Decision-Making Process for Soroosh Oil Field in National Iranian Oil Company (NIOC)

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Abstract

Decision making in petroleum reservoir management is becoming increasingly complex due to the large number of alternatives and multiple conflicting goals and a suitable decision-making model is the cornerstone for the efficiency of reservoir management. Traditional reservoir management process which is mentioned in many papers and books has been implemented in NIOC for many years, but we tried to test the new process in one of this company oil field. In this paper a decision-making model based on the CCSM (Continue Creative Strategic Management) process which takes into account PDMA (Plan, Do, Measure, Analyze) cycles, was proposed for Soroosh oil field in Iran. In this process two different approaches for Soroosh heavy oil field, EOR (Enhance Oil Recovery), Upgrading heavy oil, are analyzed. Also analytical hierarchy process (AHP), which uses pairwise comparisons with numerical judgments, was applied for ranking the objectives. The result verified that with this strategic decision model, we can find the suitable strategy for reservoir management.

Keywords
Reservoir Management strategy, Reservoir management, CCSM

1. Introduction
Heavy oil is one type of crude oil with high viscosity, meaning that it flows with some difficulty. It is called heavy because it has heavier molecular composition than light crude oil and, therefore, they have higher density and specific gravity. With today's increasing demand for energy resources, heavy-oil reservoirs are become one of the most important parts of reservoirs in worldwide for the next two decades (Anonymous, 2007& Marilyn, 2009.) Iran is also endowed the heavy oil reservoirs so heavy-oil reservoirs are one of the most important parts of reservoirs in Iran, and effective management of heavy oil reservoirs in Iran with the multiple objectives can be a complex affair. There are two approaches for dealing with heavy oil reservoirs, EOR methods or upgrading heavy oils. The recovery techniques for heavy oil basically occur in three stages. First primary then secondary. After primary and secondary recoveries, an estimated 60-80% of original oil in place (OOIP) remains trapped in the pores of the reservoir due to viscous and capillary forces. Therefore, numerous EOR have been studied to produce this oil, essentially focusing on two things: reducing oil viscosity for easy flow, or literally squeezing oil through the pores of the rock. The different tertiary recovery methods for heavy oil are thermal methods, gas injection, water flooding and chemical methods.

Nowadays, with the depletion of conventional light crude oils and more availability of the unconventional ones and growth of oil demand in 2013 in average of 90.6 million b/d compared with 89.9 million b/d last year, made researchers focusing more attention on developing suitable technologies for upgrading heavy oil and improving the crude oil quality, meanwhile environmental issues.(Conglin & Laura, 2013) ;(Nares, Schacht, Ramirez, Cabrera, & Noe, 2007) In modern refineries the major upgrading technologies can be divided in two general routes (a) carbon rejection and (b) hydrogen addition according to some authors. (Joshi et al., 2008). The first category is a thermal type of processing in which carbon is massively produced, separated from the liquid hydrocarbons, with no incorporation of hydrogen. Carbon rejection processes embrace: thermal cracking, such as coking, and residue fluid catalytic cracking (Gray, 1994);(Speight. J. G., 2004). The second route, generally known as hydroprocessing, is a type of process in which a catalyst is employed in the presence of elevated hydrogen pressures in order to: a) promote the incorporation of hydrogen into the hydrocarbon matrix; b) remove heteroatoms (sulfur, nitrogen, oxygen, etc.); c) reduce the amount of coke formed during the upgrading process; and accordingly, d) increase the marketing value of the crude oil. (Billon & Bigeard, 2001); (Dufresne, Bigeard, & Billon, 1987; Speight. J. G., 2004) . For heavy oils and bitumen, the main drawback of carbon rejection processing is the high amount of low value material, coke that is generated because heavy oils and bitumen usually contain about 50 wt% of residue fraction, a fraction that boils at temperatures higher than 545 ºC (Altgelt, 1994). More recently the increased production of heavy oils has turned carbon rejection processes (typically the refiner‟s first choice for conventional oils) as unsustainable technologies mainly due to more stringent environmental regulations. Consequently, hydroprocessing is becoming the best option to avoid coke formation in the upgrading of heavy fractions (Ancheyta & Speight, 2007). Other way to classify these technologies is by the presence or absence of a catalyst (Kovac, Movik , & Elliot, 2006; Rana, Sámano, Ancheyta, & Diaz, 2007) . Both classifications are quite similar; fig 1 presents a summary of those. All these processes have good features for specific applications.

So for improving the stability of strategy for heavy oil reservoirs in Iran, we commit to a comprehensive reservoir management decision-making model base on the CCSM (Continue Creative Strategic Management) process which takes into account PDMA (Plan, Do, Measure, Analyze) cycles. PDCA was designed to begin the process of planning to do something, executing the process to do it, verifying whether the process is meeting requirements, and acting upon those requirements to maintain an acceptable performance level (Gupta, 2006). The concept of PDCA originated from the scientific method of "inductive learning" based on Francis Bacon's theory of hypothesis "to plan", experiment "to do" and evaluation "to check"(Moen & Norman, 2010). During the plan phase, a change or test aimed at improvement is initiated(Moen & Norman, 2010). An evaluation takes place to identify the outcome and to monitor those components. During the Do phase of the process, changes or tests are carried out. In the check phase, the results are examined, evaluated, and measured. The Act phase determines the levels of efficiency that occurred during the planning of setting up teams, the doing of developing the goals and objectives, and the checking of how those measures were met against necessary corrective actions.

Fig 2 shows the indigenous CCSM model for NIOC. CCSM is based on a stripped-down PDMA (plan, do, measure, analyze) continuous improvement loop, with focus on the planning phase. The philosophy behind this model is that during the concept phase many ideas will be generated and value judgments must first be made to narrow the field to a manageable number. Then creative thinking must be used to investigate each of the best ideas in more detail. This process should move up and down in all the levels in company until specifications, concepts and detail are all matched.(Munive-Hernandez., 2004)

2. Field characteristic

Viscosity of Soroosh is about 172 cSt at 50 °C which makes this crude more viscous than conventional oil. API of Soroosh is 18.3(It is heavier than conventional crude). Black product content in Soroosh is high, atmospheric residue yield (370°C+) is 68.8 %wt. Sulphur content of Soroosh is 3.8 wt percent. Soroosh contains 123 ppm vanadium and about 32 ppm nickel. As we know acidity is an important characteristic of the crude oil. It is relating to the content of naphthenic acid. It is measured with the Total Acid Number (TAN) in mg of KOH/ g of crude. “Normal” crude have TAN lower than 0.5. Higher TAN crudes need specific precautions to avoid corrosion in processing facilities. TAN number of Soroosh in the crude assay is 0.29. The oil pay is a sand stone reservoir is not supported by an active aquifer. The rock and fluid characteristics in the heavy oil belt vary gradually from north to south. On this basis it has been divided to northern, central and southern areas even though it is a single contiguous belt.

3. Background of NIOC and process of strategy making for reservoir management

Petroleum has played an important role in the political and economic development of Iran. It has been the major source of government income and is important as a strategic commodity for industrial nations so effective petroleum reservoir management and successful strategies is essential for economic development in Iran. Iranian National Oil Company (NIOC), the governmental company, controls and handles the oil industries (upstream & downstream) exclusively. It has some subsidiaries that run the petroleum industry functions. The upstream subsidiaries are:

Exploration Directorate Company (DE) is responsible for exploration the oil fields and data gathering for Operational Company. The operational companies, operate the oil fields where related to their boundary, for example the National Iranian South Oil Company (NISOC) operates the south oil fields in Iran, and responsible for preserving the reservoirs. The service companies that are responsible for exploiting oil by drilling the wells, monitoring, controlling and all services that the operational companies need for exploiting oil. Fig 3 presents the NIOC organizational structure.

4. Model for decision making process

4.1. First phase: establishing main strategic objectives and performance targets

Series of meeting were organized with reservoir management team (fig 4) for determining the expert opinions on hierarchical model. The professional members who were involved in the meeting were selected from reservoir engineers, drilling engineers, economist, environmentalists and lawyers in NIOC and AmirKabir University of Technology(Plewa et al., 2013). Consequently, the ongoing researches of academicians and the industry expectations were bring together in order to reach tangible results with higher utility. Distribution of the numbers of participants on relevant expert groups is illustrated in Table 1. The judgments of the experts on each of the pair wise comparisons were determined after long-run discussions to ensure the different points of view as final group decisions in a consensus. Therefore, it is eagerly expected to obtain results with higher consistency.(Ozgur, 2012).

The reservoir management team determined the goals by using a two-step process. First, a list of reservoir management goals with their definitions was compiled by combining information from the previous study and interviews of some another specialist in NIOC and other petroleum universities in Iran. This list was then incorporated into a mail out survey sent to selected members of the all specialists that influence the Soroosh heavy oil reservoir in Iran for their comments. The revised list of identified reservoir management goals and sub-goals was then arranged into a decision tree using the Analytical Hierarchy Process (AHP). The initial tree was tested and refined by reservoir management team for feedback. Fig. 5 shows the final AHP tree. Since the two alternatives were determined by team due to. At the top of the tree is the overall goal of reservoir management. Four criteria were identified as essential for achieving the overall goal: economic; environment; political and technological factors. There are five main economic considerations, which are operation expenses; oil and gas price; POT, NPV and IRR. The operation expenses category is further broken down into OPEX; CAPEX and personnel(Castillo. & Dorao., 2013). Oil and gas price is determined to understand that the alternatives are valuable.

4.2. Second phase: Do

Alternatives: EOR methods, upgrading methods

4.2.1 EOR methods

Ahmad Al(Ahmad Al Adasani & Baojun Bai, 2011) reported the data base based on The Oil and Gas Journal from 2009 to 2010 and SPE the EOR projects in the world (table 2). Also he worked on the relationship between formation type and EOR methods, and it was found that in most of the sandstone formation, the thermal method was implemented.

Prediction of reservoir performance for EOR scenarios

The history matched reservoir simulation model has been used to predict the future performance of soroosh reservoir up to 2027. Assumptions have been made as to the well controls and field constraints for field. Various development scenarios have been investigated and combined with certain reservoir management aims to obtain an optimal development plan. The model has been further utilized to analyze the sensitivity of the optimal development plan to the perceived reservoir and production uncertainties within the soroosh. Also soroosh sandstone sample was used as rock samples in this study to analyze the different EOR methods.

Ranking of EOR processes.

We used the Software-based E.O.R Screening (Select EOR) for:

1- First, to screen for technical feasibility based on reservoir parameters; While average reservoir parameters were considered, the heterogeneity of reservoir was taken into account in a statistical mode (statistical heterogeneity, as expressed by Dykstra-Parsons heterogeneity factor).
2- Then, for the EOR processes that pass through the technical screening, a comparison of projected performance was made
3- Due to some tested and software the thermal steam was selected for development method

4.2.2 Upgrading methods

In table 3 the upgrading methods can be found. ARAMIS is software for simulation the main properties of the heavy crude and upgraded crudes via all of the upgraded technologies(A. Akhavan, ., Jabbari, & Hamdi, 2013), the main properties of heavy crudes and upgraded crudes via all upgrading methods are illustrated in table 4 & 5

4.3. Third phase: measurement

Due to ranking the objectives with AHP method in reservoir management team Economic factor was the most important issue for soroosh reservoir.

4.3.1 EOR economical estimation(A.Y. Zekri & K.K. Jerbi, 2002)

In table 6, we summarized the cost elements and the total amount of them for EOR method

4.3.2 Upgrading heavy oil

a)Eq 1: MVC Concerned[1] crude = MVC Reference crude

b) Eq 2: MVC= GPWC-VCC-(FOBP+FCC)

c)Eq 3: FOBP[2] Concerned crude = GPWC[3] – VCC[4] –FCC[5] – (GBWRC[6] – VCRC[7] – FCRC[8] – FOBP Reference crude)

d) Second: choose market for sale the upgraded oil

e) Set of prices

I- Products

Natural Gas Price

Eq 4: Natural Gas Price ($/t)= LSFO[9] Price ($/t)(NG[10] LHV[11] / LSFO LHV)*

Products Prices

1- North West Europe (NWE) and South China for Propane and Butane("http://www.argusmedia.com," 2007-2011)
2- Methyl tert-butyl ether (MTBE), Gasoline, Kerosene, Gasoil and Fuel Oil products("Monthly Oilgram Price Reports of Platts," 2007-2011)
3- Gasoil 350 ppm China:

Eq 5

$$\text{Gasoil 350ppm (\$/t)= Gasoil 500ppm (\$/t)} + \frac{\text{Gasoil 50ppm-Gasoil 500ppm}}{3} - \text{Singapour China transport}$$

*Gasoil

500ppm and Gasoil 50 ppm .

4- LSFO1% China: data for HSFO China("Monthly Oilgram Price Reports of Platts," 2007-2011), and the delta constant "NWE LSFO-NWE HSFO" were available, thus

Eq 6: *LSFO LSFO 1% China = HSFO China + (NWE LSFO-NWE HSFO) delta price constant*

5- Coke and Sulphur: The same methodology was used as for upgrader coke and sulphur price, then high sulphur coke price was evaluated at 20% of FOB HSFO price and sulphur price is fixed at 50 $/t.

II-Transport cost

f) Upgrader price structure

The structure of price for upgrading crude was based on historical data. ("Monthly Oilgram Price Reports of Platts," 2007-2011)

1- Propane and Butane: FOB Persian Gulf (PG) in the Argus LPG World. ("http://www.argusmedia.com," 2007-2011)
2- High sulphur coke price was evaluated at 20% of FOB HSFO PG price. Before 2007s, price of sulphur was stable (between 20$/t and 100$/t).In 2009, this price increased significantly (average price was 300

[1] MVC(($/bbl)= Margin after Variable Costs , Concerned crude: is either raw crude (Soroosh crude) or lighter crude (upgraded crude)

2 Free Of Board Price

3 GPWC: Gross Product Worth on concerned Crude

4 VCC: Variable Costs on concerned Crude

5 FCC: Freight Cost of concerned Crude

6 GPWRC: Gross Product Worth on Reference Crude

7 VCRC: Variable Costs on Reference Crude

8 FCRC: Freight Cost of Reference Crude

[9] LSFO: Low Sulphur Fuel oil

[10] NG: Natural Gas

[11] LHV: Low Heating Value

$/t in 2009) and now sulphur price comes back to a "normal" price. So for accuracy of economic calculations, we fixed the sulphur price at50 $/t.

3- Natural Gas price has been calculated by following formula:

Eq 7: *Natural Gas ($/MBtu[12]) = 0.124 * Crude ($/bbl) -0.66*

4.4. Forth: analyzes

4.4.1 The results of economic analyses for EOR soroosh field development show that IRR is more than 100%

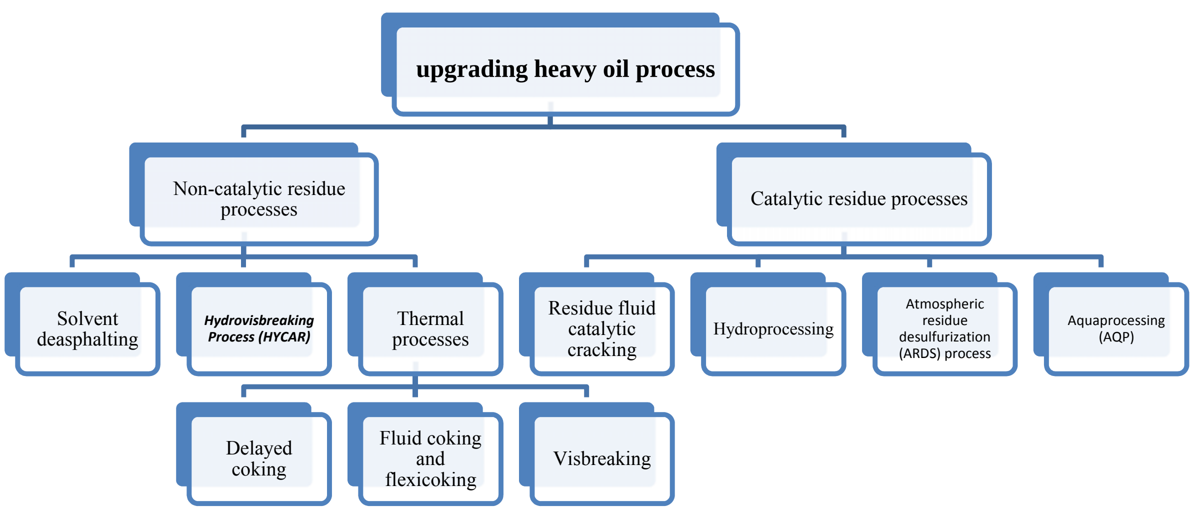
4.4.2 Economic results of upgrading heavy oil

The economic results for upgrading Soroosh heavy oil are presented in table 7 & 8

Conclusion

In this study, new method for decision making process in NIOD was tested to choose two approaches for Soroosh heavy oil field; one of them is development the field through the EOR methods or upgraded the heavy oil and finds the customer for it. In new process first the reservoir management team, ranking the economical, technological, political and environmental objectives with AHP method. In this process economical factor was selected as a most interest objectives, then the technical analysis based on history data and two software (ARAMIS & SelectEOR) were made and the thermal method as EOR and slurry hydro-cracking+ SDA showed the better results, in next step economic analysis of these two methods shows that IRR for EOR thermal method is more that 100% but for upgrading is around 12%, it is clear that the developing oil field via EOR method is most beneficial. Suitable strategy was made through the new model and the feasibility of model was approved.

Figure 1 Classification of residue upgrading processes(Rana et al., 2007)



12 MBtu: Million of British thermal unit

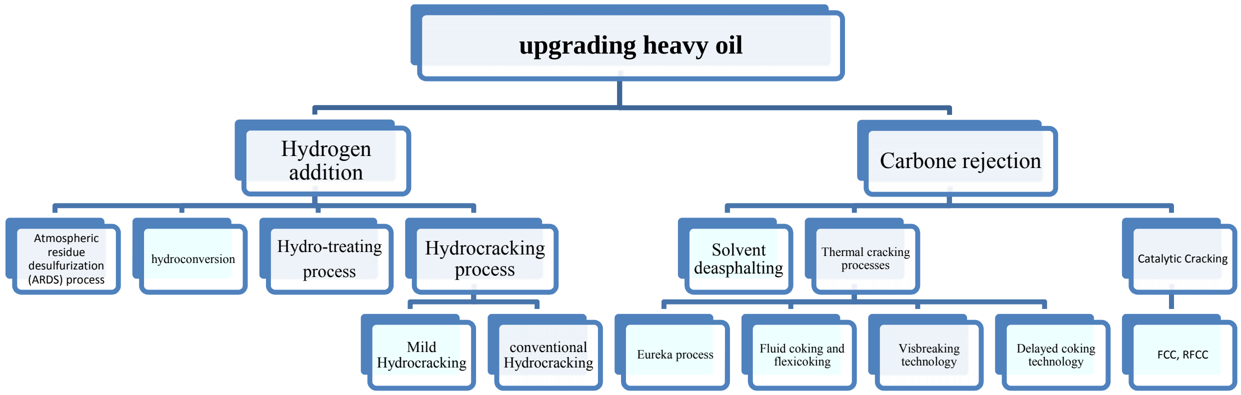


Fig 2. Indigenous CCSM structure for strategy making in reservoir management process in NIOC

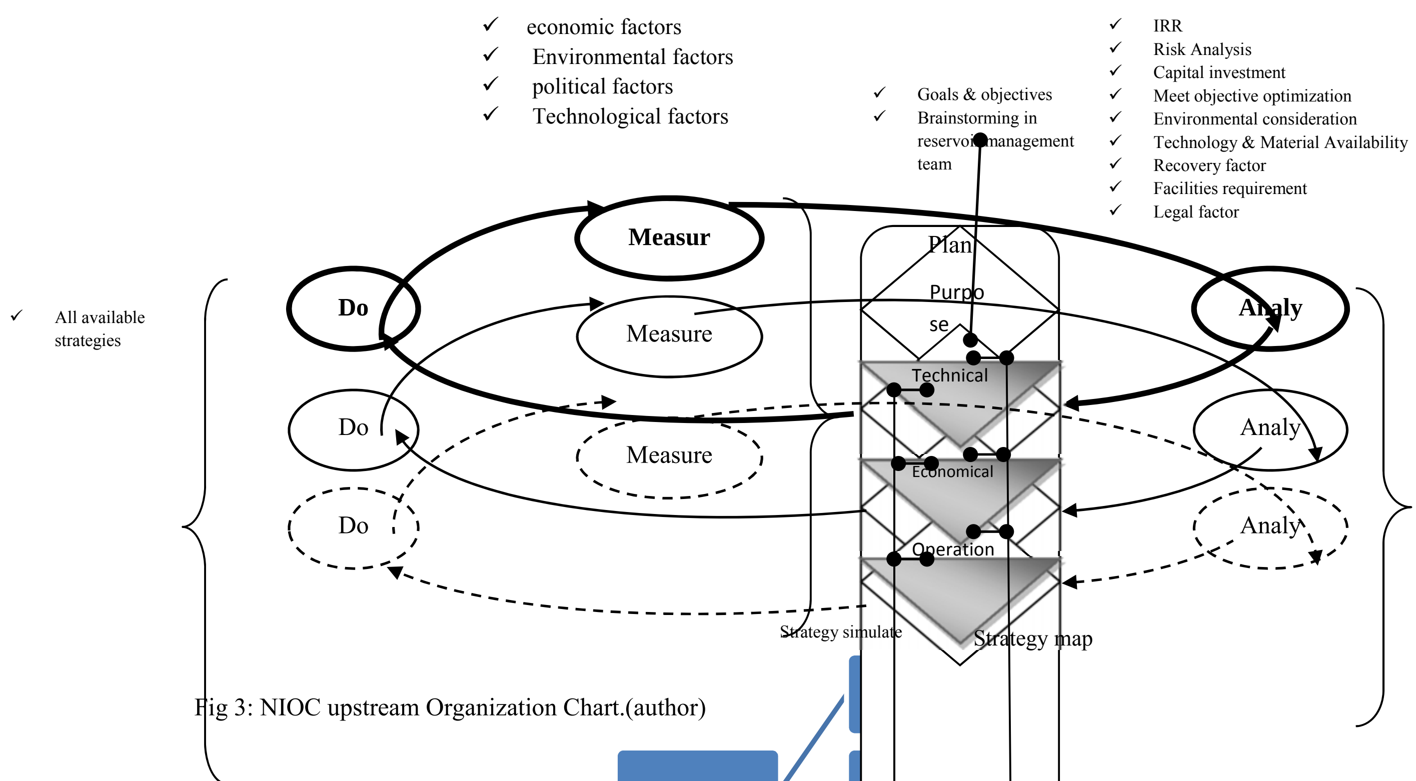


Fig 3: NIOC upstream Organization Chart.(author)

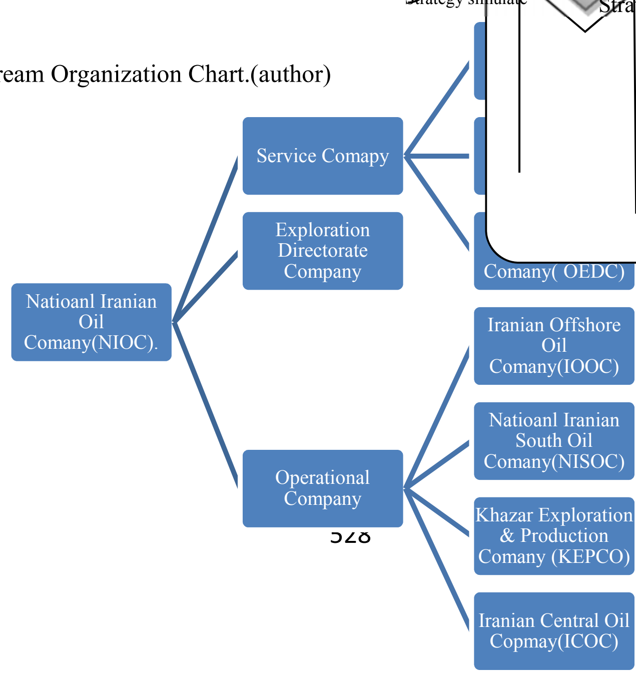


Fig 4: Reservoir Management team (A. N. Akhavan, Hamdi, & Jabbari, 2011)

Fig 5: AHP tree- Iranian EOR heavy oil reservoir objectives(A. N. Akhavan et al., 2011)

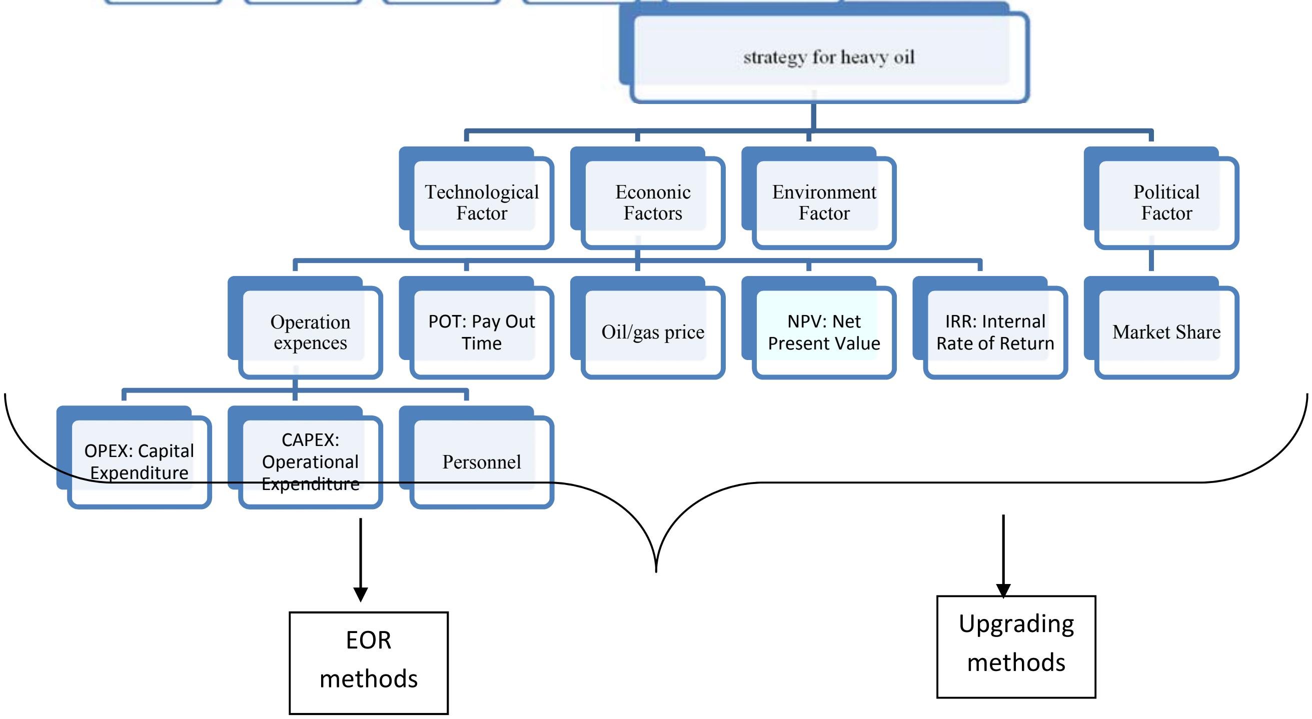


Table1: Distribution of expert groups in meeting

Expert group	Number of participation
From university	12
From NIOC	16
Total	28

Table 2: EOR methods and share in world petroleum projects

EOR methods	Share in world petroleum project
Thermal stream	42%
Thermal-Combustion	4%
Thermal-Hot water	2%
Gas Misicible	35%
Gas Immisicible	6%
Chem-Polymer	8%
Chem-ASP	3%

Table 3: Upgrading methods based on carbon rejection & hydrogen addition

Carbon rejection	
C1	Coking
C2	Coker, Hydrocracker
C3	Coker, Mild Hydrocracker
C4	Cocker with dilution
C5	Coker, Hydrocracker with dilution
C6	Coker, Mild Hydrocracker with dilution
Hydrogen addition	
EB1	Ebullated-bed,
EB2	Ebullated Bed, Hydrocracker
EB3	Ebullated Bed, Mild Hydrocracker
EB4	Ebullated Bed, Mild Hydrocracker with dilution
EST1	Slurry Reactor + C4 SDA
EST2	Slurry Reactor + C5 SDA
EST3	Slurry Reactor + C4 SDA + Hydrocracker
EST4	Slurry Reactor + C5 SDA + Hydrocracker
EST5	Slurry Reactor + C4 SDA + Mild Hydrocracker
EST6	Slurry Reactor + C5 SDA + Mild Hydrocracker

Table 4: main properties of the heavy crudes and upgraded crudes

Scheme		**Soorosh**	**C1**	**EB1**	**C2**	**EB2**	**C3**	**EB3**	**C4**	**C5**	**EB4**	**C6**
Production	BPSD	50,000	43,873	51,070	46,074	54,332	44,179	51,598	45,527	79,401	73,212	56,648
Production	Kt/y	2628	2106	2542	2073	2534	2073	2509	2193	3824	3526	2728
API		18.3	32.6	26.7	43.6	37.4	36.3	30.4	32.0	32.0	32.0	32.0
Sulphur content	%wt	3.76	2.07	1.68	0.70	0.73	0.73	0.75	2.13	2.11	1.58	1.46
TAN	mg KOH/g	0.29	0.24	0.20	0.09	0.07	0.09	0.07	0.24	0.18	0.13	0.14

Table 5: main properties of the heavy crudes and upgraded crudes

Scheme		**Soorosh**	EST1	EST2	EST3	EST4	EST5	EST6
Production	BPSD	50,000	51870	51757	55812	55313	52598	52370
Production	Kt/y	2628	2519	2523	2508	2514	2493	2489
API		18.3	30.6	43.8	43.8	41.8	34.7	34.2
Sulphur content	%wt	3.76	1.32	0.30	0.30	0.39	0.25	0.041
TAN	mg KOH/g	0.29	0.20	0.08	0.08	0.08	0.08	0.08

Table 6: Cost elements of EOR thermal project (Statistical Study of soroosh oil field in 2007- 2011)

COST ELEMENTS	M$	Total (M$)
Initial investment (fixed cost)		3504
Offshore units	1640	
Drilling and completion	944	
Unexpected cost	520	
Other cost	400	
Normal operating and maintenance costs/ year		496
Field study, engineering, and supervision	48	
Maintenance	160	
Injection equipment	96	
transfer	80	
personnel	32	
Unexpected cost	80	

Table 7: Economic result of Soroosh crude

Scheme		C1	EB1	C2	EB2	C3	EB3	C4	C5	EB4	C6
Investment	M$	1259	1284	1674	1675	1581	1597	1259	1674	1675	1581
Cash margin	M$/a	126	163	156	191	137	178	127	163	205	143
POT	a	10.0	7.9	10.7	8.8	11.5	9.0	9.9	10.3	8.2	11.1
IRR		7.9%	10.2%	7.3%	9.2%	6.7%	9.0%	8.0%	7.7%	9.9%	7.0%
NPV at 10%	M$	-185	22	-317	-99	-362	-118	-177	-272	-15	-327

Table 8: Economic result of Soroosh crude

Scheme		EST1	EST2	EST3	EST4	EST5	EST6
Investment	M$	1609	1569	2096	2005	1964	1900
Cash margin	M$/a	256	241	303	277	282	265
POT	a	6.3	6.5	6.9	7.2	7.0	7.2
IRR		12.7%	12.3%	11.7%	11.1%	11.6%	11.2%
NPV at 10%	M$	345	285	268	173	237	180

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