A Novel Screening Technique for Implementation of Intelligent Reservoir Technology

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Abstract

Throughout life cycle of oil production wells, it is imperative to have production optimization and real response time to rapid changes of well conditions and more understanding of subsurface otherwise it is the matter of expenditure losing. Smart well capabilities meet aforementioned issues. However there is a key concern in managers' mind that they have limited budget and several fields' documents in front. They cannot afford smart well technology for all fields because they know that justification through modeling, simulation and economic evaluation is vital but costly and time consuming. They can apply this box only for one filed. How can they select one field among these fields? In this paper we present a novel screening technique by Analytical Hierarchy Process engine. This technique needs criteria and sub-criteria affecting on smart well potential of fields. Application of this screening technique directed us to prioritize four fields to implement smart well completion. Interestingly; the output of this paper can be used for any set of fields throughout the world.

Keywords: Screening criteria, Smart well, Prioritization, Analytical hierarchy process, Sensitivity analysis

Introduction

Nowadays; a lot of successful smart well implementations have been applied worldwide. It is worth to mention that intelligent completion technology does not guarantee successfulness leading to added value. Experience has shown that throughout intelligent completions, the degree to which production is improved depends on such factors as porosity and permeability distribution within the reservoir. So, candidate screening processes range from a simple analytical approach to complex reservoir simulation models [1]. In a reservoir with uniform permeability, for instance remotely actuated valves at first glance would seem to be an effective tool for managing water influx, increasing well life and improving ultimate recovery. But if the completion is to be set across a relatively short interval within that reservoir, an intelligent completion may not be economically justified since a sufficiently uneven fluid front may not be developed [2].

Generally; any smart well project has six phases as Identification, Assessment, Selection, Definition, Execution and Operation [3]. In Identification phase the question of "is there any smart well opportunity for these fields?" will be answered and in Assessment phase operational limitations will be investigated. Through these phases some fields may be filtered and the rest will go through Selection phase which is very important and critical phase. In this study we passed two first phases with output of four out of six fields. These four fields go through Selection phase which will be elaborated in this paper.

2. Problem definition

We know smart well technology helps us to better development of our fields but we are worry about its economy. The situation becomes hard when there are several fields' documents on the desk. Limited budget and lack of enough expert personnel cause smart well service companies not to recommend application of this technology for all fields. How do they select the purpose field among these? We know that there is no well-established screening method in the world. In the previous publication we presented

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novel screening criteria under Multi Criteria Decision Making (MCDM) with Analytical Hierarchy Process (AHP) engine in which the most important criteria affecting prioritization of potential fields to implement smart well technology and their weights were investigated [4].In this paper we applied this technique for prioritizing four Iran fields to apply smart well technology. In fact we presented second matrix of AHP in which alternatives (fields) are compared pair-wise based on criteria or sub criteria. The novelty of this work is proposing the way to acquire fields' expert opinions for second matrix, the way to ask questions from fields' expert and the way to find the effect of on selection of one field in comparison with other ones.

In previous publication we mentioned that in our belief there are two methods to do Selection phase; one is Multi Criteria Decision Making (MCDM) and another one is modeling and simulation of smart well and economic evaluation for all fields. It is well known that performing later method is costly and time consuming. Therefore as a result MCDM, specifically AHP was taken into account. This method is fast, very much less costly and less accurate than modeling and simulation method. However; it helps investigation of other aspects of the fields such as geographical and environmental issues rather than only recovery and sensitivity.

3. Methodology

Multi Criteria Decision Making (MCDM) is a general term for a set of decision making tools. It is divided into two categories as Multiple Objective Decision Making (MODM) and Multiple Attribute Decision Making (MADM); both of them have several methods. The Analytic Hierarchy Process (AHP) is under MADM which is a structured technique for dealing with complex decisions.

AHP has two sets of matrices; first set of matrices is created from comparison of criteria and sub criteria in terms of decision goal and second set of matrices is created from comparison of alternatives based on each criteria and sub-criteria in the last level of decision tree. The final result (prioritization) of AHP is from summation of multiplication of weight of each criterion to weight of each alternative with respect to that criterion. The comparisons are performed based on Table 1 constructed by Thomas L. Saaty. Range of pair comparison is between 1/9 and 9 [5].

Table 1: Degree of importance in pair comparison

Quality of Importance	Quantity of Importance
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
In between	2, 4, 6, 8

Saaty devised the following procedure for the AHP process:

- Definition of the objective;
- Development of the hierarchy from the top (the objective from a general viewpoint) through the intermediate levels (judgment criteria) to the lowest level (the list of alternatives);
- Implementation of the pair-wise comparison among the criteria and alternatives
- Consistency evaluation
- Derivation of the global ranking among the alternatives

The following matrices present a mathematical description of the procedure.
If C= $\{C_i|i= 1, 2, \ldots, n\}$ the results of the pair-wise comparisons among the criteria, could be described in the form an (n x n) matrix, where a_{ij} indicates the relative weights of the i^{th} and j^{th} elements of C.

$$\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$$

The relative weights are determined by the eigenvector that corresponds to the largest eigenvalue, λ_{max},

$A_w = \lambda_{max} w$ Equation 1

If the comparison process is absolutely consistent, $\lambda_{max}=n$, the weights can be obtained by normalizing any of the rows or columns of A. Otherwise, the consistency level needs to be calculated before any conclusions which can be made on the final weights. Consistency Ratio, CR, the measurement of consistency for the comparison matrix is defined as:

$CR = CI/RI$ Equation 2

Where $CI = (\lambda_{max}-1) / (n-1)$, and RI is the Random Index. If $CR<0.1$, AHP yields reliable results. Otherwise, one needs to implement a series of iterative calculations, in order to validate the results [6].

In previous the publication we presented the first matrix to identify the weights of criteria and sub-criteria. The final result is summarized in Table 2 [4].

As previously mentioned, based on the procedure of Analytic Hierarchy Process all aforementioned criteria should be compared to one another in pairs. By then; all fields should be compared to one another in pairs with respect to each sub criteria placed in the last level. It is important to note that this prioritization is not a verdict. Strategic policies of company may change the made decision which not to follow this priority. These policies include financial limitation, managers' opinion and etc.

4. Pair Comparison between Alternatives (Fields) (Second Matrix)

For the second step it is imperative that fields' experts compare the fields (alternatives) in pairs based on the last level of each criterion. Here the last level includes CAPEX, OPEX, Revenue, Heterogeneity, Type of drilled wells, Remaining field life, Layering, Completion distance to water oil contact, Aquifer strength, Completion distance to gas oil contact, Gas Cap Pressure, Geographical Factor and Environmental Factor. For this step there are four fields named CH, S, M and DE. Table 1 is used for pair comparison of the fields.

Experts should answer the following question to be able to easy comparison of the fields. This is true for other criteria as well.

Question: **which field has more CAPEX and in what quantity; field M or DE? For easy comparison; the number of current wells and future wells in conventional production scenario should be taken into consideration.**

Table 2: The weight of smart well prioritization parameters based on pair comparison (First Matrix)

Goal	Criteria	Weight	Sub-Criteria	Weight
Smart Well Prioritization	Economical Factor	55.1	CAPEX	13.3
			OPEX	6
			Revenue	35.9
	Environmental Factor	7	No Sub-Criteria	
	Geographical Factor	10		
	Technical Factor	27.9	Heterogeneity	10
			Type of Drilled Wells	5.9
			Remaining field life	4.1
			Layering	3.2
			Aquifer Strength	1.2
			CDTWOC*	1.3
			CDTGOC**	1.1
			Gas Cap Pressure	1

* Completion Distance to Water Oil Contact
** Completion Distance to Gas Oil Contact

In this step; the comparison of the fields based on criteria in the last level of decision tree is performed. Figure 1 shows issues to be considered for the comparison of the fields. The output of comparisons is the weight of each field with respect to each criterion that pair comparison is based on.

Criteria in Last Level of Decision Tree	Issues to be considered for comparison of the fields
CAPEX	• The number of current wells and wells in the scenario of conventional production for future drilling • More wells in the scenario; more importance
OPEX	• The number of intervention for workover • The number of well testing operation • More OPEX; more importance
Revenue	• Remaining oil in the reservoir • More revenue; more importance
Environmental Factors	• Susceptibility of field from environmental sanitation standpoint (water dumping and gas injection into below layers) • Lessen the production of unwanted fluids • Fields with the worst conditions has more quantity o importance
Heterogeneity	• Fracture distribution (macro fracture, micro fracture, fracture intensity) • Porosity and permeability distribution • More heterogeneity; more importance
Remaining field life	• The more remaining field life; more importance
Type of drilled wells	• The number of wells • Type of wells (vertical, horizontal, deviated and multi lateral) • The more non- vertical wells; more importance
Layering	• The number of layers • The number of producing interval in the plan • The more layers; more importance
Completion distance to WOC (abbreviated by CDWOC)	• Less CDWOC; more importance
Completion distance to GOC (abbreviated by CDTGOC)	• Less CDTGOC; more importance • The combination of the results of this criterion with that of CDWOC will give the thickness of oil zone. i.e instead of comparing the fields based on thickness of oil zone; we perform the above comparison.
Aquifer strength	• Aquifer size • Productivity index of aquifer • The more aquifer strength; more importance
Gas Cap Pressure	• The more gas cap pressure; more importance • In the case of equal gas cap pressures; gas volume of gas caps is considered.
Geographical Factor	• Climate • Safety (from points of explosion, exposure to wild animals, accident and etc) • Offshore and onshore oil fields, near and far fields, accessible and inaccessible fields should be considered • Fields with the worst conditions has more quantity of importance

Figure 1: Issues to be considered for comparisons of fields

Figure 2 shows the comparison of the fields based on aforementioned criteria.

CAPEX	M	DE	CH	S
M		1/2	1/3	1
DE			1/2	2
CH				3
S				

OPEX	M	DE	CH	S
M		1/4	1/2	1
DE			2	4
CH				2
S				

Revenue	M	DE	CH	S
M		1/2	1/4	1
DE			1/2	2
CH				4
S				

Environmental Factors	M	DE	CH	S
M		3	3	1
DE			1	1/3
CH				1/3
S				

Heterogeneity	M	DE	CH	S
M		7	5	1
DE			1/3	1/7
CH				1/5
S				

Remaining field life	M	DE	CH	S
M		½	1/4	1
DE			1/2	2
CH				4
S				

Type of drilled wells	M	DE	CH	S
M		½	1/4	3
DE			1/2	5
CH				7
S				

Layering	M	DE	CH	S
M		1/6	1/6	1
DE			1	6
CH				6
S				

CDTGOC	M	DE	CH	S
M		7	9	4
DE			2	1/3
CH				1/4
S				

CDWOC	M	DE	CH	S
M		5	4	2
DE			1/2	1/3
CH				1/2
S				

Aquifer strength	M	DE	CH	S
M		½	1/7	1/5
DE			1/5	1/2
CH				3
S				

Gas Cap Pressure	M	DE	CH	S
M		7	9	2
DE			2	1/5
CH				1/7
S				

Geographical Factor	M	DE	CH	S
M		2	6	1
DE			4	1/2
CH				1/6
S				

Figure 2: Comparison of the fields based on parameters in the last level of decision tree

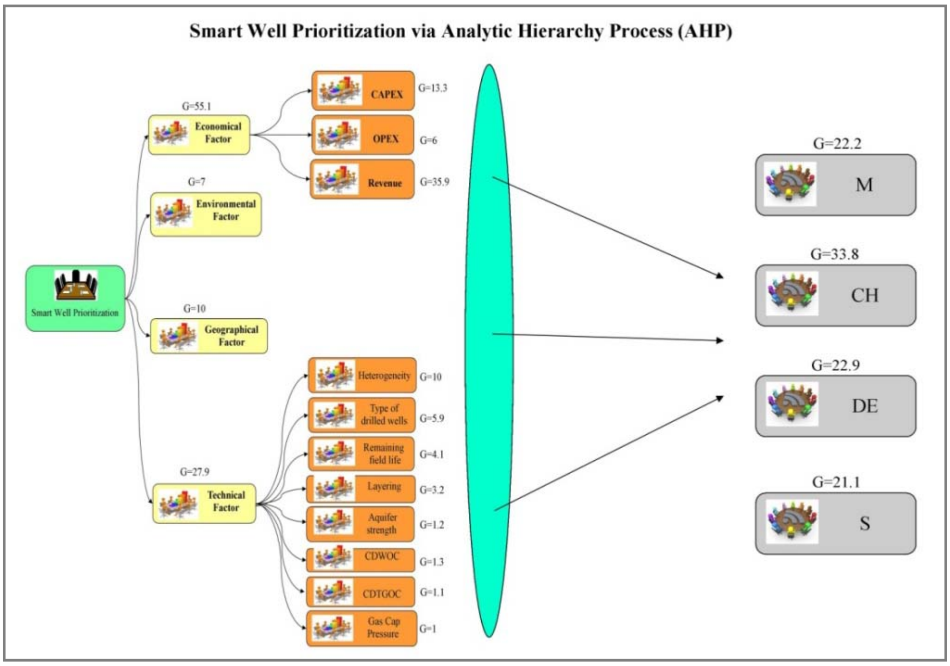


Figure 3: The combination of the results of first and second steps of AHP process

The prioritization of the S, M, DE and CH fields is concluded from the combination of the results of first step (weight of each criterion) and second step (previously mentioned) of AHP process. The final result is illustrated in Figure 3.

As the figure shows CH field with the final weight of 33.8 % is placed in the first rank for detailed study as smart well. As previously stated this prioritization is only for knowing more potential field for smart well implementation. It is obvious that after this phase it is needed to investigate the field from technical (simulation and modeling and production scenario) and economical point of view. If CH is not viable technically and economically then we will go for second rank field which is DE. Figure 4 illustrates graphical view of weights of the fields.

5. Sensitivity analysis of the results

Sensitivity Analysis is a technique for systematically changing the values of criteria in a model to determine the effects of such changes. In more general terms uncertainty and sensitivity analysis investigate the robustness of a study when the study includes some form of mathematical modeling. All results of this section are presented in Figure 5.

Sensitivity analysis with respect to criteria in the first level

Economical Factor

Since the prioritization of the fields for smart well study is very important; robustness of the results is vital. To achieve above mentioned goal we have to investigate the changes in the prioritization with respect to changes in the judgments. Figure 5 shows that with 24 % change in economical factor meaning from 55.2 to 31.2 % the M field is ranked at top in place of CH. However; this amount of change in the judgment is impossible due to the nature of the problem. It is noted that the rank of other fields may change.

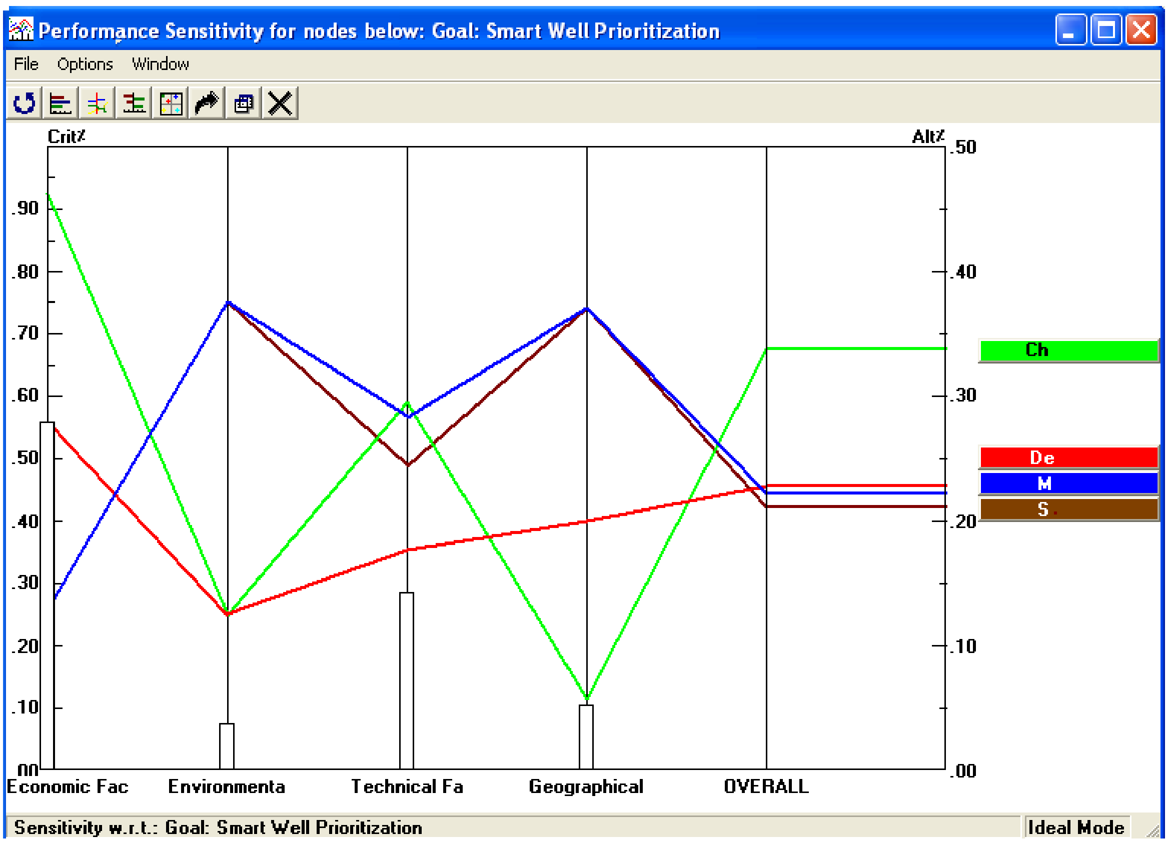
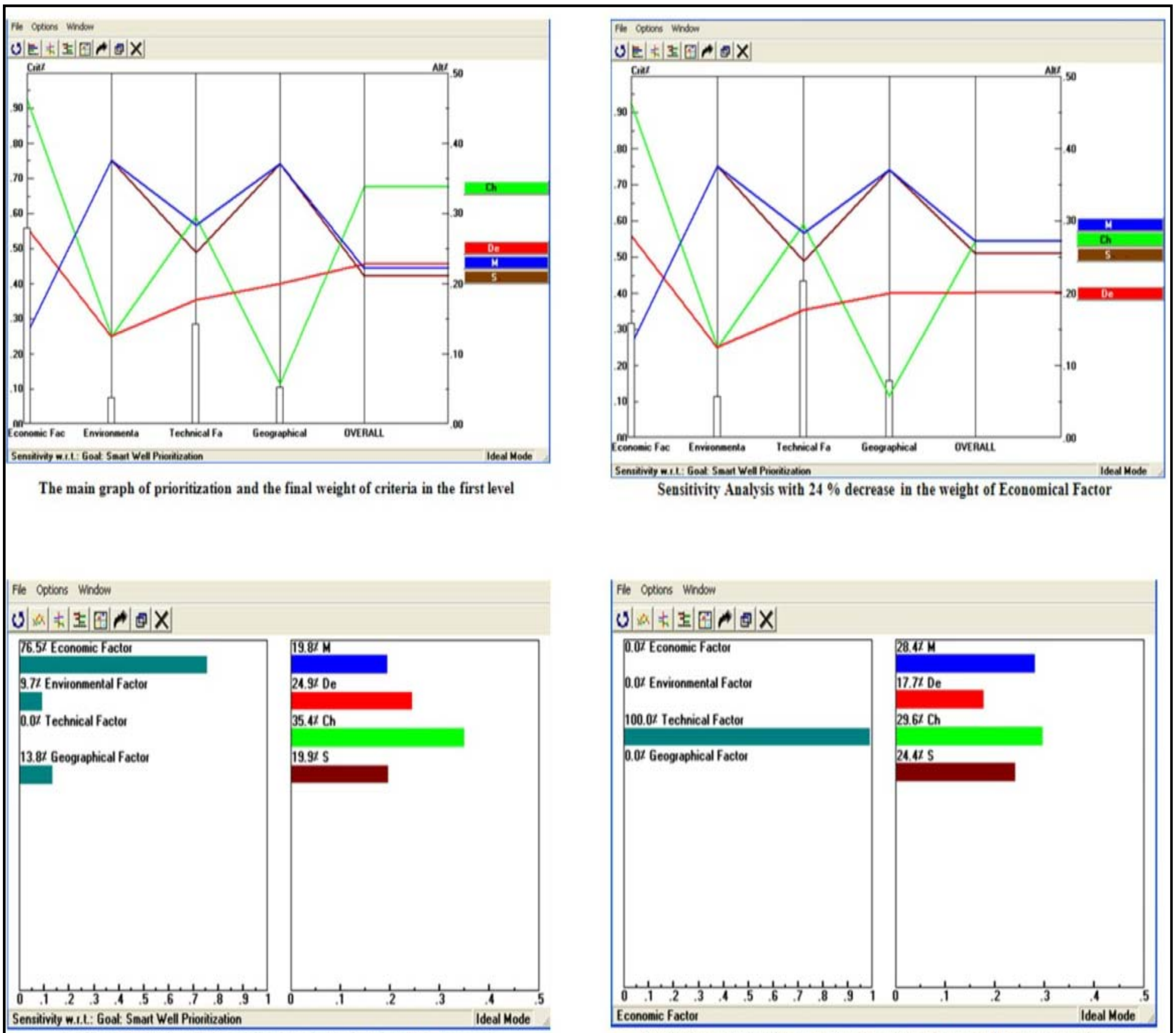


Figure 4: The main graph of prioritization and the final weight of criteria in the first level



The main graph of prioritization and the final weight of criteria in the first level

Sensitivity Analysis with 24 % decrease in the weight of Economical Factor

Sensitivity Analysis with decreasing the weight of Technical Factor to zero

Sensitivity Analysis with increasing the weight of Technical Factor to 100 %

Sensitivity of the prioritization to the changes in the weight of sub-criteria

Sensitivity Analysis over subcriteria of Economical Factor			
Sub-criteria	Interval of changes in local weight (%)	First priority	Remark
CAPEX	0 to 100	CH	
OPEX	0 to 54.5	CH	After 54.5% DE becomes first priority
Revenue	0 to 100	CH	
Sensitivity Analysis over sub-criteria of Technical Factor			
Heterogeneity	0 to 100	CH	
Remaining field life	0 to 100	CH	
Type of drilled wells	0 to 100	CH	
Layering	0 to 100	CH	
CDWOC	0 to 100	CH	
CDTGOC	0 to 96.4	CH	After 96.4% M becomes first priority
Aquifer strength	0 to 100	CH	
Gas Cap Pressure	0 to 96.7	CH	After 96.7% M becomes first priority

Figure 5: Sensitivity Analysis of the results of smart well prioritization

Technical factor

Due to the nature of this special problem for these four fields the results of prioritization is not sensitive to the technical factor. Figure 5 shows that with 0 to 100 % change in the weight of Technical Factor no change has occurred in the prioritization.

Geographical and environmental factors

The results of these sensitivity analyses are; for 7 to 36.2 % change in the weight of Environmental Factor the M field is placed at top. M Field is also ranked first by changing the weight of Geographical Factor from 10 to 34.5. This amount of change for these two criteria is impossible.

Sensitivity analysis with respect to sub-criteria in the second level

Figure 5 shows the results of sensitivity analysis by changing the weight of sub-criteria. Before doing sensitivity analysis the CH field was ranked at top. As the figure 5 shows the reliability of the result of this study can be proved. Moreover for detailed study it is eligible to put the CH field into further study as modeling and simulation and economic evaluation of smart well implementation.

Conclusion

In this paper we applied a novel screening technique under Analytical Hierarchy Process (AHP) engine over four fields. It is helpful to alleviate economic concern of smart well justification over several fields by prioritizing of the fields. In fact; selection of one field among several fields for further studies (modeling and simulation) of smart well implementation becomes easy. Moreover; after prioritization phase it is needed to investigate the field from technical (simulation and modeling and production scenario) and economical point of view. Maybe selected field is not viable technically and economically then we go for second rank field and so on.

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