

Application of AHP method in the process of evaluation of supporting structures for placing traffic signs

Katalinić, Mario; Karakašić, Mirko; Ivandić, Željko; Glavaš, Hrvoje

Source / Izvornik: **17. skup o prirodnom plinu, toplini i vodi ; 10. međunarodni skup o prirodnom plinu, toplini i vodi, 2019, 219 - 228**

Conference paper / Rad u zborniku

Publication status / Verzija rada: **Published version / Objavljena verzija rada (izdavačev PDF)**

Permanent link / Trajna poveznica: <https://um.nsk.hr/um:nbn:hr:262:297655>

Rights / Prava: [In copyright](#)/[Zaštićeno autorskim pravom.](#)

Download date / Datum preuzimanja: **2025-01-22**



Repository / Repozitorij:

repository.unisb.hr - The digital repository is a digital collection of works by the University of Slavenski Brod.

ZBORNIK RADOVA

PROCEEDINGS

17. SKUP O PRIRODNOM PLINU, TOPLINI I VODI
17th NATURAL GAS, HEAT AND WATER CONFERENCE

10. MEĐUNARODNI SKUP O PRIRODNOM PLINU, TOPLINI I VODI
10th INTERNATIONAL NATURAL GAS, HEAT AND WATER CONFERENCE

HEP-Group
HEP-Plin Ltd.
HR-31000 Osijek, Cara Hadrijana 7

J. J. Strossmayer University of Osijek
Mechanical Engineering Faculty in Slavonski Brod
HR-35000 Slavonski Brod, Trg I. B. Mažuranić 2

University of Pécs
Faculty of Engineering and Information Technology
H-7624 Pécs, Boszorkány u. 2



Suorganizator
Co-organizer



Uz potporu
Supported by
Ministarstvo znanosti i obrazovanja Republike Hrvatske
Ministry of Science and Education of the Republic of Croatia

Osijek, 25.- 27.09.2019.

PLIN 2019

ZBRONIK RADOVA 10. MEĐUNARODNOG SKUPA O PRIRODNOM PLINU, TOPLINI I VODI

PROCEEDINGS OF 10th INTERNATIONAL NATURAL GAS, HEAT AND WATER CONFERENCE

Izdavač / Publisher: Strojarški fakultet u Slavanskom Brodu

Email: plin@sfsb.hr

URL: <http://konferencija-plin.sfsb.hr>

All papers are reviewed.

The authors are only responsible for the contents and accuracy of all published material. The Editors do not accept any liability for the contents and accuracy of articles, or responsibility for any mistakes (editorial or typographical), nor for any consequences that may arise from them.

Urednici / Editors:

Pero RAOS, glavni urednik
Tomislav GALETA
Dražan KOZAK
Marija RAOS
Josip STOJŠIĆ
Zlatko TONKOVIĆ

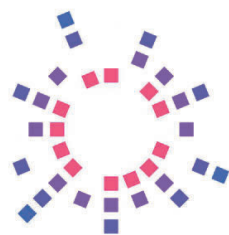
PLIN 2019 Organizacijski odbor / PLIN 2019 Organization committee:

Marija RAOS, Hrvatska, predsjednica organizacijskog odbora
Tomislav GALETA, Hrvatska
Josip CUMIN, Hrvatska
Miroslav DUSPARA, Hrvatska
Renata ĐEKIĆ, Hrvatska
Nada FLANJAK, Hrvatska
Ismeta HASANBEGOVIĆ, BiH
Zvonimir KLAIĆ, Hrvatska
Miroslav MAZUREK, Hrvatska
Ana RADONIĆ, Hrvatska
Pero RAOS, Hrvatska
Josip STOJŠIĆ, Hrvatska
Zlatko TONKOVIĆ, Hrvatska
Nikola VIŠTICA, Hrvatska

Sponzori / Sponsors



member of  energia naturalis



IOTnet
CONNECTING THINGS

Pokrovitelj/Patron



**HRVATSKA
GOSPODARSKA
KOMORA**

Izlagači / Exhibitors



PLIN 2019 Počasni odbor / PLIN 2019 Honor committee:

Ivan SAMARDŽIĆ, predsjednik, Hrvatska
Frane BARBARIĆ, Hrvatska
Vlado GUBERAC, Hrvatska
Tomislav JUREKOVIĆ, Hrvatska
Gabriella MEDVEGY, Mađarska
Damir PEĆUŠAK, Hrvatska
Tomislav ŠAMBIĆ, Hrvatska

PLIN 2019 Znanstveni odbor / PLIN 2019 Scientific committee:

Dražan KOZAK, predsjednik, Hrvatska
Antun STOIĆ zamjenik pred., Hrvatska
Bálint BACHMANN, Mađarska
Darko BAJIĆ, Crna Gora
Eraldo BANOVAČ, Hrvatska
Károly BELINA, Mađarska
Ivan BOŠNJAK, Hrvatska
Aida BUČO-SMAJIĆ, BiH
Zlatan ČAR, Hrvatska
Robert ČEP, Češka
Majda ČOHODAR, BiH
Ejub DŽAFEROVIĆ, BiH
Tomislav GALETA, Hrvatska
Antun GALOVIĆ, Hrvatska
Hrvoje GLAVAŠ, Hrvatska
Nenad GUBELJAK, Slovenija
Sergej HLOCH, Slovačka
Nedim HODŽIĆ, BiH
Željko IVANDIĆ, Hrvatska
Željka JURKOVIĆ, Hrvatska
Ivica KLADARIĆ, Hrvatska
Milan KLJAJIN, Hrvatska
Janez KOPAČ, Slovenija
Grzegors KROLCZYK, Poljska
Stanislaw LEGUTKO, Poljska
Leon MAGLIĆ, Hrvatska
Damir MILJAČKI, Hrvatska
Mladomir MILUTINOVIĆ, Srbija
Ferenc ORBÁN, Mađarska
Branimir PAVKOVIĆ, Hrvatska
Denis PELIN, Hrvatska
Miroslav PLANČAK, Srbija
Dalibor PUDIĆ, Hrvatska
Marijan RAJSMAN, Hrvatska
Marko RAKIN, Srbija
Miomir RAOS, Srbija
Pero RAOS, Hrvatska
Alessandro RUGGIERO, Italija
Aleksandar SEDMAK, Srbija

Marinko STOJKOV, Hrvatska
Josip STOJŠIĆ, Hrvatska
Igor SUTLOVIĆ, Hrvatska
Tomislav ŠARIĆ, Hrvatska
Mladen ŠERCER, Hrvatska
Damir ŠLJIVAC, Hrvatska
Vedran ŠPEHAR, Hrvatska
Zlatko TONKOVIĆ, Hrvatska
Zdravko VIRAG, Hrvatska
Nikola VIŠTICA, Hrvatska
Jurica VRDOLJAK, Hrvatska
Marija ŽIVIĆ, Hrvatska



Sadržaj / Contents

PLENARNA PREDAVANJA / KEYNOTE LECTURES

UTJECAJ PRIRODNOG PLINA NA KONKURENTNOST GOSPODARSTVA I SMANJENJE EMISIJA STAKLENIČKIH PLINOVA.....	1
D. Pudić	

ASISTIRANI TRANSFER KLJUČNIH RAZVOJNIH TEHNOLOGIJA ZA ODRŽIVU, KONKURENTNU I ENERGETSKI I RESURSNO UČINKOVITU INDUSTRIJU U EU	12
I. Štefanić	

PLIN I PLINSKA TEHNIKA / GAS AND GAS TECHNIQUE

TEHNIČKA DIJAGNOSTIKA KAO BITNA PREVENTIVNA AKTIVNOST ZA POUZDANI RAD PLINSKIH POSTROJENJA.....	22
Z. Lacković	

TEMPERATURE DEPENDENT CONSUMERS OF NATURAL GAS IN CROATIA	29
T. Pendić, I. Sutlović, P. Raos	

KONTROLA MJERILA PROTOKA PLINA.....	38
L. Maglić, G. Panić, O. Maglić	

ENERGETIKA I TOPLINSKA TEHNIKA / ENERGETICS AND HEATING TECHNIQUE

UPRAVLJANJE SUSTAVOM LED RGB RASVJETE DMX PROTOKOLOM	43
A. Martinek, Z. Galić, H. Glavaš	

INFRACRVENA TERMOGRAFIJA U ODRŽAVANJU FOTONAPONSKE ELEKTRANE "ETFOS 1"	54
H. Glavaš, I. Bićanić, E. Desnica	

PREGLED PASIVNOG I AKTIVNOG BALANSIRANJA BATERIJA.....	64
D. Pelin, B. Tomašević, A. Travančić, Kristijan Lolić	

MODEL UPRAVLJANJA ENERGETSKI UČINKOVITE RASVJETE SPORTSKOG IGRALIŠTA... ..	72
Z. Klaić, M. Juroš, Z. Kraus, M. Stojkov	

UTJECAJ POJEDINCA NA POTROŠNJU ENERGIJE I EMISIJU CO ₂	81
K. Hornung, M. Stojkov, A. Čikić	

BAKLJE NA DEPONIJAMA OTPADA U FUNKCIJI EKOLOGIJE.....	89
E. Memišević, T. Grizelj	

OLIMPIJSKI PLAMEN I VJEČNE VATRE NA PLIN	97
T. Grizelj, E. Kamenjašević	

ALTERNATIVNI, OBNOVLJIVI I ODRŽIVI IZVORI ENERGIJE.....	102
E. Kamenjašević, T. Grizelj	
PROJEKTIRANJE RASVJETE GRADSKOG PARKA.....	107
Z. Klaić, V. Kokošarević, M. Primorac, K. Fekete	
PREDVIĐANJE PROIZVODNJE VJETROELEKTRANA.....	115
M. Benić, I. Sutlović, P. Raos	
EVALUATION OF ENERGY EFFICIENCY OF PUMPS.....	124
M. Eördöghné Miklos, Á. Nyers	
ANALIZA ENERGIJSKE EFIKASNOSTI PLINSKIH KONDENZACIJSKIH KOTLOVA.....	130
M. Rauch, A. Barac, M. Živić, A. Galović	
REZULTATI ENERGETSKE OBNOVE ZGRADA NA PODRUČJU OSJEČKO-BARANJSKE ŽUPANIJE.....	137
D. Dvoržak, M. Ivanović, H. Glavaš	
<u>VODA / WATER</u>	
PRIMJENA STAKLOPLASTIKE U HIDROTEHNICI.....	144
A. Jurić, T. Mijušković - Svetinović, D. Vidaković	
MONITORING AKUMULACIJE BOROVIK.....	153
M. Šperac, T. Slunjski	
GUIDELINES FOR WATER MANAGEMENT AT THE GLOBAL AND LOCAL LEVEL.....	161
A. Sutlović, B. Vojnović, I. Čurić, A. Ludaš	
ANALIZA KVAROVA NA VODOOPSKRBNOM SUSTAVU.....	169
T. Mijušković - Svetinović, V. Blažević, S. Maričić	
<u>REGULATIVA / REGULATIONS</u>	
IMPORTANCE OF THE PROTECTION OF PERSONAL DATA ACCORDING TO REGULATION 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL.....	180
S. Franjić	
PREVENCIJA OPASNOSTI KOD DIMNJAKA.....	188
D. Vidaković, H. Glavaš, J. Pešić, D. Hećimović	
GOSPODARENJE GRAĐEVINSKIM OTPADOM I OTPADOM OD RUŠENJA.....	200
D. Hećimović, D. Pfeifer, D. Vidaković	
PROBLEMATIKA UPORABNIH DOZVOLA ZA ODREĐENE GRAĐEVINE – ANALIZA ODABRANOG PODRUČJA.....	210
D. Obradović, M. Teni, L. Međurečan	

KONSTRUIRANJE I PROIZVODNE TEHNOLOGIJE/ DESIGN AND PRODUCTION TECHNOLOGIES

APPLICATION OF AHP METHOD IN THE PROCESS OF EVALUATION OF SUPPORTING STRUCTURES FOR PLACING TRAFFIC SIGNS.....	219
M. Katalinić, M. Karakašić, Ž. Ivandić, H. Glavaš	
PRAĆENJE USPJEŠNOSTI POSTOJEĆEG SUSTAVA ODRŽAVANJA.....	229
D. Vidaković, S. Marenjak, Lj. Radovanović, H. Glavaš	
METALLURGY – METAL FORMING	242
B. Grizelj, S. Resković, I. Samardžić, D. Marić	
SUVREMENE TEHNOLOGIJE RAZVRSTAVANJA OTPADA.....	252
V. Kaučić, G. Rozing, A. Katić	
MODERN APPROACHES ON CONSTRUCTION OPTIMIZATION IN MECHANICAL ENGINEERING.....	260
I. Palinkas, E. Desnica, J. Pekez, Lj. Radovanovic	
RFID TECHNOLOGY FOR REAL-TIME CONDITION MONITORING OF PIPELINES	265
G. Zeba, M. Čičak	
PARAMETARSKO 3D OBLIKOVANJE I PRORAČUNI CIJEVNIH PROČISTAČA TIPA PY	273
B. Hršak, A. Čikić, A. Čukman	
EKOLOŠKA ANALIZA POVRŠINSKE ZAŠTITE METALA OD KOROZIJE PRIMJENOM PREMAZA	283
M. Katava, T. Šolić, D. Marić, M. Duspara, I. Putnik, I. Samardžić	
ECONOMICS DESIGN OF RECTANGULAR AND CYLINDRICAL STORAGE TANKS	293
Ferenc Orbán	



Application of AHP method in the process of evaluation of supporting structures for placing traffic signs

M. Katalinić¹, M. Karakašić^{1,*}, Ž. Ivandić¹, H. Glavaš²

¹Mechanical Engineering Faculty in Slavonski Brod, University of J. J. Strossmayer in Osijek, Slavonski Brod, Croatia

²Faculty of Electrical Engineering, Computer Science and Information Technology, University of J. J. Strossmayer in Osijek Osijek, Croatia

*Corresponding author. E-mail: mkarakas@sfsb.hr

Abstract

This paper presents the application of the Analytic Hierarchy Process (AHP) method in the process of evaluating of conceptual variants at the conceptual stage. Using the requirement list and the morphological matrix, three conceptual variants of supporting structures were created for placing traffic signs. With the AHP method, the conceptual variants (alternatives) were compared. Then a set of six criteria was defined according to which the conceptual variants were evaluated. A variant with the highest weight factor, is also the chosen design solution that will be formed as a final product in the phase of detailed design.

Key words: AHP, conceptual design, morphological matrix, requirement list

1. Introduction

Design process begins by defining a design task that describes requirements, which the product must accomplish after the design process is finished [1, 2]. According to [3], design process takes place through four phases. From the point of view of this paper, the conceptual phase is covered. Before starting the conceptual phase, it is necessary to clarify the requirements relating to the design task. It is necessary to collect information on the requirements and constraints of the design solution.

At the conceptual phase, it enters with defined requirements covered by the requirement list. Requirements, according to the certain rules and methods [4, 5], are transforming in the functional requirements. Functional decomposition method defines main function and partial functions that form functional structure of the design solution [6]. By using design tools, like morphological matrix [7], QFD method [8], matrix of function and functionality [9], etc. the principles of solutions for system of partial functions are searching. Conceptual variants are generating by linking principles of solutions. Among such structured variants, it is necessary to choose one that is, according to certain criteria of the most acceptable. For choosing the most acceptable variant, different methods of decision-making are using, like Promethee method, potential method, AHP method, Morra method, Electre method, etc. During the evaluation process (decision-making), it is necessary to define a set of criteria according to which the best variants (solutions) are chosen.

Paper presents a multi-criteria evaluation process using the AHP method in the example of three conceptual variants of supporting structures for placing traffic signs. According to the requirement list, a set of functions is defined, for which the principles of solutions are found in the morphological matrix. By linking the principles of solutions, three conceptual variants of supporting structures for placing traffic signs are obtained. According to the defined set of criteria, the best variant of the supporting structure is selected.

2. Requirement list of supporting structures for placing traffic signs

In order to increase safety, roads must be marked with prescribed traffic signs. In this way, traffic participants warn of the dangers that threaten them on certain sections of the road. Traffic signs and signalization are thus placed on supporting structures (Figure 1).



Figure 1. An example of supporting structure for placing traffic signalization

Supporting structures who carrying ordinary traffic signs are differ from supporting structures that carrying variable traffic signalization. For variable traffic signalization, it is necessary to enable the implementation of electricity through the construction, to allow the supply of luminous diodes. The light traffic sign is connected to own power source 230V (50 Hz). It is therefore necessary to ensure the autonomy of the electric meter, located close to the traffic sign inside the green area. The electrodeposition cable is placed in a channel wide 400 mm and deep 800 mm.

Alternative to the inability to connect to the power grid is the use of renewable energy sources, i.e. solar power. Solar power is possible to place on the construction, traffic sign or in addition to the same construction. Traffic signs with solar power have great lightness and are better for reading. They save electricity, because of using ecologically acceptable solar power technology.

According to collected information during market analysis, a requirement list of for supporting structures for placing traffic signs is defined (Table 1).

Table 1. Requirement list for supporting structures

REQUIREMENT LIST		
Requirement (R) / Wish (W)	List of requirements and wishes	Category
R	Minimum height above roadway: 4500 mm	GEOMETRY
R	Minimum frame support length: 11500 mm	
R	Minimum console support length: 5000 mm	
R	Maximum support length: 12500 mm	
R	Maximum height of structure: 7000 mm	
R	Three digital traffic signs	
R	Dimensions of traffic signalization: 1300 x 210 x 1300 mm	
R	Supports for traffic signalization	
R	Using LED traffic signalization	
W	Solar cells support	
W	Platform for maintenance of construction	
W	Maximum load of platform is 100 kg	
W	Platform dimensions: 11500 x 600 x 1000 mm	
W	Ladder for workman transport on the platform	
R	Connecting elements with the screw connection	FORCES
R	Wind and snow resistance	
R	Traffic signalization weight	
R	Own construction weight	
W	Weight of solar panels and their supports	
W	Reduce the mass of the construction	ENERGY
W	Renewable energy sources	
W	Solar cells	
W	Power: 3330 W	ENERGY
W	Total surface of solar cells: 3 m ²	
R	Material: steel	MATERIAL
R	Concrete foundation	
R	Corrosion protection	
W	Protective hoop on the platform and ladder	SAFETY
R	Easy montage / deconstruction	ASSEMBLAGE
R	Control and management of traffic signalization	MAINTENANCE
R	Easy maintenance	
R	Lens cleaning every 12 months	
R	Review of construction every 6 months	
W	Possibility of recycling	RECYCLING
W	Minimum costs	COSTS
R	Applying standard profiles	

3. Generating conceptual variants of supporting structures

Using morphological matrix (Figure 2), the transformation of the requirements into functional requirements was performed. With the process of the functional decomposition, partial functions were generated. They are necessary to solve the main function of the supporting structure for placing traffic signalization.

	MORPHOLOGICAL MATRIX			
PARTIAL FUNCTIONS	PRINCIPLES OF SOLUTION 1. Variant-▲ 2. Variant-◆ 3. Variant-●			
1. To form the construction	Bracket ◆	Frame ▲●	Pillar	
2. To use standard profiles	I profile	Square profile ◆●	Tube profile	Combination ▲
3. To attach the signalization	Bolted joint ▲◆●	Welded joint	Glue joint	Swirling joint
4. To attach design elements	Bolted joint ▲◆●	Welded joint	Glue joint	Swirling joint
5. To joint construction on the concrete	Dissociative bond ▲◆●		Firm bond	
6. To protect against corrosion	Galvanizing ●	Chroming ◆	Tinning ▲	
7. To protect the bolts from corrosion	Galvanizing ●	Chroming ◆	Tinning ▲	
8. To ensure power supply	Urban electrical network ◆		Renewable energy sources ▲●	
9. Tamp the cables	Through the construction ◆		With the construction ▲●	
10. To ensure power supply from renewable energy sources	Sun (solar cell) ▲●		Wind (windmill)	
11. To set solar cell carriers	To the construction ▲●	To traffic signalization	Beside of construction	
12. To connect carriers with the construction	Bolted joint ▲●		Welded joint	
13. To enable the maintenance	Platform ▲●		Crane ◆	
14. To transport operator to the platform	Ladder ▲●		Crane ◆	
15. To protect operator when is lifting	Protective metal rim ▲●		Safety belt ◆	
16. To protect operator while moving on the platform	Protective fence ▲●		Safety belt ◆	
17. To control traffic	Wired ◆		Wirelessly ▲●	
18. To transport design elements	Truck vehicle ▲◆●		Special truck vehicle	

Figure 2. Morphological matrix of supporting structures for placing traffic signalization



Figure 3. Conceptual variants of supporting structures



For some partial functions, the principles of the solution were found. By their connection, three variants of the bearing structure for variable traffic signalization were obtained (Figure 3). By applying multi-criteria decision making, using the AHP method, the best variant will be chosen. This variant then enters in the process of detailed design.

4. Multi-criteria evaluation of conceptual variants

4.1. AHP method

The Analytic Hierarchy Process (AHP) method is used to decide when the decision-making process, or choice of some of the available alternatives, is based on multiple attributes of varying importance. The analytical process consists of four steps. In the first step, goals, criteria, sub-criteria and alternatives (variants) are defined. The second step, using Saaty's scale, compares criteria and alternatives to each criterion. In third step are calculated the local weighting of the criteria (sub-criteria) and the priority alternatives. The fourth step involves sensitivity analysis.

4.2. Mathematical description of AHP method

If n is number of criteria whose weights w_i need to determine by estimating the value of their ratios which are marked as $a_{ij} = w_i/w_j$. The relative importance matrix has the following form:

$$\mathbf{A} = \begin{bmatrix} w_1/w_2 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \dots & \dots & \dots & \dots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad (1)$$

In the case of consistent estimates it is valid $a_{ij} = a_{ik} \cdot a_{kj}$. Matrix \mathbf{A} then satisfies the equation $\mathbf{A} \cdot \mathbf{w} = n \cdot \mathbf{w}$, where \mathbf{w} is the vector of priorities:

$$\begin{bmatrix} w_1/w_2 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \dots & \dots & \dots & \dots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ w_n \end{bmatrix} = n \cdot \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ w_n \end{bmatrix} \quad (2)$$

Problem of weight is solving by equation:

$$\mathbf{A} \cdot \mathbf{w} = \lambda \cdot \mathbf{w} \quad (3)$$

In equation (3) it must be $\lambda \neq 0$. Matrix \mathbf{A} is positive, reciprocal and with rank value $r(\mathbf{A})=1$. Sum of inherent values of positive matrix is equal to the trace of the matrix, i.e. the sum on the diagonal with the value n :

$$\lambda_{\max} = n \quad (4)$$

If \mathbf{A} contains inconsistent estimations, vector \mathbf{w} is possible to obtain by solving the following equations:

$$(\mathbf{A} - \lambda_{\max}) \cdot \mathbf{w} = 0 \quad (5)$$

$$\sum \mathbf{w}_t = 1 \quad (6)$$



Where λ_{\max} is largest inherent value of **A** matrix. If we take in consideration preliminary expressions, then follows:

$$\sum_j a_{ij} \cdot w_j = n \cdot w_i \quad (7)$$

$$\sum_i a_{ij} = \frac{w_1 + w_2 + \dots + w_n}{w_j} \quad (8)$$

Therefore it is:

$$w_j = \frac{1}{\sum_i a_{ij}} \quad (9)$$

The weight of each alternative is equal to:

$$w_j = \frac{1}{n} \sum_i \frac{a_{ij}}{\sum_i a_{ij}} \quad (10)$$

The synthesis of priorities is done in a way that local priority of alternatives weights with the weights of all the knots to which they belong. Then global priorities for the highest level are summed and the overall priority for each alternative is constructed.

The consistency of the assessment is achieved by comparing the pair of alternatives and the criteria pairs. The consistency index is $CI = (\lambda_{\max} - n) / (n - 1)$. The CI calculates the consistency ratio $CR = CI / RI$. RI represents a random index (consistently index for matrixes with the n order, randomly generated comparisons in pairs). Determined by table (Table 2).

Table 2. Values of RI

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,52	0,89	1,11	1,25	1,35	1,4	1,45	1,49

If for matrix **A** is $CR \leq 0,10$, assessments of the relative importance of the criteria (priority of alternatives) are considered as acceptable. Otherwise, it is necessary to consider the reasons why the consistency of the estimations is unacceptably high.

4.3. The best conceptual variant determination

For the choice of the best variant, a system of six criteria was defined and three conceptual variants (Figure 4). According to the criterion system, evaluation of conceptual variants (alternatives) was performed.

Also, it is necessary to determine the importance and importance of certain criteria. This is achieved by comparing the criteria and determining the factors of significance (Figure 5).

Then comparison of individual alternative with criterions has performed. With this comparison, we want to determine how much an individual alternative to each criterion is better than any other alternative (Figure 6).

After all relations between alternatives and criteria have been set, it has obtained a solution with the best alternative. That solution is a third conceptual variant (Figure 3). Its factor amount is 0,4338 (Figure 7). The second best alternative is the first conceptual variant with factor amount 0,3338. The second variant has a factor amount 0,2324 and is in third place.

The consistency ratio is 0,0406. This means that estimations of the relative importance of the criteria are acceptable.

Selection of supporting structure with the variable traffic signalization

<p>my alternatives</p> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Variant 1"/> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Variant 2"/> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Variant 3"/> <div style="text-align: center; margin-top: 5px;"> + - </div>	<p>my criteria</p> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Material and production price"/> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Energy source"/> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Maintenance"/> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Design"/> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Montage"/> <input style="width: 95%; margin-bottom: 5px;" type="text" value="Environmental impact"/>
---	--

Figure 4. Determination of aim, alternative and criterion

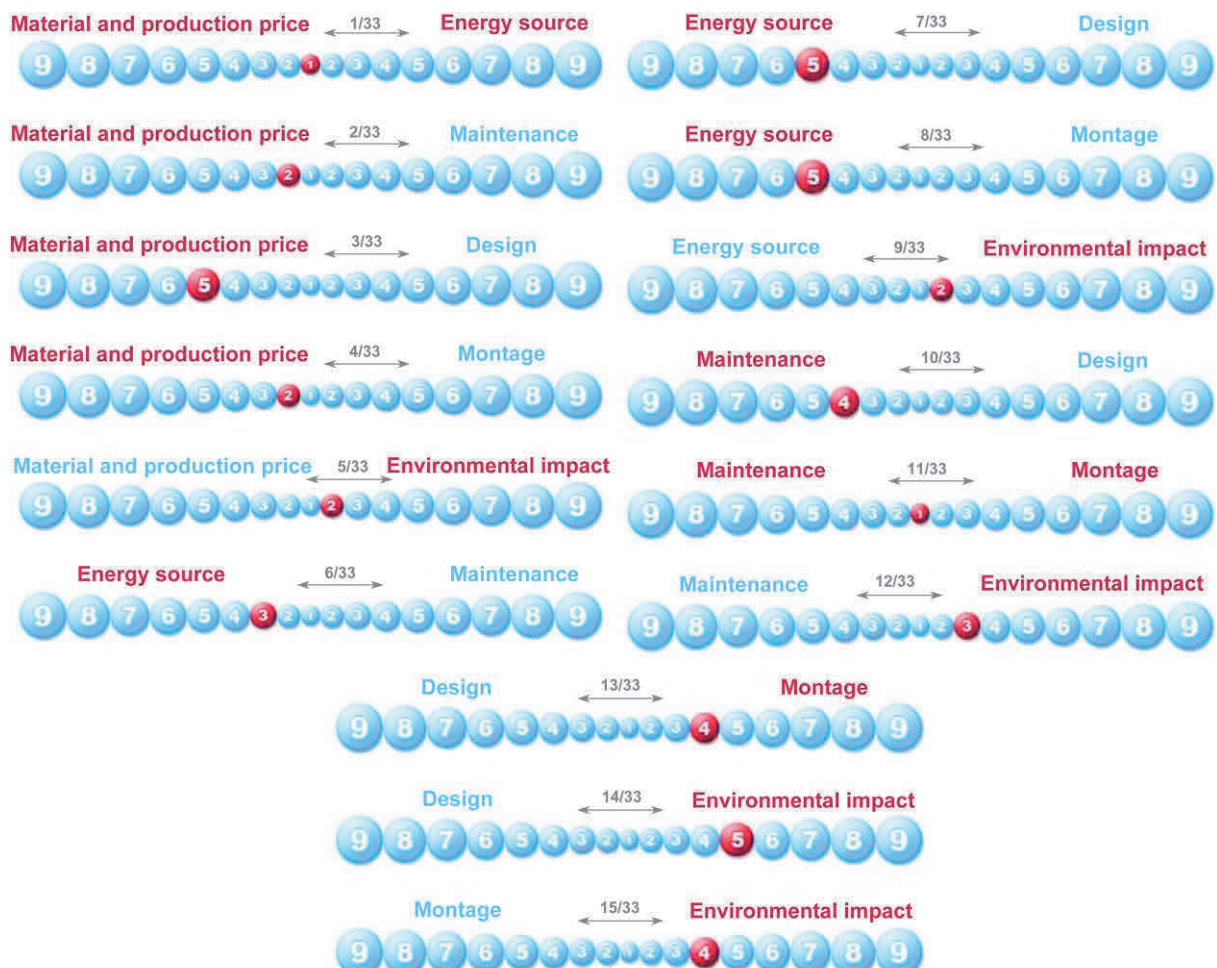


Figure 5. Mutual relations of criteria

In figure 8 is presented rank of criteria. It is possible to see the importance of a particular criterion in the decision-making process. The most influential criterion is *environmental*

impact whose factor amounts is 0,3307. The least influential criterion is *design* whose factor amounts is 0,0384.

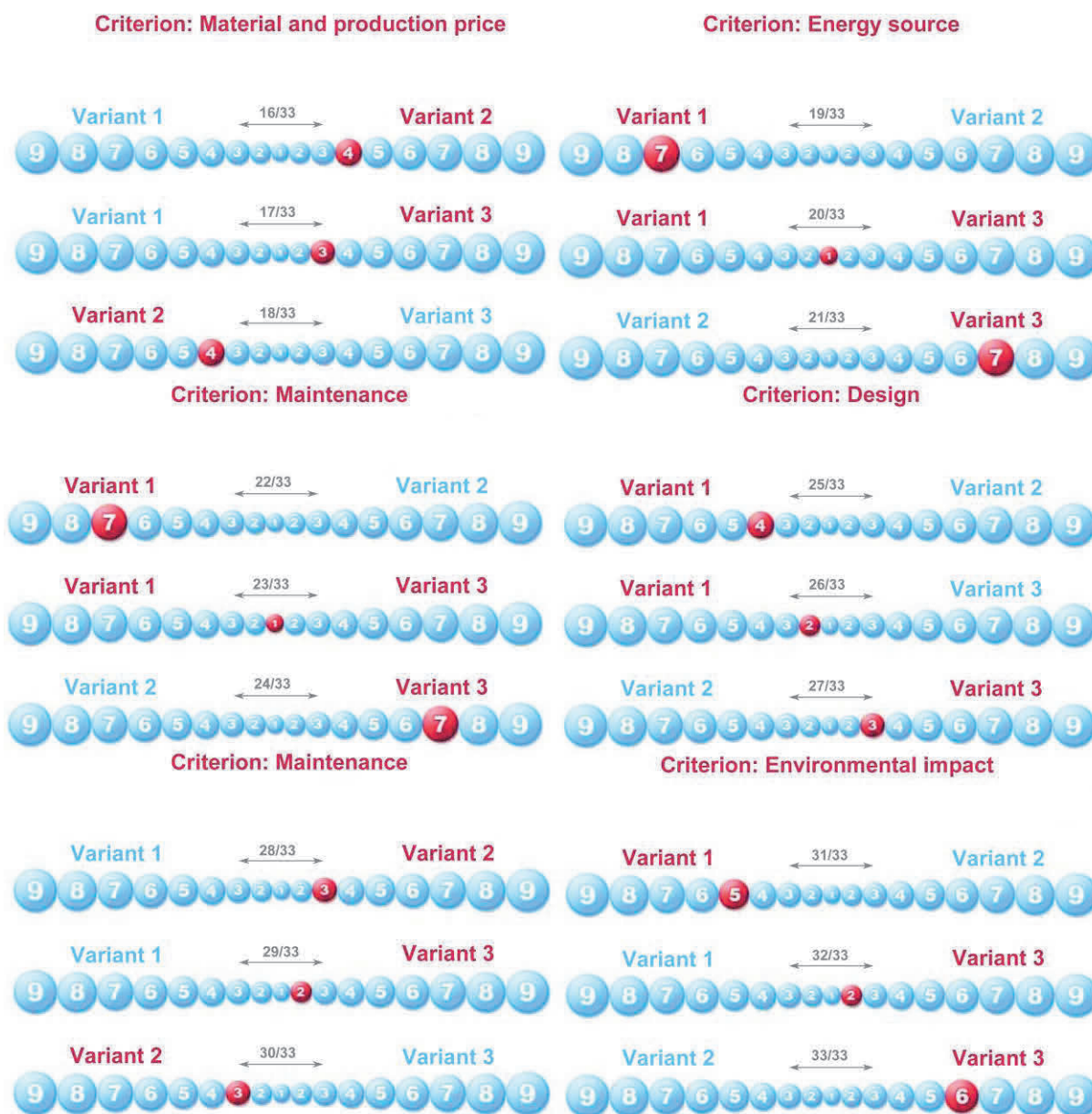


Figure 6. Relation between variants and criteria

Alternative structure	Material and production price	Energy source	Maintenance	Design	Montage	Environmental impact	Result
Variant 1	0,0213	0,1162	0,0473	0,0214	0,0144	0,1131	0,3338
Variant 2	0,1231	0,0166	0,0068	0,0047	0,0544	0,0258	0,2324
Variant 3	0,0444	0,1162	0,0473	0,0123	0,0229	0,1908	0,4338

Figure 7. Alternative structure

An overview of the final solutions of the decision-making process, using the AHP method, is shown in figure 9. It is possible to see that third alternative (conceptual variant) is the best

variant of the evaluation process. The most influential criterion is *environmental impact*. The picture also shows the impact of a particular criterion on a particular alternative.

Criteria rank	Result
Material and production price	0,1888
Energy source	0,249
Maintenance	0,1014
Design	0,0334
Montage	0,0917
Environmental impact	0,3307

Figure 8. Criteria rank

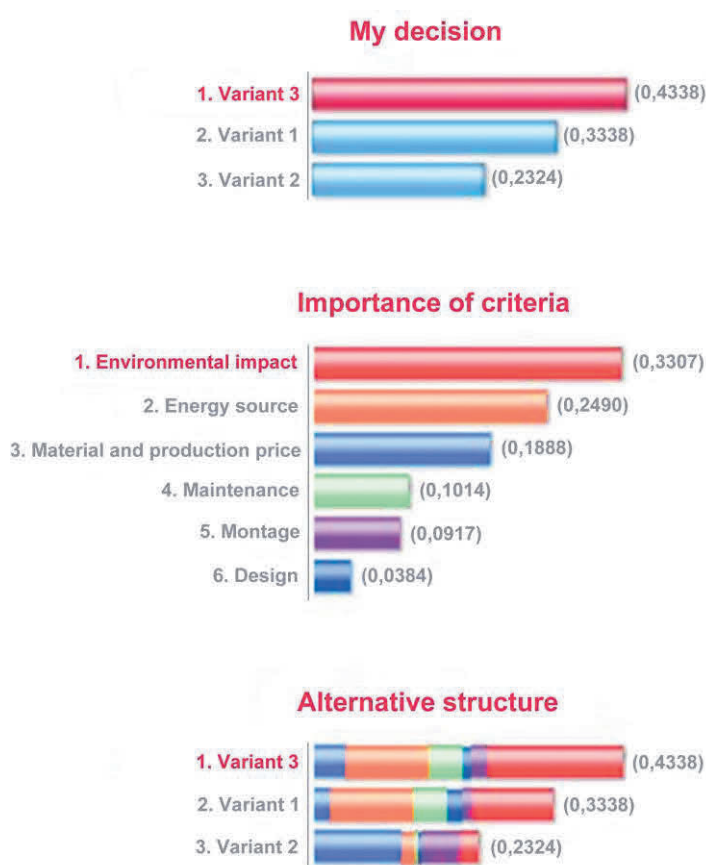


Figure 9. Results of the decision-making using the AHP method

5. Conclusion

In the paper is presented evaluation process of three conceptual variants of supporting structures for placing traffic signs. For evaluation was used Analytic Hierarchy Process (AHP) method. According to the requirement list, the functional structure is defined, which is described in the morphological matrix.



For each function, principal of the solutions are required. By linking the principle of the solutions, three conceptual variants of supporting structures for placing traffic signs have obtained.

To select the best variant (alternative), the evaluation process has begun. Numerous evaluation methods are using today like Promethee method, Electre, Morra, Potential methods, Conjunctive methods, Disjunctive methods, Topsis Vikor, AHP method, etc. In this paper we decided to apply the AHP method. The method is based on comparing pairs of alternatives with each other. The decision maker should express intensity, the weight of the preference of one alternative in relation to the other within the set of criteria. We have defined a system of six criteria and evaluated variants according to them.

It has found that the third conceptual variant has selected as the best variant of the AHP evaluation method. It is possible to expect that the system of criteria is extended with some new criteria so that the solution of the evaluation process will result in the selection of another alternative.

The currently selected variant also satisfies the requirement for power supply of traffic signalization by means of solar cells placed on the frame of the construction. Also, this variant has the ability to set variable LED traffic signs.

6. References

- [1] Salopek, Damir. Sustav za prepoznavanje uzoraka pri varijantnom konstruiranju. Zagreb: Fakultet strojarstva i brodogradnje, 2002.
- [2] Duhovnik, Jože; Tavčar, Jože. Elektronsko poslovanje in tehnični informacijski sistemi. Ljubljana: Fakulteta za strojništvo, 2000.
- [3] Pahl, Gerhard; Beitz, Wolfgang; Feldhusen, Jörg; Grote, Karl – Heinrich. Engineering Design: A Systematic Approach. London: Springer – Verlag, 2007.
- [4] Zadnik, Žiga; Karakašić, Mirko; Kljajin, Milan; Duhovnik, Jože. Function and Functionality in the Conceptual Design Process // *Strojniški vestnik*, 55(2009), 7 - 8; 455 - 471. (ISSN 0030 - 2480)
- [5] Zadnik, Žiga. Matrika funkcij in funkcionalnosti izdelka v razvojno konstrukcijskem procesu. Ljubljana: Fakulteta za strojništvo, 2012.
- [6] Hubka, V.; Eder, W. E. Theory of Technical Systems. Heidelberg: Springer – Verlag, 1988.
- [7] Zwicky, F. The morphological method of analysis and construction. New York: Courant, Intersciences, 1948.
- [8] Starbek, Marko; Kušar, Janez. QFD as a Method of Integrated Product Implementation // *Strojarstvo*, 45(2003), 4/6, 159 – 171.
- [9] Karakašić, Mirko; Zadnik, Žiga; Kljajin, Milan; Duhovnik, Jože. The matrix of function and functionality in product development process // *International journal of simulation modelling*, 17(2018), 3, 391 – 404. (ISSN 1726 – 4529)