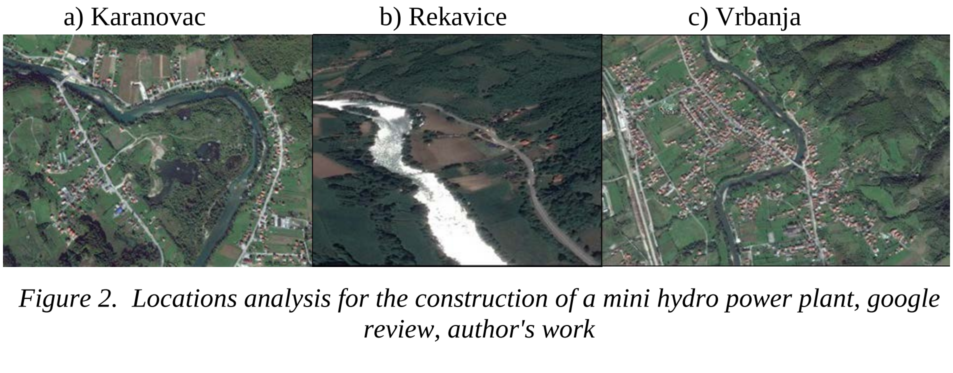


*Figure 2. Locations analysis for the construction of a mini hydro power plant, google review, author's work*

The construction of this type project is intended for investors, households who are visionaries and have modern thoughts about global problems and achievements in the world of renewable energy source's application. They want to own their own eco-system service and to adapt it to themselves and their needs.
In next chapter, the analytical and hierarchical comparison of 3 different locations and their evaluation according to set criteria were carried out.

## 4. EVALUATION LOCATIONS USING THE AHP METOD

AHP (analytical-hierarchical process) treats decision-making problem as a hierarchy of elements important for decision-making [10]. This method offers opportunity to explain all problems to problem matrix, with aim at top and criteria and alternatives at lower levels that can be easily understood and subjectively evaluated (Figure 3).[10], [12] It is used quite a lot in field of research because it has a number of its advantages, such as [11]: relative simplicity, intuitive approach, ability to use qualitative and quantitative information in the decision-making process, matrix of comparing system elements by pairs,ability to calculate index of inconsistency, existence of user-oriented software, and simple interpretation of results. The obtained values / results represent weight (priorities) of observed alternatives. Different ways of prioritizing objects are applied in AHP models, such as: the method of own values, the method of additive normalization, the lowest-order logarithmic method, the least-squares method of difficulty, the method of the programming of priorities, etc. [12, 13]. In this paper the method of own values is used. This means that in the analysis and comparison in pairs (Figure 4), for each criterion, values are assigned separately to the criterion (in this case, these values are from 1-9 in relation to priority and comparison). The formula based on this type of comparison is [13]:

$$Aw = \lambda \mathrm{w}, \mathrm{eT} \qquad (1)$$

Where:
A is matrix of criteria (Figure 4)
w = 1, is requested priority vector

It is solved so that the maximal own matrix value A is obtained. The maximum own value for an inconsistent matrix can be estimated by successive squaring of the matrix, by normalizing element's sum by type each time and by interrupting the procedure when the difference between the normalized sums in two consecutive calculations is lower than the expected value. Comparison's consistency in pairs and result's quality is checked by calculating the degree of consistency, and the accepted tolerant indicator's value is 0.10. If value of CR (degree of consistency) is CR<0.10 for matrix A is obtained, the values of the alternative (estimating the relative importance of the criterion) are considered acceptable [13].

In the concrete case, the method analyzes 10 criteria, in accordance with required goal "Choosing the best location for SHPP", where they are set in same ranking (Figure 3).

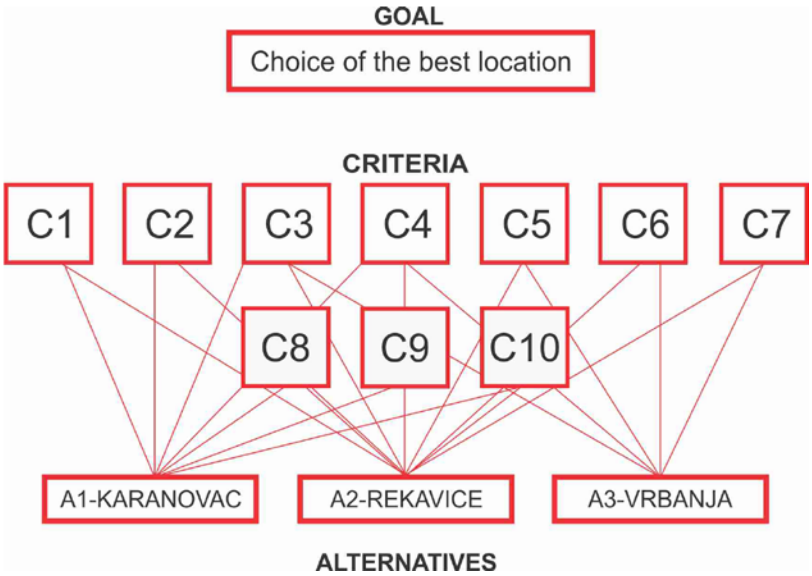


*Figure 3. AHP matrix for the presented research - selection of the best location for SHPPs, author's work*

Only when comparative analysis of each criterion with each matrix is performed (Figure 4) can the ranged comparison's results of criteria be created [10].

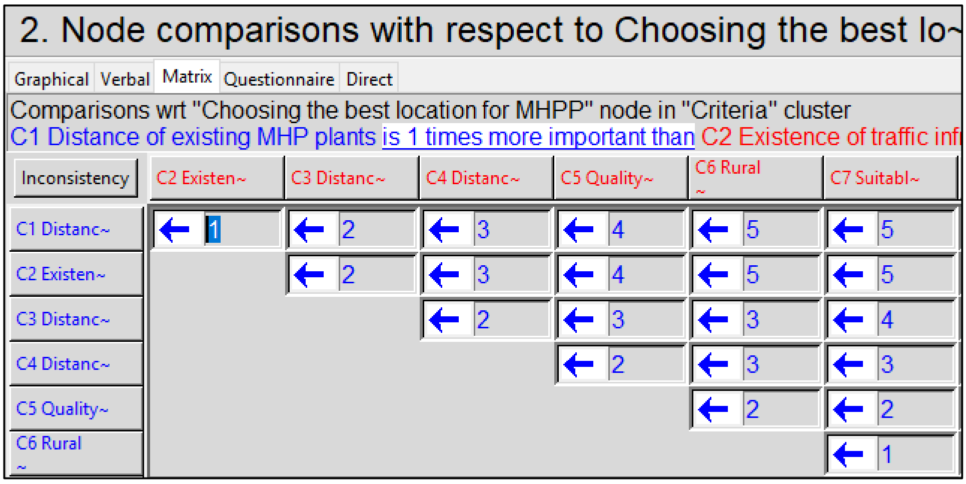


*Figure 4. Evaluation and comparison's matrix of criteria in pairs for SHPP's construction, author's work*

Based on analysis of the criteria according to the comparison matrix and the results of weight factor for criteria, which program is calculate, it is concluded that the most important criterion is "C8 - Flow velocity", then criteria are ranked by importance: C10, C9, C1, C2, C3, C4, C5, C6, C7.

| Criterion | Graphic | Weight factor for criteria | |
|---|---|---|---|
| C1 Distance of existing MHP plants | | 0.10791 | 0.053953 |
| C2 Existence of traffic infrastructure | | 0.10791 | 0.053953 |
| C3 Distance of traffic infrastructure | | 0.06871 | 0.034356 |
| C4 Distance from the city center | | 0.04639 | 0.023195 |
| C5 Quality of existing EE supply on site | | 0.03269 | 0.016345 |
| C6 Rural development of the environment | | 0.02411 | 0.012055 |
| C7 Suitable density of population | | 0.02356 | 0.011778 |
| C8 Flow rate of the river | | 0.25275 | 0.126377 |
| C9 Connection distance to the mains | | 0.16799 | 0.083994 |
| C10 Distance of consumers from MHP plant | | 0.16799 | 0.083994 |

*Figure 5. Calculate the local priorities and weight factors of the AHP model criteria, author's work*

In next steps, the assessment of alternative locations was made in relation to the offered criteria. First, each location is evaluated for each criterion separately (Figure 6, 7). Also, for each comparison of criteria with alternatives, the degree of consistency (inconsistency) is determined (Figure 7). For shown example - Comparison of C4 criterion with alternative locations (Figure 6) inconsistency is shown in Figure 7.

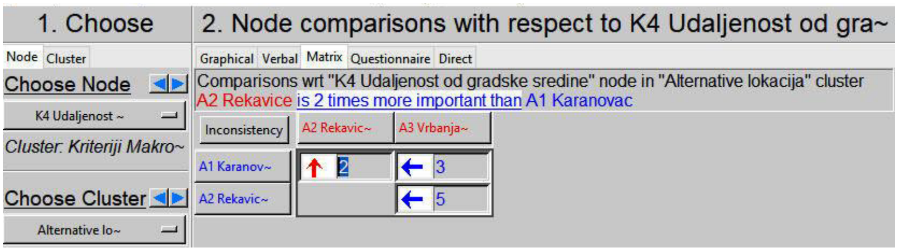


*Figure 6. Comparison matrix and the values of local priorities of the criterion C4, author's work*

For other comparisons, the consistency degrees are shown in Table 1. The overall degree of consistency, which the program determines based on previous analyzes is
CR = 0, 02395 (Figure 8). This is the total result of the comparison of criteria with alternatives. This value is less than the allowance, which means that the result of the analysis is acceptable and valid.

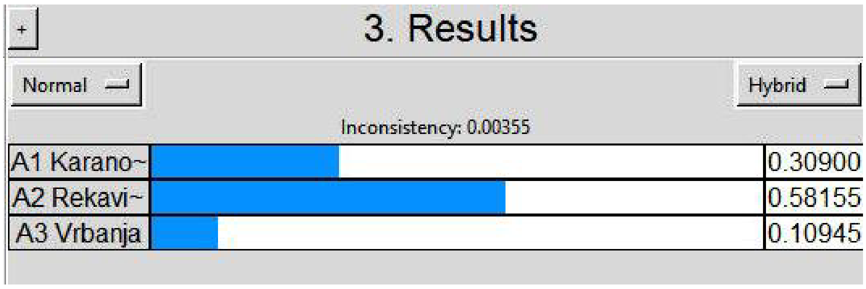


*Figure 7. Comparison matrix and the values of local priorities of the criterion C4, author's work*

*Table 1. Consistency level for each comparation criterion and alternatives, author's work*

| Comparison of criteria and alternatives | Inconsistency - CR |
|---|---|
| Comparison of criteria 1 (C1) with all 3 alternatives (A1, A2, A3) | 0.00000 |
| Comparison of criteria 2 (C2) with all 3 alternatives (A1, A2, A3) | 0.00000 |
| Comparison of criteria 3 (C3) with all 3 alternatives (A1, A2, A3) | 0.00000 |
| Comparison of criteria 4 (C1) with all 3 alternatives (A1, A2, A3) | 0.00355 |
| Comparison of criteria 5 (C5) with all 3 alternatives (A1, A2, A3) | 0.00000 |
| Comparison of criteria 6 (C6) with all 3 alternatives (A1, A2, A3) | 0.00000 |
| Comparison of criteria 7 (C7) with all 3 alternatives (A1, A2, A3) | 0.00885 |
| Comparison of criteria 8 (C8) with all 3 alternatives (A1, A2, A3) | 0.02395 |
| Comparison of criteria 9 (C9) with all 3 alternatives (A1, A2, A3) | 0.00835 |
| Comparison of criteria 10 (C10) with all 3 alternatives (A1, A2, A3) | 0.00550 |

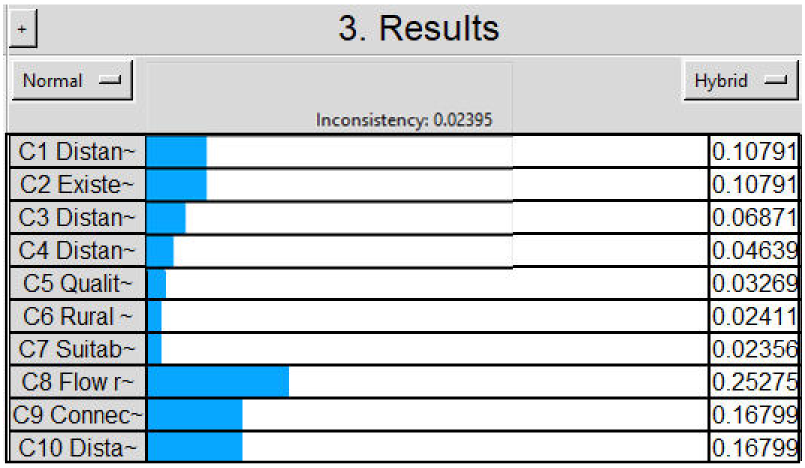


*Figure 8. Overall degree of consistency, author's work*

In the end, programmatically, all relationships are evaluated and evaluated together, and the final result is the ranking (Figure 9), which represents the ultimate result of the research.

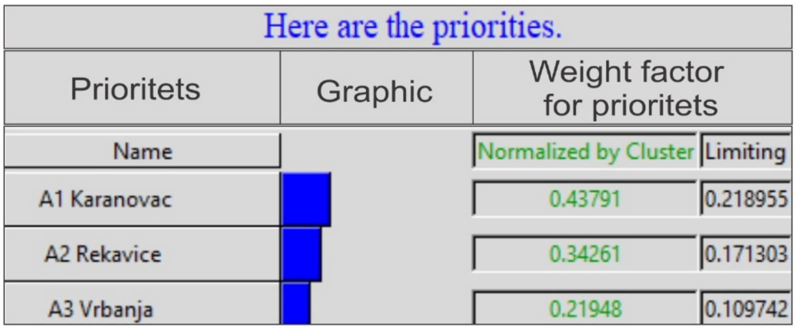


*Figure 9. Total calculate priority of observed locations, author's work*

The analysis has shown that the highest priority, or the best location for the construction of a 0.5 MW power line, has a Karanovac settlement, then Rekavice and at the end - Vrbanja. When choosing a site for analysis, it was taken into consideration that all three sites are quite good for construction of this type of MHPP and they all have the potential. The location in Karanovac settlement (Figure 10) has good accessibility, it is connected by road, has a relatively fast water flow, proximity to the connection to the network and there are no built MHPPs in the vicinity.


*Figure 10. Short view of the location, Karanovac settlement, google review, author's work*

## 5. CONCLUSION

The Republic of Srpska abounds in various forms of renewable energy and the highest potentials are: water, sun, but also bioenergy and wind energy. Climate change, as well as additional costs associated with the change in fossil fuel prices, have spurred a greater interest in renewable energy sources, and thus MHP plants, which should partly compensate for fossil fuels and contribute to environmental conservation. In the Republic of Srpska, there are 7 mini hydro power plants with an installed power of more than 16, 95 MW and an average production of electricity - 68, 14 GWh. If all potentials were used in more than 100 adequate locations with technical possibilities for construction of MHPP from 100 kW to 10 MW, the annual electricity production would increase by about 1400 GWh.

The paper analyzes some of the possible locations for the construction of the mini hydroelectric on the Vrbas with AHP method. Of the 3 locations which are analyzed, the most adequate and favorable position is the Karanovac settlement near Banja Luka. Mini hydro power plant in Karanovac, with installed power of 0.5 MW, would serve as auxiliary device for additional electricity generation and additional exploitation of river potential. By connecting the energy produced in a minihid power plant to a large network power supply system, the energy demand of the selected settlement could be met. What makes the process easier is the existence of a nearby substation and a transmission line system. It was also concluded that the most important criteria for construction are: the speed of the river flow, the distance of the consumers from the plant, the distance of the existing systems and the traffic connections.

Energy efficient constructions and applications of renewable energy sources represent the future, along with the applications of new technologies that enable the collection, absorption and consumption of such forms of energy both in international practice and in the region. This type of design is a complex process, a holistic process, in which different and diverse professions must co-operate, whose co-operation must be integrated into a single compact entity. Environmental awareness and obligations arising from international agreements imply the need to reflect more and more in our region on the increased share of renewable energy sources in the overall energy balance.

## 6. LITERATURE


[1] O. Dino. Male hidroelektrane i korištenje vodenih snaga. Sveučilište u Zagrebu, 2012, pp. 1-33.

[2] K. Ankit Naveen, S. Gupta, A. Pradeep and A.S.Jethoo. “Mini/Micro Hydro Power System Design and its Implementation in Rajasthan”, In Proc. ICWRCOE 2015, pp .1537 – 1544.

[3] Z.Šimić. Obnovljivi izvorienergije-Najvažnije vrste, potencijal i tehnologija, 2009. pp. 1-133.

[4] Tanzania Traditional Energy Development and Environment Organisation (TaTEDO). "70 kW Micro hydroelectric Plant in Zege village." Internet: http://toolkits.reeep.org/file_upload/10501005_10.pdf, 01.07.2007. [28.01.2018.]

[5] European Small Hydropower Association – ESHA. Guide on How to Develop a Small Hydropower Plant, ESHA: 2004, pp.12-199.

[6] D. Vasić. Ekonomsko-finansijska ocjena projekta izgradnje male hidroelektrane na primjeru MHE „Vrbanja 1“, Banja Luka, pp.1-50, 2012.

[7] Službeni glasnik Republike Srpske. Zakon o vodama - opšte odredbe. 2006. pp. 1-106.

[8] Energetski institut Hrvoje Požar i ekonomski institut ad Banja Luka. Strategija razvoja energetike Republike Srpske do 2030. godine, Banja Luka, 2012, pp. 20 - 62.

[9] Agencija FENA. "Počela izgradnja male hidroelektrane Medna u opštini Mrkonjić-Grad." Internet: http://novovrijeme.ba/pocela-izgradnja-male-hidroelektrane-medna-u-opcini-mrkonjic-grad/, 12. 09.2014. [28.01.2018.]

[10] T. Saaty and L. Vargas. "Decision Making With The Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks", Springer Science+Business Media, LLC, New York, 2006.

[11] B. Gaudenzi and A. Borghesi, (2006) "Managing risks in the supply chain using the AHP method", The International Journal of Logistics Management, Vol. 17 Issue: 1, pp. 114-136, 2006.

[12] G. Janjić, Z. Tanasić and M. Benea. "Improvement of the system of business success measurment in a company using multicriteria decision-making method." International journal of engeenering, pp. 159-165, 2012.

[13] B. Srđević, V. Kolarov. "Varijanta AHP vrednovanja dispozicija crpnih stanica na slivnom području". In Proc. Vodoprivreda 2005. pp. 204-2014.