

## A Mathematical Prediction Based on Vikor Model

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**Abstract:** Artificial Lift is defined as any system that adds energy to the fluid column in a wellbore with the objective of initiating and enhancing production from the well. Artificial Lift is needed when reservoir drives do not sustain acceptable rates or cause fluids to flow at all in some cases. Artificial Lift systems use a range of operating principles, including Pumping and Gas lifting. Višekriterijumsko kompromisno Rangiranje (VIKOR), Compromise Ranking Model or Method is one of the most prevalent Multi Criteria Decision Making (MCDM) methods required to be paid attention. MCDM is an approach employed to solve problems involving selection from among a finite number of criteria. An MCDM method specifies how attribute information is to be processed in order to arrive at a choice. This literature review of used Artificial Lift selection methods in oil industry shows that the most studies in this field have been based on only experiential calculations by now despite the significant importance of this matter. As well, none of them has been based on the scientific MCDM methods, itself implying one of the Artificial Lift selection previous procedures major imperfections. In this paper a novel expert computer method based on VIKOR model is presented for Artificial Lift selection in oil industry. The application of VIKOR model on the basis of MCDM scientific methods can present the best Artificial Lift method selection in each circumstance.

**Key words:** Artificial lift • Višekriterijumsko KOMPROMISNO Rangiranje • Multi Criteria Decision Making-VIKOR

### INTRODUCTION

Artificial Lift is defined as any system that adds energy to the fluid column in a wellbore with the objective of initiating and enhancing production from the well.

When a reservoir lacks sufficient energy for oil, gas and water to flow from wells at desired rates, supplemental production methods can help. Lift processes transfer energy down hole or decrease fluid density in wellbore to reduce the hydrostatic load on formation.

Major types of Artificial Lift are Gas Lift (GL) design (Continuous Gas Lift, Intermittent Gas Lift) and Pumping (Electrical Submersible Pump (ESP), Progressive Cavity Pump (PCP), Sucker Rod Pump (SRP), Hydraulic jet type Pump (HP)).

As the well is produced, the potential energy is converted to kinetic energy associated with the fluid

movement. This dissipates the potential energy of the reservoir, thereby causing the flow rate to decrease and the flow to eventually cease.

It may be economical at any point in the life of a well to maintain or even to increase the production rate by the use of Artificial Lift to offset the dissipation of reservoir energy.

MCDM refers to making decisions in the presence of multiple, usually conflicting criteria.

The problems of MCDM can be broadly classified into two categories: Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM), depending on whether the problem is a selection problem or a design problem. MODM methods have decision variable values that are determined in a continuous or integer domain, with either an infinitive or a large number of choices, the best of which should satisfy the decision maker's constraints and preference

priorities. MADM methods, on the other hand, are generally discrete, with a limited number of predetermined alternatives.

By now, the usage of Artificial Lift methods throughout of the world has been recently reported that for GL, ESP, SRP, PCP, HP as different Artificial Lift methods has been equal to 50%, 30%, 17%, >2% and <2% respectively.

The most studies in this field have been based on only experiential calculations by now despite the significant importance of this matter. As well, none of them has been based on the scientific MCDM methods, itself implying one of the Artificial Lift selection previous procedures major imperfections.

However, about the previous Artificial Lift selection procedures, it can be said that some researchers have studied on this matter briefly expressed as the following:

In (1981), Neely considered the geographical and environmental circumstances as the dominant factors for Artificial Lift selection.

In (1988), Valentine used Optimal Pumping Unit Search (OPUS) for Artificial Lift selection. Indeed OPUS was a smart integrated system possessing the characteristics of Artificial Lift methods.

In (1993), Bucaram and Clegg studied on some of the operational and designing factors based on Artificial Lift methods overall capability comparison and design.

In (1994), Espin used SEDLA for Artificial Lift selection. Indeed SEDLA was a computer program possessing the characteristics of Artificial Lift methods.

In (1995), Heinze used "the Decision Tree" for Artificial Lift selection. The most major factor in it was based on a longtime economic analysis.

The paper objective is to specify VIKOR model as a predicted method for Artificial Lift selection.

## MATERIAL AND METHODS

The usage of Artificial Lift methods throughout of the world by now has been recently reported (Figure 1), (Weatherford Com.).

It is necessary to mention that Sucker Rod Pump (SRP) is a positive displacement pump that compresses liquid by the motion of a piston. The piston is actuated by a string of sucker rods that extends from the bottomhole pump to the pumping unit at the surface. The rod or structure may limit rate at depth [1].

A Progressive Cavity Pump (PCP) is a kind of pump which transfers fluid by means of a sequence of small, fixed shape, discrete cavities, that move through the pump as its rotor turns.

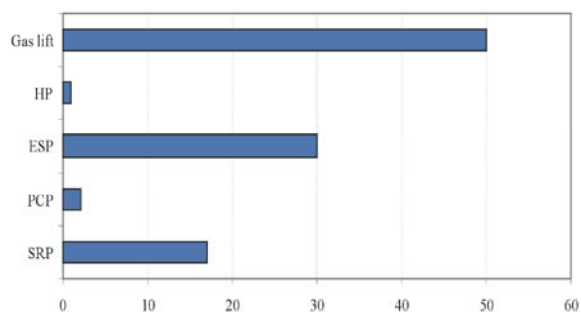


Fig. 1: The usage of Artificial Lift methods throughout of the world, (Weatherford Com.)

The cavities taper down toward their ends and overlap with their neighbors, so that, in general, no flow pulsing is caused by the arrival of cavities at the outlet [1].

An Electric Submersible Pump (ESP) is a dynamic displacement, multistage centrifugal turbine pump coupled by a short shaft to a downhole electrical motor. The motor is supplied with electrical power by a cable extending to the surface. ESP systems have a wide range of applications and offer an efficient and economical lift method. Even if sand production, high Gas Oil Ratio (GOR) and viscosity are concerns, we can find the right ESP for our well and improve production. From onshore high water cut applications to complex offshore, deepwater, or subsea applications, we have a system to meet our needs [1].

A Hydraulic jet type Pump (HP) is an ejector type dynamic displacement pump operated by a stream of high pressure power fluid converging into a jet in the nozzle of the pump. Downstream from the nozzle, the high velocity, low pressure jet is mixed with the well's fluid. The stream of the mixture is then expanded in a diffuser and as the flow velocity is dropped the pressure is built up. The fluid flow can carry some corrosive additives into wellbore and function as a maintenance material. The constraints to use HP are related to high GOR or contamination in the fluid flow bringing about low efficiency of pump at last [1].

As well, during Gas Lift (GL), gas is injected into the tubing string to lighten the fluid column and allow the well to flow when it will not flow naturally.

The injected gas is mixed with produced fluid, decreases the flowing gradient in the production string and thus lowers the bottom hole flowing pressure.

Basic objective of gas lift design is to equip wells in such a manner as to compress a minimum amount of gas to produce a maximum amount of oil [1].

#### Previous Artificial Lift Selection Procedures:

- In (1981), Neely designated some Artificial Lift methods such as: SRP, ESP, HP, GL and studied about the application circumstances, advantages, disadvantages and constraints of each method. He considered the geographical and environmental circumstances as the dominant factors for Artificial Lift selection and also some other subordinate factors such as: reservoir pressure, productivity index, reservoir fluid properties and inflow performance relationship [2].
- In (1988), Valentine used Optimal Pumping Unit Search (OPUS) for Artificial Lift selection. Indeed OPUS was a smart integrated system possessing the characteristics of Artificial Lift methods. OPUS had the capability to control the technical and financial aspects of Artificial Lift methods. It can be said that the production system was consisted of the downhole pump up to the surface facilities (stock tank). The technical and financial evaluation of this procedure was done by means of some specific computer algorithms. Therefore, knowing the primary required investment value, costs (maintenance, equipment) and technical ability of each Artificial Lift method, Artificial Lift selection was done [3].
- Also in (1988), Clegg mentioned some economic factors such as: revenue, operational and investment costs as the basis for Artificial Lift selection. He believed that the selected Artificial Lift method could have the best production rate with the least value of operational costs [4].
- In (1993), Bucaram and Clegg studied on some of the operational and designing characteristics of Artificial Lift methods categorized into 3 types based on Artificial Lift methods overall capability comparison and design, some specific operational factors and Artificial Lift methods factors probably causing some specific problems respectively [5].
- In (1994), Espin used SEDLA for Artificial Lift selection. Indeed SEDLA was a computer program possessing the characteristics of Artificial Lift methods. It was composed of 3 modules based on an information bank of human activities, the theoretical knowledge of Artificial Lift methods and the economic evaluation of Artificial Lift methods respectively. Therefore the Artificial Lift selection was done on the basis of profit value [6].

- In (1995), Heinze used "the Decision Tree" for Artificial Lift selection. The most major factor in it was based on a longtime economic analysis. Also, the Artificial Lift methods evaluation was based on operational costs, primary investment and lifetime cost and energy efficiency. Ultimately, considering these factors besides the decision maker, the Artificial Lift selection was done [7].

#### Some Engineering Applications of VIKOR Model Used up to Now:

- The application of VIKOR model for the selection of suppliers based on Rough Set Theory and VIKOR algorithm, the proposed methodology consisted of two parts: 1) The RST was a fairly new methodology developed for dealing with imprecise, uncertain and vague information. 2) According to index systems we have established for selection of suppliers, VIKOR algorithm has been used to select the best suppliers [8].
- The application of VIKOR model for the evaluation of software development projects using a fuzzy multi criteria decision approach, this model has been used to process data, to provide a more comprehensive evaluation in a fuzzy environment and to measure the performance of enterprise resource planning (ERP) software products [9].
- Application of VIKOR model as a Multi Criteria Decision Analysis of alternative fuel buses for public transportation, the result has shown that the hybrid electric bus has been the most suitable substitute bus for Taiwan urban areas in the short and median term. But, if the cruising distance of the electric bus extends to an acceptable range, the pure electric bus could be the best alternative [10].

Some other certain scientific programs based on MCDM models or methods are listed as below, but because VIKOR model has been validated with several certain oil fields Artificial Lift selection operations results and a considerable accordance between their final results has been gained, this model has been chosen for Artificial Lift selection. As well, this model gives an appropriate solution that is not only the closest to the best alternative, but also the farthest from the worst alternative.

- VIKOR (Višekriterijumsko KOmpromisno Rangiranje), Compromise Ranking model
- SAW (Simple Additive Weighting) model
- TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) model
- ELECTRE (Elimination et Choice in Translating to Reality) model
- WPM (Weighted Product Model)

## DISCUSSION

In this paper a novel expert computer method (VB.net code) based on VIKOR model has been presented for Artificial Lift selection in oil industry. It was essential to mention to the mathematical and logical strategy and calculations of the novel expert computer method (VB.net code) based on this model. Also, the designed executive file (Figure 2) through (Figure 7) of Artificial Lift selection programming has been shown.

**Višekriterijumsko KOmpromisno Rangiranje (VIKOR) Compromise Ranking Model:** The foundation for Compromise Solution was established by Yu (1973) and Zeleny (1982) and later advocated by Opricovic and Tzeng (2002, 2003, 2004 and 2007). The Compromise Solution is a feasible solution that is the closest to the ideal solution and a Compromise means an agreement established by mutual concession. The Compromise Solution Method, also known as the VIKOR (Višekriterijumsko KOmpromisno Rangiranje) model, was introduced as one applicable technique to implement within MADM [11, 12].

The VIKOR model was developed to solve MCDM problems with conflicting (different units) criteria, assuming that compromising is acceptable for conflict resolution, the decision maker wants a solution that is the closest to the ideal and the alternatives are evaluated according to all established criteria. This model focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria and on proposing compromise solution [13].

The main procedure of VIKOR model for the selection of the best alternative from among those available is described as below:

At first it was required to allocate suitable quantities scaled from 0 through 10 for the alternatives relative to the criteria, (higher each of their qualities, more its value out of 10), [13].

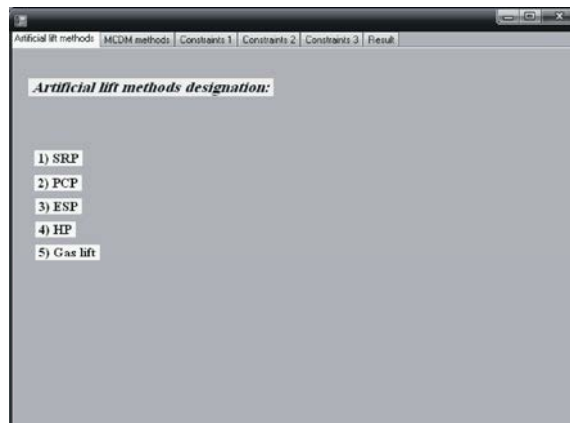


Fig. 2: Artificial Lift methods designation

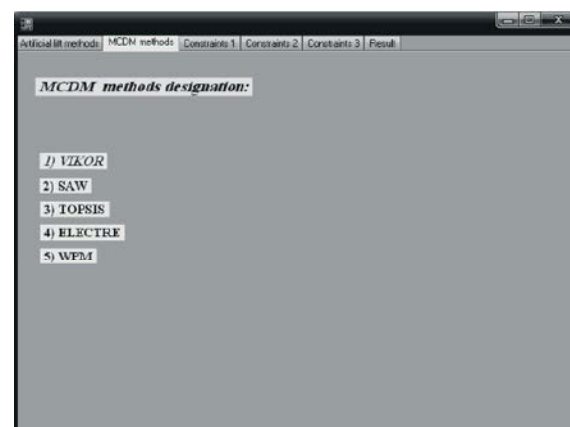


Fig. 3: MCDM methods designation

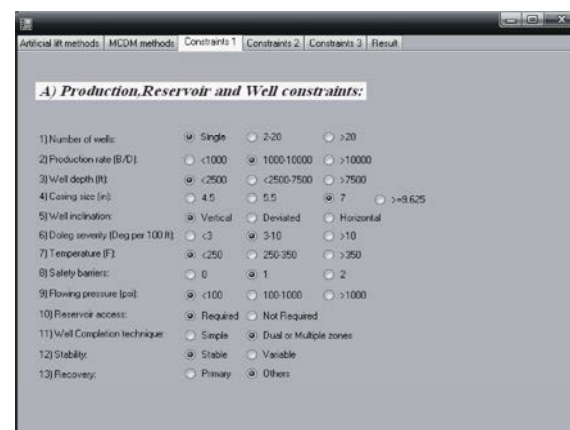


Fig. 4: Production, Reservoir and Well constraints

The relative scores of different methods relative to Production, Reservoir and Well constraints as well as Produced fluid properties and Surface infrastructure constraints (all the criteria) have been based on the Schlumberger Company certain practical reports

**B) Produced fluid properties:**

14) Water cut: ☐ Low ☒ Moderate ☐ High

15) Fluid viscosity (cp): ☒ <100 ☐ 100-500 ☐ >500

16) Corrosive fluid: ☐ Yes ☒ No

17) %sand (ppm): ☒ <10 ☐ 10-100 ☐ >100

18) GOR (SCF/stb): ☒ <500 ☐ 500-2000 ☐ >2000

19) VLR: ☒ <0.1 ☐ 0.1-1.0 ☐ >1.0

20) Contaminants: ☐ Scale ☐ Paraffin ☒ Asphaltene

21) Treatment: ☐ Scale inhibitor ☒ Solvent ☐ Corrosion inhibitor ☐ Acid

Fig. 5: Produced fluid properties

**C) Surface infrastructure:**

22) Location: ☐ Onshore ☒ Offshore ☐ Remote ☐ Sensitive environment

23) Electrical power: ☒ Utility ☐ Generation

24) Space restrictions: ☐ Yes ☒ No

25) Well service: ☒ Workover rig ☐ Snubbing unit ☐ Pulling unit ☐ Wireline ☐ Coiled tubing unit

Fig. 6: Surface infrastructure constraints

Click the following button to view the result:

**VIKOR model:**

**Result**

**Artificial lift selection:**

**Conclusion**

The best Artificial Lift method to be applied with these circumstances is:

**D) HP application is the best choice**

Fig. 7: Artificial Lift selection result

(Schlumberger Com.). The value of 1 (good to excellent) has been considered as 7 out of 10, the value of 2 (fair to good) has been considered as 5 out of 10 and the value of 3 (not recommended and poor) has been considered as 3 out of 10 in the following, on the whole, it is believed that the calculations results and the related graphs

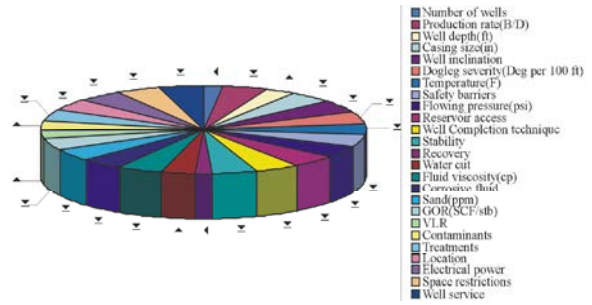


Fig. 8: The alternatives relative to the criteria quantities scaled from 0 out of 10, (here as a sample figure only to show the HP (best) alternative row scores of its whole related matrix)

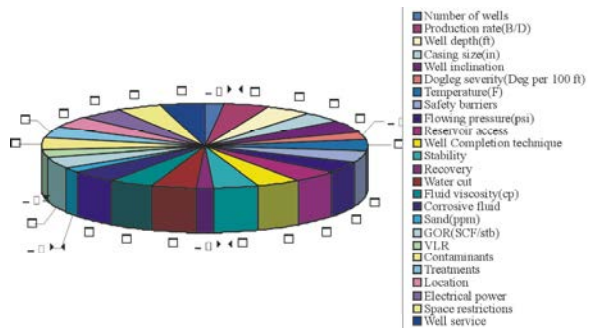


Fig. 9: The linearly normalized alternatives relative to the criteria quantities matrix, (here as a sample figure only to show the HP (best) alternative row scores of its whole related matrix)

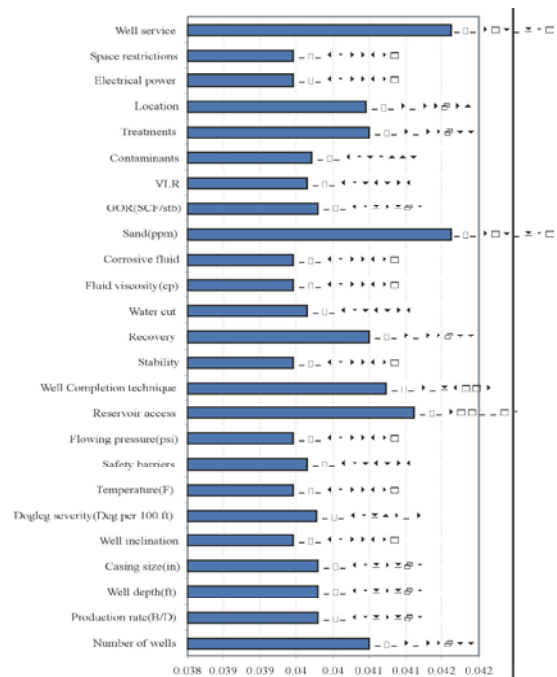


Fig. 10: The resulted weights of the alternatives relative to the criteria all quantities

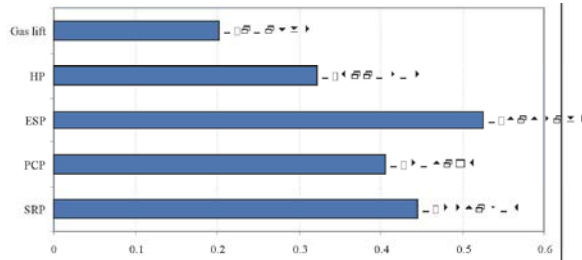


Fig. 11: The resulted alternatives  $E_i$  values

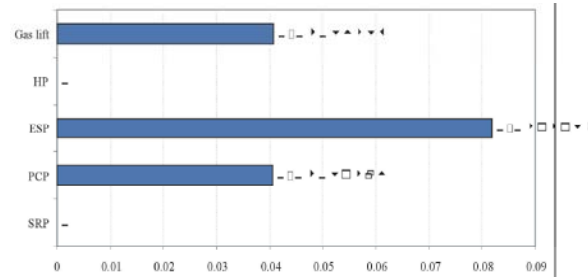


Fig. 12: The resulted alternatives  $F_i$  values

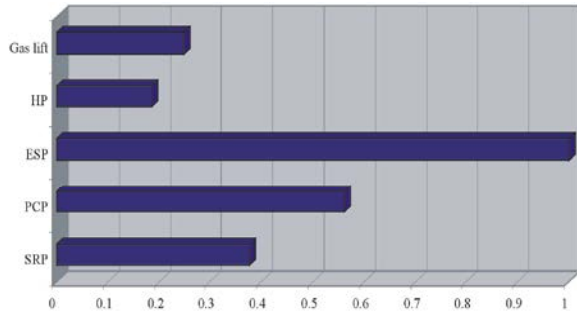


Fig. 13: Artificial lift selection result

configurations shown as (Figure 8) through (Figure 14) vary in different circumstances.

But here, ((Figure 8) through (Figure 14) have been related to the condition that HP application has been the best choice as the shown result in (Figure 7)). As seen in (Figure 2) through (Figure 6), the quantities have been scaled from 0 through 10 for the alternative relative to the criteria quantities matrix. In the matrix the number of the alternatives and the number of criteria have been considered as the number of matrix rows and matrix columns respectively. Here as a sample schematic only for the HP alternative relative to the criteria quantities of its related matrix could be graphically illustrated (Figure 8).

Then, the normalizing of the resulted alternatives relative to the criteria quantities matrix had to be done. Here as a sample schematic only for the HP alternative relative to the criteria quantities of its related matrix could be graphically illustrated (Figure.9), [13].

This resulted normalized matrix had to be weighted by means of a specific weights calculating mathematical method (such as Entropy method), (Figure.10), [13-16].

Then the following  $E_i, F_i, P_i$  parameters had to be calculated (Figure 11) through (Figure 13).

$$E_i = \sum_{j=1}^M W_j [(V_{ij})_{\max} - (V_{ij})] / [(V_{ij})_{\max} - (V_{ij})_{\min}] \quad (1)$$

$$F_i = \max_j \{ W_j [(V_{ij})_{\max} - (V_{ij})] / [(V_{ij})_{\max} - (V_{ij})_{\min}] \mid j=1, 2, \dots, m \} \quad (2)$$

$$P_i = v((E_i - E_{i-\min}) / (E_{i-\max} - E_{i-\min})) + (1-v)((F_i - F_{i-\min}) / (F_{i-\max} - F_{i-\min})) \quad (3)$$

Where  $i, j$  are the numbers of (rows) alternatives and (columns) criteria in the matrix respectively?

$(V_{ij})$  is related to the alternatives relative to the criteria all quantities matrix values.  $(W_j)$  is related to the alternatives relative to the criteria all quantities matrix weights.

$v$  is introduced as the weight of the majority of attributes strategy. Usually, the value of  $v$  is taken as 0.5. However,  $v$  can take any value from 0 to 1.

The alternative with the lowest  $P_i$  value has been considered the best alternative (Figure 13).

## CONCLUSION

In this paper a novel expert computer method based on VIKOR model was presented for Artificial Lift selection in oil industry.

The application of VIKOR model on the basis of MCDM scientific methods could present the best Artificial Lift method selection in each circumstance. The validity of this scientific designed program has been checked and validated with several certain oil fields Artificial Lift operations results by means of the comparison between them. Finally it has been resulted that between this designed programs final result and the related oil fields Artificial Lift operations results, a considerable accordance has been available.

Indeed the paper objective has been a history matching study for Artificial Lift selection done with VB.net code applicable for oil industry throughout of the world.

## REFERENCES

1. Gholinegad, J., 2007. Artificial Lift. Sharif University of Technology Workshop, Tehran, Iran.

2. Neely, B., F. Gipson, B. Capps, J. Clegg and P. Wilson, 1981. Selection of Artificial Lift method. Dallas, Texas, SPE#10337.
3. Valentine, E.P., F.C. Hoffman and Francais du petrole, 1988. OPUS: An expert adviser for Artificial Lift, SPE#18184.
4. Clegg, J.D., 1988. High-rate Artificial Lift. Journal of Petroleum Technology, SPE#17638.
5. Clegg, J.D., S.M. Bucaram and J. Heln, 1993. Recommendations and comparisons for selection of Artificial Lift methods. Journal of Petroleum Technology.
6. Espin, D.A., S. Gasbarri, J.E. Chacin and S.A. Intevpe, 1994. Expert system for selection of optimum Artificial Lift method. Argentina, SPE#26967.
7. Heinze, L.R., W. Herald and J.F. Lea, 1995. Decision Tree for selection of Artificial Lift method. Oklahoma, SPE#26510.
8. Guo, J. and W. Zhang, 2008. Selection of suppliers based on Rough Set Theory and VIKOR algorithm. International Symposium on Intelligent Information Technology Application Workshops.
9. Büyüközkan, G. and D. Ruan, 2008. Mathematics and Computers in Simulation, 77: 464-475.
10. Tzeng, G.H., C.W. Lin and S. Opricovic, 2005. Energy Policy, 33: 1373-1383.
11. Hwang, C.L. and K. Yoon, 1981. Multiple Attribute Decision Making: a state of the art survey, Springer-Verlog.
12. Pimerol, J.C. and S.B. Romero, 2000. Multi Criteria Decision in management: principles and practice, Kluwer Academic Publishers.
13. Rao, R.V., 2007. Decision making in the manufacturing environment: Using graph theory and fuzzy Multiple Attribute Decision Making methods, Springer-Verlog.
14. Hossein Berenjeian Tabrizi, Ali Abbasi and Hajar Jahadian Sarvestani, 2013. Comparing the Static and Dynamic Balances and Their Relationship with the Anthropometrical Characteristics in the Athletes of Selected Sports, Middle-East Journal of Scientific Research, 15(2): 216-221.
15. Anatoliy Viktorovich Molodchik, 2013. Leadership Development: A Case of a Russian Business School, Middle-East Journal of Scientific Research, 15(2): 222-228.
16. Kabiru Jinjiri Ringim, 2013. Understanding of Account Holder in Conventional Bank Toward Islamic Banking Products, Middle-East Journal of Scientific Research, 15(2): 176-183.