BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXVIII No. 2/2016	28 – 40	Seria Tehnică

Selection of the Optimum Artificial Lift Method, on the Basis of ARAS, COPRAS and TOPSIS Models

Codruț Ștefan Săraru

OMV Petrom SA, E & P PETROM CITY, 22 Coralilor Str., 013329, Bucuresti
email: codrutstefan.sararu@petrom.com

Abstract

In the early stages of their lives, oil wells flow to the surface naturally. They are usually called, natural flowing wells. After this stages, when the bottom pressure is not enough to overcome the pressure losses to surface, it's important to rejuvenate the wells by using an artificial lift system. Technique for order preference by similarity to ideal solution (TOPSIS) and complex proportional assessment (COPRAS) are some of the most prevalent multi criteria decision making methods. These methods are used to solve problems that involve a big amount of criteria. In this paper, three Visual Basic Excel applications will be enabled, in order to select the optimum artificial lift method for a well from Romanian oil fields.

Key words: *artificial lift, multi criteria decision making, technique for order preference by similarity to ideal solution, a new additive ratio assessment, complex proportional assessment.*

Introduction

Artificial lift systems are generally used to add energy to the fluid column, in order to initiate production (for dead wells), but also to enhance the current production. If the desired rates are not achieved, artificial lift methods can be used to reduce the hydrostatic load on formation. In this moment, in the world, more than 50 % of the wells are equipped with artificial lift systems.

In Romania, the most used artificial lift system is the reciprocating rod pump system (RRP), also named sucker rod pumping system (SRP). The main types of artificial lift systems used in the petroleum industry are reciprocating rod pumps (RRP), progressive cavity pump (PCP), electrical submersible pump (ESP), hydraulic jet pump (HJP), hydraulic plunger pump (HPP) and gas lift (GL).

Multi criteria decision making (MCDM) methods are basically evaluating the alternatives to solve a problem, in relation to each criterion, and propose the best solution for that problem. MCDM methods are very useful, especially when the optimum alternative must be selected in the presence of multiple and conflicting criteria. The methods can be classified in two main categories: multi attribute decision making (MADM) and multi objective decision making (MODM). Lately, new methods have been developed and the old ones have been improved. In this paper will be analysed and used three methods: TOPSIS, COPRAS and ARAS. The first two methods (TOPSIS and COPRAS) are considered some of the most prevalent multi criteria decision making methods. ARAS is one of the easiest MCDM methods, and it doesn't have high accuracy.

Alemi et al. [1], stated that the usage of artificial lift methods throughout the world is as follows: GL (50%), ESP (30%), SRP (17%), PCP (> 2%) and HP (< 2%).

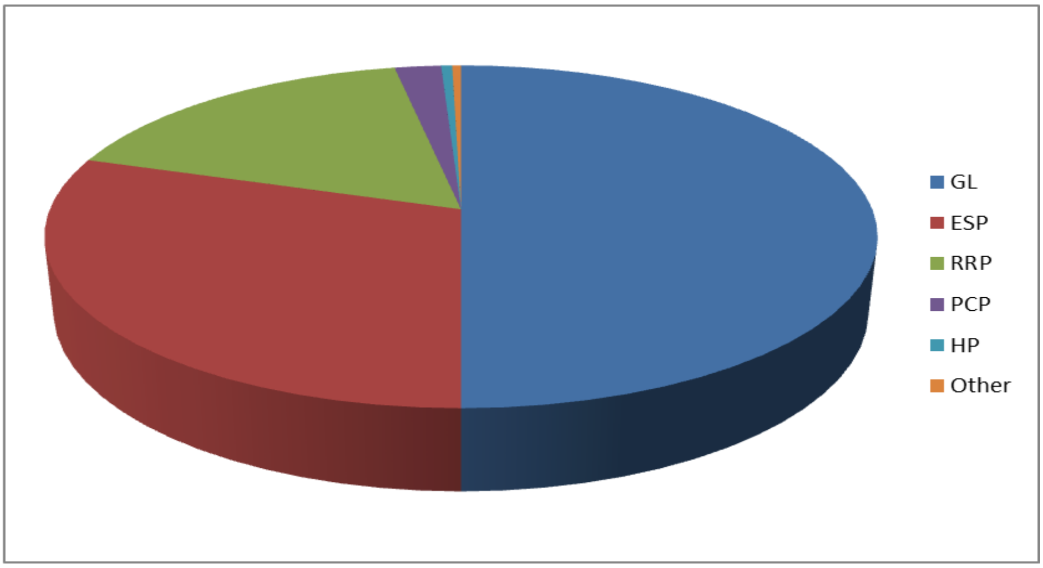

Fig. 1. The usage of the artificial lift methods

The selection of the best artificial lift system was done based only on experience and experimental calculation. Recently, in 2010, Mehrdad et al. have used a scientific MCDM method (TOPSIS) to select the best artificial lift system. Regarding the artificial lift system selection procedures, some researchers have developed some computer programs that possessed the characteristics of every artificial lift system and also decision trees based on economic analysis.

In this paper will be developed three applications, based on TOPSIS, COPRAS and ARAS MCDM methods, which will be able to select the optimum artificial lift system for different wells.

Artificial Lift Methods

Worldwide, reciprocating rod pump (RRP) is very used, representing more than 17% of the artificial lift systems. This system uses a pumping unit at the surface to transform the rotation movement of the motor, into the translation movement of the horse head. The string of sucker rods is the bridging element between horse head and plunger.

Advantages of the RRP:
- high system efficiency;
- optimization controls available;
- economical to repair and service;
- positive displacement/ strong drawdown;
- upgraded materials reduce corrosion concerns;
- flexibility- adjust production through stroke length and speed;
- high salvage value for surface and downhole equipment.

Limitations of the RRP:
- potential for tubing and rod wear;
- most systems limited by the ability of rods to handle loads- volume decreases as depth increases;
- environmental concerns.

Progressive cavity pumps, or Moineau pumps, named after the engineer Rene Moineau who invented this kind of pumps in the late 20's. These pumps have three elements: a stator and a rotor. The rotor is rotated inside the elastomeric pump body (stator), which has been molded in the form of a double helix with a pitch of the same diameter and exactly twice the length of the pitch given to the rotor.

Advantages of the PCP:
- low capital cost;
- low surface profile for visual and height sensitive area;
- high system efficiency;
- simple installation, quiet operation;
- pumps oil and water with solids;
- low power consumption;
- portable surface equipment;
- low maintenance costs;
- use in horizontal/ directional wells.

Limitations of the PCP:
- limited depth capability;
- temperature;
- sensitivity to produced fluids;
- low volumetric efficiencies in high-gas environments;
- potential for tubing and rod coupling wear;
- requires constant fluid level above pump.

An electrical submersible pump (ESP), is a multistage centrifugal pump, which is connected with a downhole motor. The motor is connected to a source of electrical power, through a cable that is extending to surface.

Advantages of the ESP:
- high volume and depth capability;
- high efficiency over 1000 BPD;
- low maintenance;
- minor surface equipment needs;
- good in deviated wells;
- used for well testing.

Limitations of the ESP:
- available electric power;
- limited adaptability to major changes in reservoir;
- difficult to repair in the field;
- free gas and/ or abrasives;
- high viscosity;
- higher pulling costs.

Hydraulic pumping systems transmit power downhole by means of pressurized power fluid that flows in wellbore tubulars. Hydraulic transmission of power downhole can be accomplished with reasonably good efficiency using a reciprocating piston pump.

Even higher efficiencies can be achieved with water as the hydraulic medium because of its lower viscosity.

The downhole pump acts a transformer to convert the energy into pressure in the produced fluids. A common form of a hydraulic downhole pump consists of a set of coupled reciprocating pistons, one driven by the power fluid and the other pumping the well fluids. Another form of a hydraulic downhole pump that has become more popular is the jet pump, which converts the pressurized power fluid to a high-velocity jet that mixes directly with the well fluids.

HPP advantages:
- often “free” or wireline retrievable;
- positive displacement – strong drawdown;
- double-acting high-volumetric efficiency;
- good depth/ volume capability + 15000 ft;
- deviated wells;
- multi-well production from single surface package;
- horsepower efficiency.

HPP limitations:
- solids;
- requires specific bottomhole assemblies;
- medium volume potential;
- require service facilities;
- free gas;
- requires high-pressure surface line.

Advantages of the HJP system:
- no moving parts;
- high volume capability;
- “free” pump;
- deviated wells;
- multi-well production from single surface package;
- low pump maintenance.

HJP limitations:
- producing rate relative to bottomhole pressure;
- some require specific bottomhole assemblies;
- lower horsepower efficiency;
- high-pressure surface line requirements.

Gas lift is a process of compressing and injecting gas into a well’s production casing to draw fluid up the tubing to the surface. This method is generally used on wells that have associated gas production, or when a big amount of high pressure gas is available for injection from other nearby wells. As the gas pressures diminish over time in mature fields, gas lift becomes less efficient. As the gas reserve is depleted, the operator begins to look for alternative lift methods.

Advantages of GL:
- high degree of flexibility;
- wireline retrievable;
- handles sandy conditions well;
- surface wellhead equipment requires minimal space;
- multi-well production from single compressor;
- multiple or slimhole completion.

GL limitations:
- needs high-pressure gas well or compressor;
- one well leases may be uneconomical;
- fluid viscosity;
- bottomhole pressure;
- high back-pressure.

Decision Making Process

"Decision making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. Making a decision implies that there are alternative choices to be considered, and in such a case we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values and so on." (Harris) [5]

János Fülöp developed the decision making process, with the following steps [4]:

Step 1. Define the problem

It's very important in decision making process to write the problem statement. The text must be concise and unambiguous, and must be agreed by all decision makers and stakeholders. "Even if it can be sometimes a long iterative process to come to such an agreement, it is crucial and necessary point before proceeding to the next step." (János Fülöp) [4]

Step 2. Determine requirements

The requirements must be stated in exact quantitative form, because it's important to decide unambiguously for every solution, whether it meets the requirements or not. Also, it's recommended to put the requirements down on paper and to conceive a written material that shows hot to check the requirements.

Step 3. Establish goals

Goals are objectives, while the requirements are constraints. It's possible for the goals to conflict, but this is normal for practical decision situations.

Step 4. Identify alternatives

Any alternative must meet the requirements. The alternatives must be checked one by one, to establish if they meet the requirements. We can obtain the explicit list of the alternatives, by screening out the infeasible ones. In this case, the alternatives are the artificial lift systems: RRP, PCP, ESP, HJP, HPP and GL.

Step 5. Define criteria

The goals will be represented by criteria, so every goal must generate minimum one criterion. It is very helpful to group the criteria in sets that relate to separate and distinguishable components of the overall objective for the decision. Doing this, it's easily to check if the selected set of criteria is suitable for the problem and also facilitates the calculations of criteria weights in some methods.

According to Baker et al. [2], criteria should be:

- able to discriminate among the alternatives and to support the comparison of the performance of the alternatives;
- complete to include all goals;
- operational and meaningful;
- non-redundant;
- few in number.

For the selection of the optimum artificial lift system, the following criteria are taken in consideration: volume lift capability/ depth, dogleg severity, temperature, fluid viscosity, sand and abrasives handling capability, corrosion handling capability, wax handling capability, gas handling ability, operating efficiency, intake capabilities, flexibility of system, prime mover flexibility, surveillance, relative service cost, gas source, lifting depth, facilities footprint, CAPEX and water cut.

Step 6. Select a decision making tool

There are several MCDM methods. And three of them will be presented in this paper: ARAS, COPRAS and TOPSIS. Selecting a decision making tool it's not a easy task, especially that there are a lot of methods. The selection depends on the concrete decision problem. Sometimes "the simpler the method, the better", but complex problems should require complex MCDM methods.

Step 7. Evaluate alternatives against criteria

Depending on the criterion, the assessment may be objective or subjective. It's very important that every alternative to be evaluated against every criteria, in order to correctly select the best alternative. Every alternative will receive a mark from 0 to 10, against every criteria, where 0 is the worst and 10 the best.

Step 8. Validate solutions against problem statement

In the end, the alternatives selected by the decision making tools must be validated against the requirements and the goals of the decision problem. It may happen that the MCDM method to be misapplied. Also, now can be observed future improvements that can be brought to the model.

ARAS (A new additive ratio assessment)

A new additive ratio assessment (ARAS) method was proposed by Zavadskas and Turskis. The ARAS method is considered a newly formed, but very effective and easy to use method [11].
Based on Stanujkic and Jovanovic, the procedure of solving problems by using ARAS methods, can be described by using the following steps [8]:

Step 1. Determine optimal performance rating for each criterion

After the decision matrix was build, the next step is to determine the optimal performance rating for each criterion [7]:

$$x_{Oj} = \max_{i} x_{ij}, \tag{1}$$

where x_{Oj} is optimal performance rating in relation to the j-th criterion.

Step 2. Calculate the normalized decision matrix $R=[r_{ij}]$

The normalized performance ratings are calculated using the following formula [7]:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \quad (2)$$

where r_{ij} is normalized performance rating of *i*-th alternative in relation to the *j*-th criterion.

Step 3. Calculate the weighted normalized decision matrix $V=[v_{ij}]$

The weighted normalized performance ratings are calculated using the following formula [7]:

$$v_{ij} = w_j \cdot r_{ij}, \quad (3)$$

where v_{ij} is weighted normalized performance rating of *i*-th alternative in relation to the *j*-th criterion.

Step 4. Calculate the overall performance index for each alternative

The overall performance index S_i, for each alternative, can be calculated as the sum of weighted normalized performance ratings, using the following formula [7]:

$$S_i = \sum_{j=1}^{n} v_{ij}. \quad (4)$$

Step 5. Calculate the degree of utility for each alternative

In our case, it's not important only to determine the optimum artificial lift system, but also to determine the relative quality of the artificial lift systems, in relation to the best ranked artificial lift system. For this, it's used the degree of utility, which can be calculated using the following formula [7]:

$$Q_i = \frac{S_i}{S_o}, \quad (5)$$

where Q_i is degree of utility of *i*-th alternative, and S_o is overall performance index of optimal alternative.

Step 6. Rank alternatives and/or select the most efficient one

The alternative with the largest value of Q_i is the best placed, so the alternatives are ranked by ascending Q_i.

COPRAS (Complex Proportional Assessment)

The MCDM method COPRAS, is used for multi-criteria evaluation. This method takes in consideration, both maximizing and minimizing criteria ratings. It was developed in 1996 by Zavadskas and Kaklauscas, two researchers of Vilnius Gediminas Technical University (Zavadskas, Kaklauscas 1996). [6]

The algorithm of the COPRAS method consists of the following steps [10]:

Step 1. Preparing the decision making matrix

$$DM = \begin{vmatrix} x_{11} & x_{12} & x_{13} & \dots & x_{1j} & \dots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \dots & x_{2j} & \dots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \dots & x_{3j} & \dots & x_{3n} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ x_{m1} & x_{m2} & x_{m3} & \dots & x_{mj} & \dots & x_{mn} \end{vmatrix},$$

where x_{ij} is the rating of *i*-th alternative, against *j*-th criterion, *m* is the number of alternatives, *n* is the number of criteria.

Step 2. Calculate the normalized decision matrix $R=[r_{ij}]$

The normalized performance ratings are calculated using the following formula [10]:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \qquad (6)$$

where r_{ij} is normalized performance rating of *i*-th alternative in relation to the *j*-th criterion.

Step 3. Calculate the weighted normalized decision matrix $V=[v_{ij}]$

The weighted normalized performance ratings are calculated using the following formula [10]:

$$v_{ij} = w_j \cdot r_{ij}, \qquad (7)$$

where v_{ij} is weighted normalized performance rating of *i*-th alternative in relation to the *j*-th criterion.

Step 4. Calculate the sums of maximizing, respectively minimizing criteria ratings

The sum of the maximizing criteria ratings is calculated using the following formula:

$$S_i^+ = \sum x_{ij}^+. \qquad (8)$$

The sum of the minimizing criteria ratings is calculated using the following formula:

$$S_i^- = \sum x_{ij}^-. \qquad (9)$$

Step 5. Calculate the relative weight of each alternative

The weighted normalized performance ratings are calculated using the following formula:

$$Q_i = S_i^+ + \frac{\sum_{i=1}^{m} S_i^-}{S_i^- \cdot \sum_{i=1}^{m} \frac{1}{S_i^-}}. \tag{10}$$

Step 6. Calculate the utility degree of each alternative

The weighted normalized performance ratings are calculated using the following formula [10]:

$$U = \frac{Q_i}{Q_{max}} \cdot 100\,[\%], \tag{11}$$

where Q_{max} is the maximum relative weight.

Step 7. Rank alternatives

The alternatives are ranked based on utility degree. The best alternative, is the alternative with the greater utility degree.

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

TOPSIS model was developed by Hwang and Yoon. The method is based on the principle, that the best alternative must have the shortest Euclidean distance from the ideal solution and the largest Euclidean distance from the negative ideal solution (Hwang and Yoon 1981; Pimerol et al., 2000) [1].

The TOPSIS model can be described by the following steps [1]:

Step 1. Preparing the decision making matrix

$$DM = \begin{vmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1j} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2j} & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3j} & \cdots & x_{3n} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mj} & \cdots & x_{mn} \end{vmatrix},$$

where x_{ij} is the rating of *i*-th alternative, against *j*-th criterion, *m* is the number of alternatives, *n* is the number of criteria.

Step 2. Calculate the normalized decision matrix $R=[r_{ij}]$

The normalized performance ratings are calculated using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \tag{12}$$

where r_{ij} is normalized performance rating of i-th alternative in relation to the j-th criterion.

Step 3. Calculate the weighted normalized decision matrix $V=[v_{ij}]$

The weighted normalized performance ratings are calculated using the following formula:

$$v_{ij} = w_j \cdot r_{ij}, \tag{13}$$

where v_{ij} is weighted normalized performance rating of i-th alternative in relation to the j-th criterion.

Step 4. Establish the ideal solution and the negative ideal solution

The ideal solution (A^+) is calculated using the following formula:

$$A^+ = \left\{\left[\left(\max v_{ij} \middle| j \in J\right), \left(\min v_{ij} \middle| j \in J'\right)\right] \middle| i = 1,2,\ldots,m\right\} = \left\{v_1^+, v_2^+, \ldots, v_n^+\right\}. \tag{14}$$

The negative ideal solution (A^-) is calculated using the following formula:

$$A^- = \left\{\left[\left(\min v_{ij} \middle| j \in J\right), \left(\max v_{ij} \middle| j \in J'\right)\right] \middle| i = 1,2,\ldots,m\right\} = \left\{v_1^-, v_2^-, \ldots, v_n^-\right\}. \tag{15}$$

where A^+- ideal solution;
A^-–negative ideal solution;
J-associated with maximizing criteria;
J'-associated with minimizing criteria.

Step 5. Calculate the Euclidean distances between every alternative and ideal solution, respectively negative ideal solution

The Euclidean distance between ideal solution and alternatives is calculated using the following formula:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_j^+ - v_{ij})^2}, i = 1, 2, \ldots, m. \tag{16}$$

The Euclidean distance between negative ideal solution and alternatives is calculated using the following formula:

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_j^- - v_{ij})^2}, i = 1, 2, \ldots, m. \tag{17}$$

Step 6. Calculate the relative closeness of a particular alternative to the ideal solution

The relative closeness of a particular alternative to the ideal solution is calculated using the following formula:

$$cl_i^+ = \frac{d_i^-}{d_i^- + d_i^+}, i = 1, 2, \ldots, m. \quad (18)$$

Results

In this paper were presented three MCDM methods. For every method was developed an application and here will be presented the results of the optimum artificial lift system selection. The results will be presented for a well from Romanian oil fields, that is equipped in this moment with reciprocating rod pump system (RRP) (table 1).

Table 1. Data for the analysed well

Flow rate	14	m^3/ zi
Depth	1782	m
Dogleg severity	< 3	ºC
Temperature	< 250	º/ 30 m
Viscosity	< 100	cP
Sand and abrasives contents	< 0,3	%
Corrosion problem	Yes	-
Paraffin problem	No	-
Gas problem	Yes	-
Gas source	No	-
Pump intake pressure	< 69	bar
Water cut	> 60	%

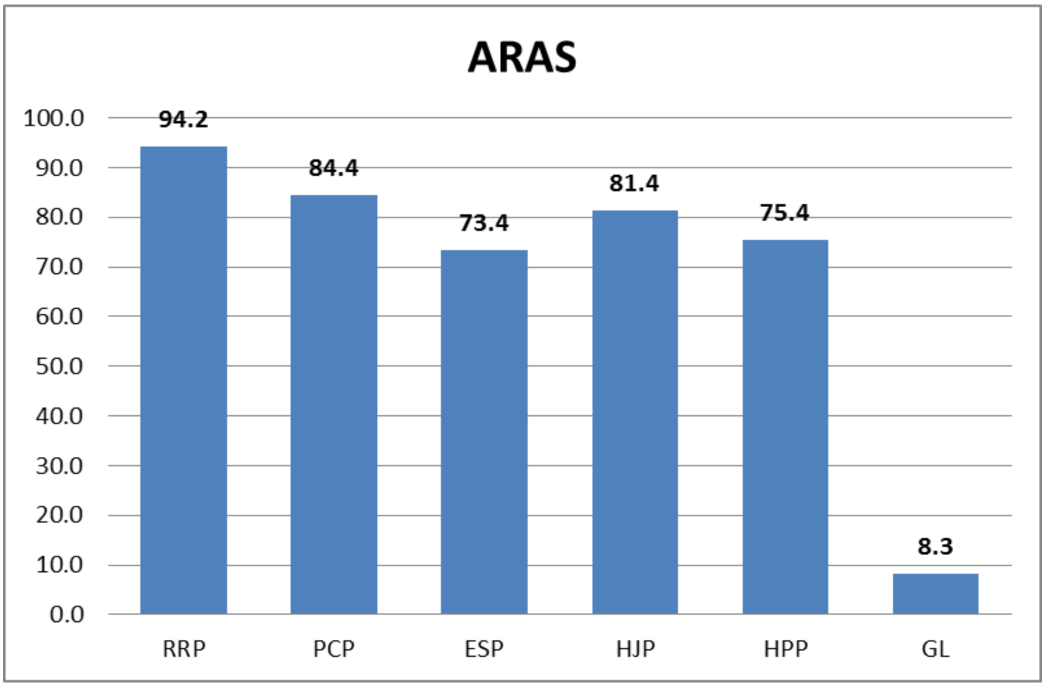

Fig. 2. ARAS application results for the analysed well

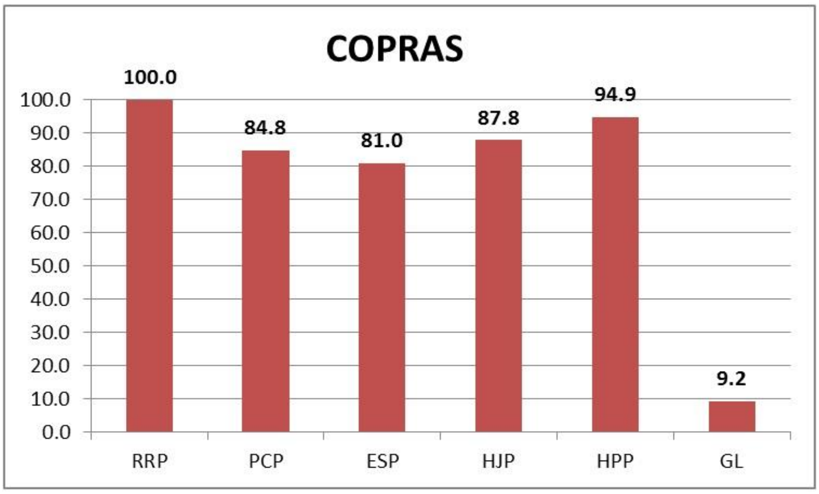

Fig. 3. COPRAS application results for the analysed well

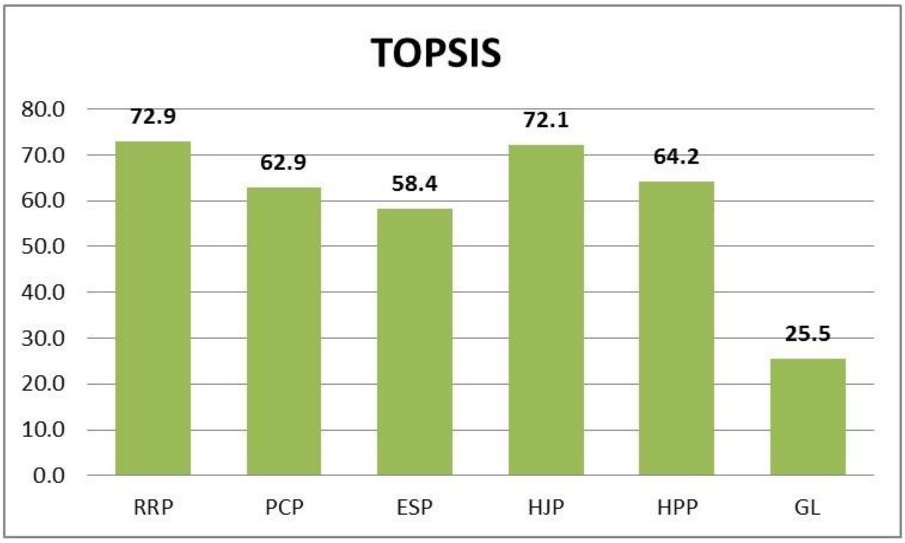

Fig. 4. TOPSIS application results for the analysed well

Conclusions

In this paper were presented the artificial lift systems, with advantages and limitations. Also, three MCDM methods were described step by step. Based on these, were developed three applications (one for each method) in VBA Excel. The applied methods proved their validity, being applied for a large range of wells operating data.

Also, it can be easily observed in the results of the present paper, that all the applications indicate the same optimum artificial lift system for a certain well operating parameters. Additionally, the artificial lift method indicated by statistical model corresponds with well field application.

MCDM methods proved that can be used in petroleum industry and that can be used to select the optimum artificial lift system. Of course, that in the future, all this applications can be improved. A better way forward, is to improve the decision matrix, in order to contain more criteria that can be taken in consideration.

References

1. Alemi, M., Jalalifar, H., Kamali, G., Kalbasi, M. – A prediction to the best artificial lift method selection on the basis of TOPSIS model, *Journal of Petroleum and Gas Engineering*, Vol. 1(1) , March 2010, pp. 9-15.
2. Baker,D., Bridges, D., Hunter, R., Johnson, G., Krupa, J., Murphy, J., Sorenson, K. – *Guidebook to decision making methods,* WSRC-IM-2002-00002, Department of Energy, USA, 2002.
3. Chatterjee, P., Chakraborty, S. – Gear material selection using complex proportional assessment and additive ratio assessment- based approaches: a comparative study, *International Journal of materials Science and Engineering*, Vol. 1, No. 2, December 2013.
4. Fulop,J. – *Introduction to decision making methods*, Laboratory of Operations Research and Decsion Systems, Computer and Automation Institute, Hungarian Academy of Sciences.
5. Harris,R. – *Introduction to decision making*, VirtualSalt, 1998. http://www.virtualsalt.com/creebook5.htm
6. Podvezko, V. – The comparative analysis of MCDA methods SAW and COPRAS, *Inzinerie Ekonomika- Engineering Economics*, **22**(2), 2011, pp. 134-146.
7. Stanujkic, D., Djordjevic, B., Karabasevic, D. – Selection of candidates in the process of recruitment and selection of personnel based on the SWARA and ARAS methods, *Quaestus multidisciplinary research journal*.
8. Stanujkic, D., Jovanovic, R. – Measuring a quality of faculty website using ARAS method, *Proc. of International scientific conference Contemporary Issues in Business, Management and Educatio '2012, selected papers*, Vilnius Gediminas Technical University, Lithuania, 15 November 2012, pp. 545-554.
9. Zavadskas, E.K., Kaklauskas, A. – Multicriteria evaluation of building, Vilnius: *Technika*, 1996.
10. Zavadskas,E.K., Kaklauskas, A., Turskis, Z.,Tamosaitiene, J. – Multi-attribute decision-making model by applying grey numbers, *Institute of Mathematics and Informatics, Vilnius, Informatica*, Vol. 20, No. 2, 2009, pp. 305-320.
11. Zavadskas,E.K., Turskis, Z. – A new additive ratio assessment (ARAS) method in multicriteria decision-making, *Technological and Economic Development of Economy*, **16**(2), 2010, pp. 159-172.
12. Zavadskas,E.K., Turskis, Z., Vilutiene, T. – Multiple criteria analysis of foundation instalment alternatives by applying additive ratio assessment (ARAS) method, *Archives of Civil and Mechanical Engineering*, **10**(3), 2010, pp. 123-141.

Selectarea sistemului optim de extracție a țițeiului, pe baza metodelor ARAS, COPRAS și TOPSIS

Rezumat

Alegerea sistemului de extracție a țițeiului este o activitate complexă, impunând cunoașterea principalelor caracteristici ale fiecărei metode de extracție. Aceasta se referă în principal la avantajele, dezavantajele și domeniul de aplicabilitate al fiecărui sistem de extracție în parte. Dacă procesul de selecție se bazează pe analiza a două sau trei criterii, procesul de alegere poate fi controlat de factorul uman. În cazul activității de extracție a țițeiului, care presupune existența unui număr mare de criterii (tehnico-economice), procesul de selectare a sistemului de extracție este mult mai complex, impunând o abordare statistică. În acest sens, lucrarea își propune prezentarea a trei metode statistice de selecție din categoria generală a MCDM, și anume: TOPSIS, ARAS și COPRAS.