MODEL FOR RANKINK OFFER APARTMENTS BASED ON MULTICRITERIA OPTIMIZATION

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Summary: *The aim of this research is to collect apartment offers and to select the best offer in relation to the preferences of the decision maker. When defining the task, the customer defined some limitations in the form of his needs, desires and possibilities. After detailed analysis of the requirements, the expert limited himself in terms of basic characteristics (attributes) of immovable property, respectively apartment. He selected an apartment on Banovo Brdo in Belgrade, Municipality of Cukarica, the order of the size of the total price from 20000 to 50000 euros and of the area from 20 to 50 square meters. Accordingly, the expert approached the definition of a model that will make the best possible choice with the optimum satisfaction of the customer and his system of values as per the manner shown in this paper.*

Keywords: *multicriteria optimization, multidimensional decision making, market analysis, ranking of apartments, AHP method*

1. INTRODUCTION

Every day we face dilemma of how to derive the final decision about choosing a particular alternative. We are often unsure what goal we want to achieve, and more often, what influences the fulfillment of our goal and how much impact it actually has. As we are faced with the issue of deriving a numerous decisions, both for minor and major, likewise when buying a car or apartment, we usually have a lack of knowledge of what is important, how important it is, what is better or worse, what is esthetical, what is functional or usable, what is more valuable etc. In general, we use a comparative way of thinking, when from a lack of capacity, we compare small number of alternatives with only a few criteria. When coming to comparison, the first image that comes to our mind is a “Beam Scale”, a device that functions on the principle of equilibrium. The question is whether this principle is sufficient in comparison of complex elements or it gives results only when it comes to single size and different quantity? At first glance, certain things cannot be compared, however when we place them in a certain context, they become quite comparable. An example of this would be qualitative attributes that can be compared just for the purpose to find out the preferences of the stakeholder and its goal. When observing different sociological groups the value system varies. That is reflected through different desires and needs of children, youth, adults and elderly, as well as

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employed, pensioners and persons with disabilities. All this influences a broader aspect of the perception of the problem for which solution is provided by multicriteria optimization - multidimensional solution [1].

2. MARKET ANALYSIS

In order to carry out any analysis, evaluation, ranking and, ultimately, the final decision on the choice, initially we need to carry out the collection of data about the offer of a particular item (whether it is mobile or immobile). A large number of real estate data are publicly available in internet advertisements. The publicly accessible database of apartment offers was used for the purposes of this research [2].

Imovina.net is one of the sites where sellers advertise their real estate. The site contains basic information about the flats used for evaluation and ranking. Filters are important to distinguish apartments that are of interest to our client. To limit the apartments to our interest and reduce the list of offers we selected the following filters: **location** (Banovo brdo); **municipality** (Cukarica, Beograd); **type of property** (apartmants); **total price** (from 20000 to 50000 euros); **area** (from 20 to 55 sq.m.). After completion, we conducted the collection of raw data about the apartments that are available and that are considered important in the process of selection.

3. DATA COLLECTION

Data on 24 apartments were collected, respectively about their following available characteristics: number of rooms; total price; the street in which the apartment is located; address of the apartment; area in square meters; the floor on which the apartment is located; the number of floors of the building in which the apartment is located; type of heating; subjective grade of images from 1 to 5; number of ad reviews; special features; additional information; contact of the owner (agent or agency); description of the location of the apartment; the coordinates of the location where the apartment is located. Subsequently, the raw data that were collected are classified in a table in which the attributes are placed in the header of the table, and the rows represent particular flats.

Raw data are not suitable for training the model without prior processing. In some characteristics, for example, special features and additional information, there are a number of features that need to be considered separately. For example, special features contain information on whether the apartment is registered in cadaster, whether it has an elevator, basement and/or terrace, etc.

For previously mentioned reason, data has been rearranged to a new set of data for further analysis, and this paper presents only the first 3 of the total 24 collected apartments.

Set of data

APARTMENT i = [unit price] (number of rooms; total price; area; floor; building size; heating; image rating; number of ad reviews; special features; elevator; basement; age of the building; terrace; additional information; vacant; registered in cadaster; location description; distance from the center of the B.b.; address; number of missing attributes)

apartment 1 = [973,68] (1,5; 37000; 38; ground floor; 5; CH; 3; 318; 6; yes; yes; old; null; 5; yes; yes; near MC Donald's; 1529; Pozeska 106; 1)
apartment 2 = [1681,82] (studio; 37000; 22; 2; 5; TAH; 4; 416; 4; no; yes; old; null; 5; yes; yes; null; null; Pozeska; 4)
apartment 3 = [1081,08] (1; 40000; 37; ground floor; 2; TAH; 2; 153; 2; no need; null; null; yes; 3; yes; null; near Roda Cineplex; 3421; Nedeljka Cabrinovica 52a; 4)

4. STATISTICAL DATA ANALYSIS BY CHARACTERISTICS

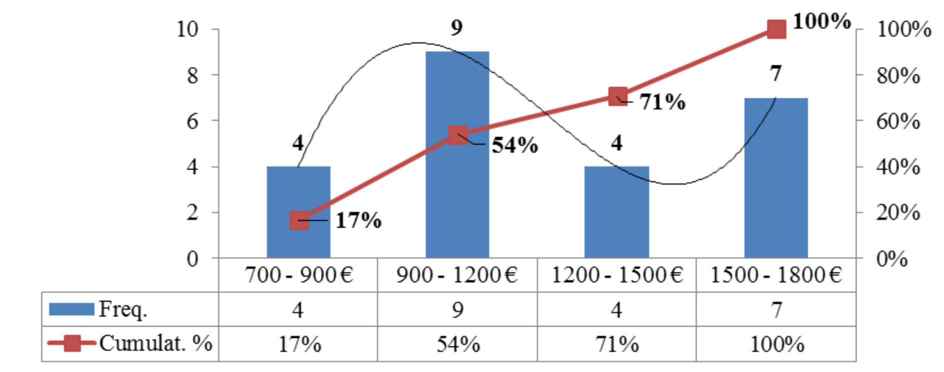
In this chapter, statistics will be shown only for some of the characteristics analyzed during this phase, although the analysis has been performed by all characteristics individually, with the aim of easier understanding of all alternatives and making a informed final decision. Data analysis as well as the creation of the model itself is done in MS Excel.

Table 1: Data on Total price, Area and Unit price

Altern-atives	Total price [€]	Area [m^2]	Unit price [€/m^2]	Altern-atives	Total price [€]	Area [m^2]	Unit price [€/m^2]
Apar. 1	37000	38	974	Apar. 13	34500	22	1568
Apar. 2	37000	22	1682	Apar. 14	36500	42	869
Apar. 3	40000	37	1081	Apar. 15	39000	23	1696
Apar. 4	37500	27	1389	Apar. 16	20000	25	800
Apar. 5	35000	22	1591	Apar. 17	27000	27	1000
Apar. 6	22500	30	750	Apar. 18	45000	33	1364
Apar. 7	40000	38	1053	Apar. 19	48000	28	1714
Apar. 8	34700	22	1577	Apar. 20	50000	37	1351
Apar. 9	40000	37	1081	Apar. 21	50000	47	1064
Apar. 10	31500	34	927	Apar. 22	47000	37	1270
Apar. 11	38000	22	1728	Apar. 23	48000	54	889
Apar. 12	40000	37	1081	Apar. 24	45000	45	1000

Table 2: Statistcs – Total price, Area and Unit price

	Total price [€]	Area [m^2]	Unit price [€/m^2]
Min	20000	22	750
Q1	34925	25	993
Medijan	38500	34	1081
Q3	45000	37	1570
Max	50000	54	1727
Max – Min	30000	32	977
Xsr	38467	33	1229
Standard Deviation	7921	9	322
Skewness	-0,610	0,498	0,294
Curvature	0,330	-0,346	-1,372



	700 - 900€	900 - 1200€	1200 - 1500€	1500 - 1800€
Freq.	4	9	4	7
Cumulat. %	17%	54%	71%	100%

Figure 1. Distribution of Unit price of apartments [€/sq.m]

5. MATHEMATICAL BASIS OF THE AHP METHOD

Solving such a complex problem with a large number of attributes and alternatives is not possible without the mathematical apparatus and the use of some of the methods by which the process is automated, which is the goal of the whole concept. The AHP method of multidimensional decision making is applied, which will be described in this chapter.

The AHP method (Analytical hierarchical process) was developed by Tomas Saaty in the 1970's **Error! Reference source not found.**[3]. It is applied in multicriteria decision making, where, on the basis of a defined set of criteria and value criteria for each alternative, the choice is most acceptable. As a result of the work model, a complete order of importance of the alternative is displayed.

The process itself is based on determining the goal, defining the criteria, and collecting alternatives. In the first phase, the "everyone with each" criterion is compared. This is done through the matrix of comparisons, and then a series of transformations leads to the order and relative significance, respectively the weight of the criteria.

In the second phase, the same is done with alternatives for each criterion separately. In both phases, verification of the consistency of the solution is carried out. The third phase leads to the final order of alternatives by summing up the products of the corresponding weights of the criterion and the weight of the concrete values of the alternatives, and after that the sums are ranked [5][6].

The following are the basic algorithmic steps of this method, which are encoded in a certain way.

GOAL	**CRITERIA**	**ALTERNATIVES**			
		Alternative	Crit. 1	Crit. j	Crit. J
Choice of alternative	Criteria 1	Alternative 1	E_{11}	E_{1j}	E_{1J}
	Criteria j	Alternative s	E_{s1}	E_{sj}	E_{sJ}
	Criteria J	Alternative S	E_{S1}	E_{Sj}	E_{SJ}

FIRST PHASE (Determining the most important criteria)

First, a comparison of the criteria is made in table 4 and the values thus obtained are stored in the matrix A.

Table 4: Comparison of criteria

	Criteria 1	Criteria j	Criteria J
Criteria 1	1	a_{1j}	a_{1J}
Criteria j	$1/a_{1j}$	1	a_{iJ}
Criteria J	$1/a_{1J}$	$1/a_{iJ}$	1

$$A=\left(a_{ij}\right)=\begin{pmatrix} a_{11} & a_{1j} & a_{1J} \\ a_{i1} & a_{ij} & a_{iJ} \\ a_{J1} & a_{Jj} & a_{JJ} \end{pmatrix}=\begin{pmatrix} 1 & a_{1j} & a_{1J} \\ 1/a_{1j} & 1 & a_{iJ} \\ 1/a_{1J} & 1/a_{iJ} & 1 \end{pmatrix} \tag{1}$$

Then the vector is determined Y :

$$Y=(y_i)=\sum_{k=1}^{J} a_{kj}=\begin{pmatrix} y_1 \\ y_i \\ y_J \end{pmatrix}^T=\begin{pmatrix} 1+(1/a_{1j})+(1/a_{1J}) \\ a_{1j}+1+(1/a_{iJ}) \\ a_{1J}+a_{iJ}+1 \end{pmatrix}^T \tag{2}$$

The value J represents the rank of the comparison matrix A, namely the total number of criteria, $i, j=1,...,J$. Then, the comparison matrix is normalized $A_{NORM.}$:

$$A_{NORM.}=(a_{n,ij})=a_{ij}/y_i$$

$$A_{NORM.}=\begin{pmatrix} a_{n,11} & a_{n,1j} & a_{n,1J} \\ a_{n,i1} & a_{n,ij} & a_{n,iJ} \\ a_{n,J1} & a_{n,Jj} & a_{n,JJ} \end{pmatrix}=\begin{pmatrix} 1/y_1 & a_{1j}/y_i & a_{1J}/y_J \\ (1/a_{1j})/y_1 & 1/y_i & a_{iJ}/y_J \\ (1/a_{1J})/y_1 & (1/a_{iJ})/y_i & 1/y_J \end{pmatrix} \tag{3}$$

The vector is then determined Z :

$$Z=(z_i)=\sum_{k=1}^{J} a_{n,ik}=\begin{pmatrix} z_1 \\ z_i \\ z_J \end{pmatrix}=\begin{pmatrix} a_{n,11}+a_{n,1j}+a_{n,1J} \\ a_{n,i1}+a_{n,ij}+a_{n,iJ} \\ a_{n,J1}+a_{n,Jj}+a_{n,JJ} \end{pmatrix} \tag{4}$$

Finally, the weight of the criterion is determined $W_{CR.}$:

$$W_{CR.}=Z/J=\left(z_1/J \quad z_i/J \quad z_J/J\right)^T=\left(w_{CR.,1} \quad w_{CR.,i} \quad w_{CR.,J}\right)^T \tag{5}$$

Checking the consistency of the solution is a mandatory phase when checking whether the comparison is adequately performed. First, the consistency index CI is determined, and then the degree of consistency CR. The degree of consistency should be less than 0.1. The random index RI is taken from table 5 [3].

$$CI = \frac{\lambda_{\max} - J}{J-1} \;;\; CR = \frac{CI}{RI} = ... \;(< 0{,}10) \;;\; B = A \times W_{CR.} = \begin{pmatrix} b_{11} & b_{i1} & b_{J1} \end{pmatrix}^T \tag{6}$$

$$\Lambda = \begin{pmatrix} \lambda_1 & \lambda_i & \lambda_J \end{pmatrix}^T = \begin{pmatrix} \frac{b_1}{w_{CR.,1}} & \frac{b_i}{w_{CR.,i}} & \frac{b_J}{w_{CR.,J}} \end{pmatrix}^T \;;\; \lambda_{\max} = \frac{1}{J}\sum_{i=1}^{J} \lambda_i \tag{7}$$

Table 5: Random index (Saaty, 1980)

J	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0,0	0,0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

SECOND PHASE (Determining the most important alternative)

At this phase, the order of the attributes value is determined by each criterion. If the values of attributes of the criteria j are of the category character, the comparison is done in the table, and then the values are stored in the matrix A_j, analogously to the comparison of the criteria in the previous phase.

Table 6: Determining the most important alternative - Criteria j

	E_{1j}	E_{sj}	E_{Sj}
E_{1j}	1	$a_{j,1q}$	$a_{j,1S}$
E_{sj}	$1/a_{j,1q}$	1	$a_{j,pS}$
E_{Sj}	$1/a_{j,1S}$	$1/a_{j,pS}$	1

$$A_j = \left(a_{j,pq}\right) = \begin{pmatrix} a_{j,11} & a_{j,1q} & a_{j,1S} \\ a_{j,p1} & a_{j,pq} & a_{j,pS} \\ a_{j,S1} & a_{j,Sq} & a_{j,SS} \end{pmatrix} = \begin{pmatrix} 1 & a_{j,1q} & a_{j,1S} \\ 1/a_{j,1q} & 1 & a_{j,pS} \\ 1/a_{j,1S} & 1/a_{j,pS} & 1 \end{pmatrix} \tag{8}$$

$$(CR < 0{,}10)$$

Then the vector is determined Y_j:

$$Y_j = (y_{j,p}) = \sum_{k=1}^{S} a_{j,kq} = \begin{pmatrix} y_{j,1} \\ y_{j,p} \\ y_{j,S} \end{pmatrix}^T = \begin{pmatrix} 1+(1/a_{j,1q})+(1/a_{j,1S}) \\ a_{j,1q}+1+(1/a_{j,pS}) \\ a_{j,1S}+a_{j,pS}+1 \end{pmatrix}^T \tag{9}$$

The value S represents the rank of the comparison matrix A_j, namely the total number of alternatives, $p,q=1,...,S$. Then, the comparison matrix is normalized $A_{NORM.,j}$:

$$A_{NORM.,j} = (a_{j,pq}) = a_{j,pq} / y_{j,p}$$

$$A_{NORM.,j} = \begin{pmatrix} a_{nj,11} & a_{nj,1q} & a_{nj,1S} \\ a_{nj,p1} & a_{nj,pq} & a_{nj,pS} \\ a_{nj,S1} & a_{nj,Sq} & a_{nj,SS} \end{pmatrix} = \begin{pmatrix} 1/y_{j,1} & a_{j,1q}/y_{j,p} & a_{j,1S}/y_{j,S} \\ (1/a_{j,1q})/y_{j,1} & 1/y_{j,p} & a_{j,pS}/y_{j,S} \\ (1/a_{j,1S})/y_{j,1} & (1/a_{j,pS})/y_{j,p} & 1/y_{j,S} \end{pmatrix} \tag{10}$$

The vector is then determined Z_j:

$$Z_j = (z_{j,p}) = \sum_{k=1}^{S} a_{nj,pk} = \begin{pmatrix} z_{j,1} \\ z_{j,p} \\ z_{j,S} \end{pmatrix} = \begin{pmatrix} a_{nj,11}+a_{nj,1q}+a_{nj,1S} \\ a_{nj,p1}+a_{nj,pq}+a_{nj,pS} \\ a_{nj,S1}+a_{nj,Sq}+a_{nj,SS} \end{pmatrix} \tag{11}$$

At the end of the second phase, the vector weight of the altern. is determined $W_{ALT.CR,j}$:

$$W_{ALT.CR,j} = Z_j / S = \left(z_{j,1}/S \quad z_{j,p}/S \quad z_{j,S}/S \right)^T = \begin{pmatrix} w_{ALT.CR.j,1} \\ w_{ALT.CR.j,p} \\ w_{ALT.CR.j,S} \end{pmatrix}^T \tag{12}$$

If the values of the attribute criteria j are of the numerical type, the relative importance is determined as follows:

First, a linear transformation is made $t_{t,s}$:

$$t_{t,s} = (E_{sj} - E_j^{\min}) / (E_j^{\max} - E_j^{\min}) \tag{13}$$

and then normalization, which gives the relative importance $W_{ALT,CR.j}$:

$$W_{ALT.CR,j} = \begin{pmatrix} w_{ALT.CR.j,1} \\ w_{ALT.CR.j,p} \\ w_{ALT.CR.j,S} \end{pmatrix}^T = \begin{pmatrix} t_{tj,1} / \sum_{i=1}^{S} t_{tj,s} & t_{tj,s} / \sum_{i=1}^{S} t_{tj,s} & t_{tj,S} / \sum_{i=1}^{S} t_{tj,s} \end{pmatrix} \tag{14}$$

THIRD PHASE (Determining the final solution)

Priority Matrix Alternatives ($W_{ALT.}$), Criteria ($W_{CR.}$) and Goal (W_{GOAL})

$$W_{ALT.} = \begin{pmatrix} w_{ALT.CR,1} \\ w_{ALT.CR,j} \\ w_{ALT.CR,J} \end{pmatrix}^T = \begin{pmatrix} w_{ALT.CR.1,1} & w_{ALT.CR.j,1} & w_{ALT.CR.J,1} \\ w_{ALT.CR.1,p} & w_{ALT.CR.j,p} & w_{ALT.CR.J,p} \\ w_{ALT.CR.1,S} & w_{ALT.CR.j,S} & w_{ALT.CR.J,S} \end{pmatrix} \tag{15}$$

$$W_{CR.} = \begin{pmatrix} w_{CR.,1} \\ w_{CR.,j} \\ w_{CR.,J} \end{pmatrix} \; ; \; W_{GOAL} = W_{ALT.} \times W_{CR.} = \begin{pmatrix} w_{GOAL,1} \\ w_{GOAL,i} \\ w_{GOAL,S} \end{pmatrix} \tag{16}$$

Table 7: SOLUTION - Rank list alternatives

Alternatives	**Priority value**	**Rank**
Alternative 1	$w_{GOAL,1}$	Rank ($w_{GOAL,1}$)
Alternative i	$w_{GOAL,i}$	Rank ($w_{GOAL,i}$)
Alternative K	$w_{GOAL,K}$	Rank ($w_{GOAL,K}$)

6. RESULTS

This chapter presents the results of the model, the relative significance of the criteria, and the complete order of alternatives. The relative significance of the alternatives by criteria is not shown.

Table 8: The relative importance of the criteria (w_i)[%]

Criteria	**w_i**	**Criteria**	**w_i**	**Criteria**	**w_i**
Total price	13,27	Number of missing attributes	5,92	Elevator	1,84
Distance from the center of the B.b.	12,34	Age of construction	5,63	Terrace	1,76
Location description	8,90	Vacant	4,29	Additional information	1,71
Registered in cadaster	8,47	Special features	3,71	Floor building	1,45
Area	7,04	Heating	3,59	Basement	1,32
Address	6,49	Image rating	2,91	Number of ad reviews	1,04
Floor	6,08	Number of rooms	2,24		

Table 9 shows the order of the first 10 alternatives in the ranking list according to the relative benefit ratio and the unit price.

Table 9: The ratio of price and benefit and ranking list of alternatives

ALTERNATIVES									
APARTMENTS	Unit price [€/m^2]	Unit price (rel.) [%]	Benefit [%]	Benefit (rel.) [%]	Ratio (Benefit rel./Unit price rel.)	Rank (Unit price)	Rank (Benefit)	Rank (Unit price-Benefit)	DECISION
Apar. 1	*974*	3,3	27,9	6,2	1,89	**6**	**1**	**1**	*Apartment 1*
Apar. 6	*750*	2,5	20,1	4,5	1,77	**1**	**8**	**2**	
Apar. 7	*1053*	3,6	16,8	3,8	1,05	**9**	**16**	**10**	
Apar. 9	*1081*	3,7	18,8	4,2	1,14	**11**	**12**	**8**	
Apar. 12	*1081*	3,7	18,0	4,0	1,10	**11**	**14**	**9**	
Apar. 14	*869*	3,0	15,9	3,5	1,20	**3**	**19**	**6**	
Apar. 16	*800*	2,7	17,2	3,9	1,42	**2**	**15**	**3**	
Apar. 20	*1351*	4,6	26,3	5,9	1,28	**15**	**2**	**5**	
Apar. 21	*1064*	3,6	18,9	4,2	1,17	**10**	**10**	**7**	
Apar. 23	*889*	3,0	18,6	4,2	1,38	**4**	**13**	**4**	

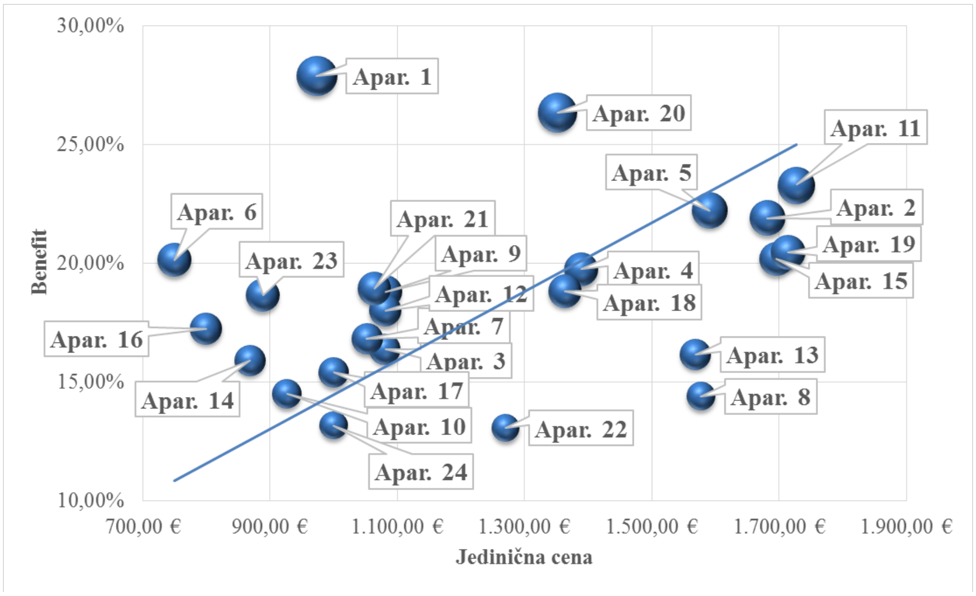


Figure 2. Unit price-benefit analysis

7. CONCLUSION

So, the most important question which is posed is whether a final decision can be made on the basis of a such model. The answer to this question would certainly be, no! But why not apply it to the first stage of the selection? The answer to this question would surely be, yes!

In situations with numerous alternatives that might be taken into account, one such model will be of extreme benefit. Based on our personal or required and pre-defined value system, we automatically reach the ranking list of alternatives. In a concrete problem, it saves time, and so does the money, in a way that considers in more detail a smaller number of alternatives at the top of the list.

A great contribution to such concept is also shown in graphic representation of the problems that provides the possibility that the solution obtained or the solution set is additionally checked and reanalyzed. The quality and volume of data has a significant influence on the choice and number of criteria, and so on the final solution.

We are witnessing rapid development and improvement of systems for automatic data collection. This fact contributes to the presented endpoint and will be increasingly applied in the future.

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MODEL ZA RANGIRANJE PONUDA STANOVA BAZIRAN NA VIŠEKRITERIJUMSKOJ OPTIMIZACIJI

Rezime: *Cilj ovog istraživanja je prikupljanje ponuda o stanovima i izbor najpovoljnije ponude u odnosu na preferencije donosioca odluke. Prilikom definisanja zadatka, naručilac je definisao i neka ograničenja u vidu njegovih potreba, želja i mogućnosti. Nakon detaljne analize zahteva, ekspert se ograničio po pitanju osnovnih karakteristika (atributa) nepokretnosti, odnosno stana. Odlučio se da to bude stan na Banovom brdu u Beogradu, Opština Čukarica, reda veličine ukupne cene od 20.000,00 do 50.000,00 evra i površine od 20 do 50 metara kvadratnih. Prema tome, ekspert je pristupio definisanju modela koji će izvršiti najbolji mogući izbor uz uslov optimalnog zadovoljenja naručioca i njegovog sistema vrednosti na način koji je prikazan u ovom radu.*

Ključne reči: *višekriterijumska optimizacija, višeatributno odlučivanje, analiza tržišta, rangiranje ponuda stanova, AHP metoda*