Applying Soft Computing to Estimation of Resources' Price in Oil and Gas Industry

Sholpan Mirseidova, Atsushi Inoue, Lyazzat Atymtayeva

Kazakh-British Technical University
Tole bi st., 59
Almaty, Kazakhstan
s.mirseidova@gmail.com

Abstract

The oil and gas industry is highly risky capital-intensive field of business. Many companies are working hard to perform projects on a global scale in order to get, produce and deliver their final products. No matter the economic conditions, it is vital for organizations to efficiently manage their capitals projects, which facilitates to control expenditure, handle priorities and mineral resources, and make assets productive as quickly as possible. It is also critical to efficiently and safely maintain and improve these assets. Probably the most volatile item of the project cost in oil and gas industry is the market price of resources or assets. Both sides (stakeholders) seek for efficient profitable price for selling and buying final product. This paper provides the description of application developed for fair oil price estimation using Fuzzy Sets and Logic approach of Soft Computing and FRIL inference language with its environment installed on UNIX virtual machine.

Introduction

Managing the complexity and profit of major projects in today's oil and gas landscape has never been more critical. Against the backdrop of a decline in both global economic conditions and corporate revenues, stakeholders are demanding improved return on investment (ROI), reduced risk and exposure and greater transparency. Since capital construction projects in the upstream oil and gas industry comprise a significant percentage of company spend, there must be a particular focus on predictability, transparency and reliability, including estimation of profit, controlling and reducing the costs associated with these projects. The best opportunity to make a positive impact on the life cycle of capital project in this industry is during early planning, even before the capital outlay occurs. In order to control planning it is useful to develop an integrated cost management function that aligns all cost-related processes and functions and incorporates data developed or maintained in other processes. Emphasis should be placed on budget control, approved corporate budget changes and project management internal budget transfers.[1] As the prices of oil and gas fluctuate every day this is the most difficult part of budget control, because even slight changes in the value has a huge impact on overall financial situation of project. That's why it will be very convenient to use Fuzzy Logic methodology of Soft Computing to make certain calculations in order to estimate the total profit of the project and remove the uncertainty of non clear boundaries of oil price.

In the direction of application of fuzzy logic to similar economic problems, the following research was made: the problem of developing automated system of technical – economic estimation in oil and gas fields was considered by Yu.G. Bogatkina [2], and The Fuzzy Logic Framework was build on investigation of risk-based inspection planning of oil and gas pipes [3]. The first one describes economic estimation of oil and gas investment projects witnesses' necessity of taking into account a great number of uncertainty factors. Uncertainty factors influence on investment project can bring about unexpected negative results for the projects, which were initially recognized economically expedient for investments. Negative scenarios of development, which were not taken into consideration in investment projects, can occur and prevent realization of investment project. Especially important is accounting of information uncertainty, which directly depends on mathematical apparatus choice, defined by mathematical theory, and provides for formalization of uncertainty, appearing during control over investment flows. The second framework emphasizes attention on important feature of plant operation – availability of a considerable amount of information as qualitative and imprecise knowledge. Risk-based inspection schedule was developed for oil and gas topside equipment with supporting fuzzy logic models.

No study was made in Kazakhstan connected with problems of uncertainty in oil prices and project costs in terms of the principles of fuzzy logic, which could give a more complete picture of price changes and their influence on the general economic situation in the country, which allows forecasting of rising inflation and determining the most optimal range of prices taking into account various economic factors.

Problem Solving

The given application offers solution to the problem of the project profit estimation considering the price of oil as a fuzzy set. Such types of applications are developed for project managers in oil and gas industry to make evaluation of project profit for the future decision. Also all investors and financial institutions of this industry could be interested in using the given tool.

The total profit of the project could be generally expressed as follows:

$$P = Oil\_price * Supply\_scope$$

According to the research [4] there are three main standards for the formation of market prices for Kazakhstan's oil exports: prices of Brent dtd type of oil, Urals (REBKO) and a mixture of CPC. The prices are usually published by Platts organization (see table 1). The price of Kazakhstan's oil is calculated according to the formula:

$$Price = Brent\_Price\ (or\ Urals\_Price) +/- Market\_Differential$$

Key benchmarks ($/bbl)				
	Data code	**Change**	**Assessment**	**Change**
Dubai (SEP)	PCAAT00	-1.47	110.10-110.12	-1.47
Dubai (OCT)	PCAAU00	-1.57	110.28-110.30	-1.57
Dubai (NOV)	PCAAV00	-1.54	110.48-110.50	-1.54
MEC (SEP)	AAWSA00	-1.47	110.10-110.12	-1.47
MEC (OCT)	AAWSB00	-1.57	110.28-110.30	-1.57
MEC (NOV)	AAWSC00	-1.54	110.48-110.50	-1.54
Brent/Dubai	AAJMS00	-0.30	5.76-5.78	-0.30
Brent (Dated)	PCAAS00	-0.95	116.84-116.85	-0.95
Dated North Sea Light	AAOFD00	-0.95	116.84-116.85	-0.95
Brent (AUG)	PCAAP00	-1.32	116.46-116.48	-1.32
Brent (SEP)	PCAAQ00	-1.21	115.66-115.68	-1.21
Brent (OCT)	PCAAR00	-1.22	115.60-115.62	-1.22
Sulfur De-escalator	AAUXL00		0.40	
WTI (AUG)	PCACG00	-1.35	94.94-94.96	-1.35
WTI (SEP)	PCACH00	-1.38	95.41-95.43	-1.38
WTI (OCT)	AAGIT00	-1.40	95.87-95.89	-1.40
ACM AUG)*	AAQHN00	-1.10	107.59-107.61	-1.10
ACM (SEP)*	AAQHO00	-1.38	107.61-107.63	-1.38
ACM (OCT)*	AAQHP00	-1.40	107.87-107.89	-1.40

Table 1: Prices of key benchmarks (Source: Platts)

Usually traders make an agreement for the value of market differential. Market price construction for Kazakhstani oil depends on CIF August's (CIF stands for cost, insurance, freight) market differential.

The main idea is to consider these two parameters (the price of Brent dtd. oil and market differential) as fuzzy sets, because the former changes every day, and the second is a result of contract between traders.

The research is based on the theory of fuzzy sets and logic. Fuzzy sets were initially offered by Lotfi A. Zadeh [5] in 1965 as an extension of the classical notion of set. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition — particular element either belongs or does not belong to the set (crisp set). In opposite, fuzzy set theory allows the gradual assessment of the membership of elements in a set. According to the definition, a *fuzzy subset* of a set U is defined by means of a membership function $\mu : U \rightarrow [0, 1]$. And a membership of an element x in (crisp) set U is determined by an *indicator (characteristic)* function $\mu : U \rightarrow \{0, 1\}$[6].

Using fuzzy sets in estimation of oil price gives opportunity to remove straight principles of crisp sets. For example, in the case of crisp sets we should take only three exact numbers for oil price and market differential and calculate assessment for the worst, standard, and the best cases. In opposite, with the help of fuzzy sets it is possible to take into account the variation of price in time, in other words statistical or historical changes. Another significance of fuzzy sets is in possibility to manage uncertainty. It means that we can more precisely define which numbers that represent the price of oil can be called normal or higher/lower than that and with which membership degree.

Concerning all of conditions described above three universal sets can be defined:

$U_{X1} = [80, 140]$ – price of Brent dtd.
$U_{X2} = [-5, 5]$ – market differential
$U_Y = [50, 160]$ – oil price

The approximate values of borders of sets are taken from statistical values of mentioned parameters for the previous year [6] (see fig.2 for the set of Brent dtd. price). So there are 2 Inputs and 1 Output in the system.

Also fuzzy sets on inputs X_1 and X_2 and output Y were created with membership values as follows:

Fuzzy sets on X_1(for the price of Brent dtd. see fig.1):

'less than usual' = {1/80, 0.8/90, 0.7/100, 0.5/110, 0.2/113, 0.1/115, 0/118, 0/120, 0/130, 0/140}

'more than usual' = {0/80, 0/90, 0/100, 0/110,0.2/113,0.4/115,0.5/118,0.7/120,0.9/130, 1/140}

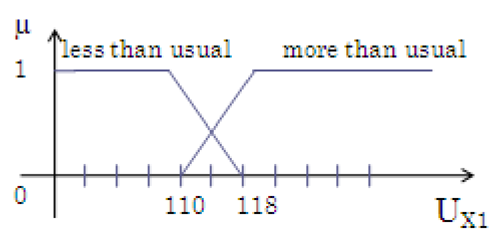

Figure 1: Fuzzy sets for the price of Brent dtd.

The given sets were constructed following principle: as the price for Brent dtd. has changed between 80 and 140 (according to statistics [7] and fig.2), then element 80 belongs to the set 'less than usual' with higher membership which equal s to 1 than 140 belongs to this set (membership equals to 0), and the rest members own steadily decreasing membership degrees. Similarly the set 'more than usual' can be explained.

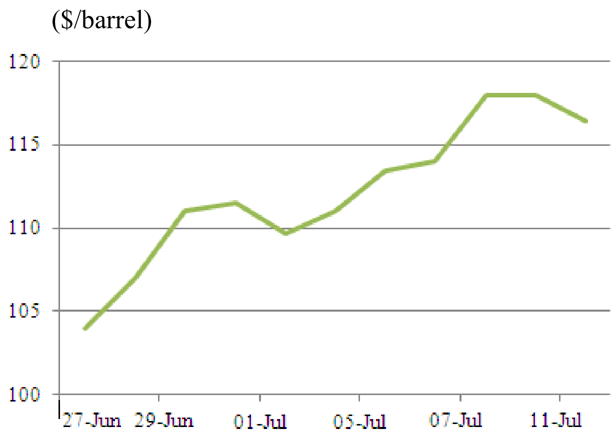

Figure 2: Dated Brent (Source: Platts)

Fuzzy sets on X_2 (for the value of market differential see fig.3)

'significantly high'={1/-5, 0.8/-4, 0.5/-3, 0.2/-2, 0/-1, 0/0, 0.1/0.1, 0.2/1, 0.4/2, 0.6/3, 0.9/4, 1/5}

'significantly low'={0/-5, 0.2/-4, 0.4/-3,0.7/-2, 0.8/-1, 1/0, 0.9/0.1, 0.8/1, 0.6/2, 0.3/3, 0.1/4, 0/5}

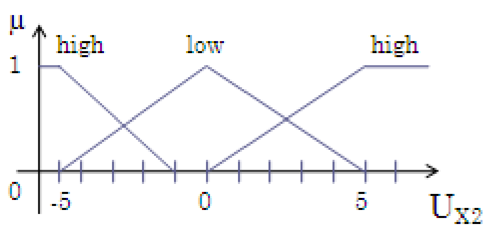

Figure 3: Fuzzy sets for the value of market differential

The most frequently used market differentials vary from -5 to 5 as was mentioned in the list of universal sets for three parameters. The higher the value of market differential (without sign) the more significant influence it has to the final price of resource, so that the members -5 and 5 have the highest membership degree in the set 'significantly high'. Other members of this universal set, which are close to 0, have higher degree in the set 'significantly low' respectively.

Finally, the resulting universal set for oil price was divided into three approximate subsets: cheap, normal or optimal, and expensive. The membership degrees of the elements were assigned following the same principle described above.

Fuzzy sets on Y (for the resulting value of oil price see fig.4):

'cheap'={1/50, 0.9/60, 0.8/70, 0.7/80, 0.6/90, 0.4/100, 0.2/110,0/115, 0/120,0/140,0/160}

'normal'={0/50, 0/60, 0.1/70, 0.3/80, 0.5/90, 0.7/100, 0.9/110, 1/115, 0.5/120, 0/140,0/160}

'expensive'={0/50, 0/60, 0/70, 0/80, 0/90, 0/100,0/110, 0/115, 0.7/120, 0.9/140, 1/160}

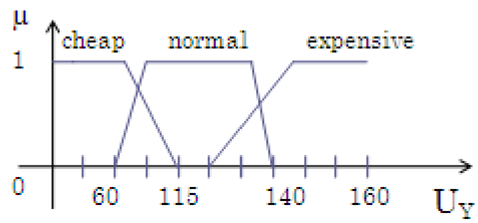

Figure 4: Fuzzy sets for the resulting value of oil price

There are 4 "IF-THEN" rules in the system.

RULE 1: IF X_1 is 'less than usual' AND X_2 is 'significantly low' THEN Y is 'cheap'

RULE 2: IF X_1 is 'less than usual' AND X_2 is 'significantly high' THEN Y is 'normal'

RULE 3: IF X_1 is 'more than usual' AND X_2 is 'significantly low' THEN Y is 'normal'

RULE 4: IF X_1 is 'more than usual' AND X_2 is 'significantly high' THEN Y is 'expensive'

These rules express the direct dependency (proportionality) between two parameters – the price of Brent dtd. and market differential – and oil price according to the formula above.

Development Technologies

The given application was developed using FRIL. With the help of FRIL method of inference number of cases can be calculated.

FRIL was initially an acronym for "Fuzzy Relational Inference Language", which was the predecessor of the current FRIL language, which was developed in the late 1970's following Jim Baldwin's work on fuzzy relations.

FRIL is an uncertainty logic programming language which not only comprises Prolog as one part of the language, but also allows working with probabilistic uncertainties and fuzzy sets as well.

The theory of mass assignments developed by J.F. Baldwin in the Artificial Intelligence group of the Department became a foundation to FRIL language. A fuzzy set is defined as a possibility distribution which is equivalent to a family of probability distributions. FRIL supports both continuous and discrete fuzzy sets.

FRIL gives opportunity to express uncertainty in data, facts and rules with the help of fuzzy sets and support pairs. There are three special types of uncertainty rule besides the Prolog rule. They are: the basic rule, the extended rule, and the evidential logic rule. The second, extended, rule is widely used for causal net type applications, and the evidential logic rule is appropriate to case-based and analogical reasoning. Every rule can have related conditional support pairs, and the method of inference from these rules is based on Jeffrey's rule which is connected with the theorem of total probability. Fuzzy sets can be used to represent semantic terms in FRIL clauses. In addition, a process of partial matching of fuzzy terms like this, which is called semantic unification, gives support for FRIL goals [8], [9].

Analysis of Results

For instance, if the price of Brent dtd equals to 120 (which belong to the set 'more than usual') and CIF market differential is -3 the application outputs defuzzyfied value equal to 116.199. If we apply initially described formula to this data, we will get 120 – 3 = 117. So, the result, which was received by fuzzy sets application, is close to the output of calculations following formula. However, there is a difference in 1 dollar per barrel that can considerably affect the final project cost. More results for the values of the Brent dtd. price and market differential from different sets are listed in appendix below.

The application gives the fair price to the sellers' side, so that the price by contract, that is lower than this, is not profitable, and the price that higher than this, is not competitive on the market. On the other side, buyer takes the reasonable price for the product, which correspond reality with taking into account situation in the market.

Finally, the project profit can be obtained by multiplication of output value to whatever value of the supply scope following the volume in the contract.

Conclusion

As a result let us notice that Fuzzy Sets and Logic can be successfully applied to estimate project profit by assuming several parameters as fuzzy sets, constructing those sets and applying fuzzy logic to them in order to reduce uncertainty. There are still many opportunities to improve the precision of calculations.

The market price of Kazakhstani oil depends on several fundamental factors, which can be divided into fixed and variable. Variable factors, such as the level of consumption of petroleum and petroleum products in a specific period of time, the amount of energy resource available on the market, conditions of delivery, the number of traders, significantly affect on the fluctuation of oil prices. Moreover, the quality of exported oil (density, content of sulfur and wax, etc.), maintenance of quality, stable production and supply, and the cost of oil production in a particular region have an impact on market price [4].

Yet another example, oil price in Kazakhstan also depends on dollar variation. So, additional fuzzy set representing the value of dollar in Kazakhstani tenge can be added and application will calculate it without any problems. In addition, the application can be easily customized to calculate the price of gas and prices of other mineral resources.

Appendix

Source Code

```
%% oil-price.frl
%% NOTE: we use FRIL method of inference
%%      (different from Mamudani, Sugeno,etc.)
% estimate the price of oil depending on Brent dtd. and
market differential
% INPUTS: price of Brent, market differential
% OUTPUT: oil price

%% universe of diccourse

set (dom-brent 80 140)
set (dom-market_dif -5 5)
set (dom-oil_price 50 160)

 %% fuzzy sets on Brent dtd.

(less_than_usual [80:1 90:0.8  100:0.7 110:0.5 113:0.2
115:0.1 118:0 120:0 130:0 140:0] dom-brent)

(more_than_usual  [80:0  90:0  100:0  110:0  113:0.2
115:0.4 118:0.5 120:0.7 130:0.9 140:1] dom-brent)

%% fuzzy sets on market differential

(significantly_high [-5:1 -4:0.8 -3:0.5 -2:0.2 -1:0 0:0
0.1:0.1 1:0.2 2:0.4 3:0.6 4:0.9 5:1] dom-market_dif)

(significantly_low [-5:0 -4:0.2 -3:0.4 -2:0.7 -1:0.8 0:1
0.1:0.9 1:0.8 2:0.6 3:0.3 4:0.1 5:0 ] dom-market_dif)

%% fuzzy sets on oil price

(cheap  [50:1  60:0.9  70:0.8  80:0.7  90:0.6  100:0.4
110:0.2 115:0 120:0 140:0 160:0] dom-oil_price)

(normal  [50:0  60:0  70:0.1  80:0.3  90:0.5  100:0.7
110:0.9 115:1 120:0.5 140:0 160:0] dom-oil_price)

(expensive [50:0 60:0 70:0 80:0 90:0 100:0 110:0
115:0 120:0.7 140:0.9 160:1] dom-oil_price)

%% Fuzzy Associative Matrix (FAM)
```

```
%
%  b\d | L | H |
% --------------
%    L  | C | N |
%   M  | N | E |
%
%% fuzzy rules based on FAM

((price cheap)
      (brent less_than_usual)(market_dif significantly_low))

((price normal)
      (brent less_than_usual)(market_dif significantly_high))

((price normal)
      (brent more_than_usual)(market_dif significantly_low))

((price expensive)
      (brent more_than_usual)(market_dif significantly_high))


((simulation-v B D)
          (addcl ((brent B)))
          (addcl ((market_dif D)))
          (p 'Price of Brent:' B ', ' 'Market differetial:' D)(pp)
          (qsv ((price X)))
          (delcl ((brent B)))
          (delcl ((market_dif D))))

%% eof %%
```

Execution Results

```
Fril >?((simulation-v 80 1))
Price of Brent: 80 ,  Market differetial: 1

((price 76.9223)) : (1 1)
Fuzzy set [49.9978:0 50:0.8 60:0.8 70:0.82 71.6666:0.826667 90:0.68 110:0.36 115:0.2 ] defuzzifies to 76.9223 over sub-domain (50 140)

no (more) solutions

yes

Fril >?((simulation-v 120 -3))
Price of Brent: 120 ,  Market differetial: -3

((price 116.199)) : (1 1)
Fuzzy set [115:0.65 119.545:0.872727 120:0.86 140:0.72 160:0.72 160.011:0] defuzzifies to 116.199 over sub-domain (60 160)

no (more) solutions

yes

Fril >?((simulation-v 90 -1))
Price of Brent: 90 ,  Market differetial: -1

((price 74.128)) : (1 1)
Fuzzy set [49.989:0 50:1 90:0.744 110:0.488 115:0.36 160.007:0.36 160.011:0] defuzzifies to 74.128 over sub-domain (50 115)

no (more) solutions

yes

Fril >?((simulation-v 140 5))
Price of Brent: 140 ,  Market differetial: 5

((price 142.216)) : (1 1)
Fuzzy set [115:0 120:0.7 140:0.9 160:1 160.011:0] defuzzifies to 142.216 over sub-domain (115 160)

no (more) solutions
yes
```

References

1. Ernst & Young. 2011 Capital projects life cycle management. Oil and Gas., pp. 1,6. EYG No. DW0085 1103-1237776
2. "APPLICATION OF THEORY OF FUZZY SET IN AUTOMATED SYSTEM OF TECHNICAL-ECONOMIC ESTIMATION OF OIL AND GAS FIELDS." by Yu.G. Bogatkina,, Institute of Oil and Gas Problems of the Russian Academy of Sciences, 2010
3. Risk-based Inspection Planning of Oil and Gas Pipes – The Fuzzy Logic Framework in EXPLORATION & PRODUCTION – Oil and Gas review Volume 8 Issue 2, p. 26-27.
4. RFCA RATINNGS Rating Agency. Almaty, 2010. АНАЛИЗ НЕФТЕДОБЫВАЮЩЕЙ ОТРАСЛИ РК., pp. 32-37
5. L. A. Zadeh, 1965, "Fuzzy sets". Information and Control 8 (3) 338–353.
6. Page Ranking Refinement Using Fuzzy Sets and Logic., Inoue A., Laughlin A., Olson J., Simpson D., 2011, Eastern Washington University, USA
7. platts.com Value 32, Issue 134, July 11, 2011. Crude Oil Marketwire., pp. 1-13
8. Fril Systems Ltd (1999). Fril - Online Reference Manual - Preliminary Version (incomplete). Retrieved October 20, 2005.
9. Pilsworth, B. W. (n.d.). The Programming Language Fril. Retrieved October 18, 2005