RISK ANALYSIS APPLIED IN OIL EXPLORATION AND PRODUCTION

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Abstract

This research investigated the application of risk analysis to Oil exploration and production. Essentially, different organizations approach risk analysis from various perspectives depending on the companys policies. Some problems were identified as the causes of poor risk analysis procedures such as wrong concepts and miscommunication by the risk analysis staff. The risk associated with investments in oil exploration and production among others include: risk of storm damage to offshore installations; risk relating to future oil and gas prices; risk of exploration or development of dry hole and environmental risk. The analysis in this work is based on the actual field data obtained from Devon Exploration and Production Inc. The Net Present Value (NPV) and the Expected Monetary Value (EMV) were computed using Excel and Visual Basic to determine the viability of these projects. Although the use of risk management techniques does not reduce the uncertainty in Oil field projects; it reduces the impact of the losses should an unfavourable event occur.

Keywords: risk analysis, oil field, risk management, projects, investment opportunity

1. Introduction

The Oil Exploration and Production is a capital- intensive business that frequently use economic analysis to assess and evaluate the viability of projects that will consume investment capital. Development of criteria for the screening and ranking of projects, which have the same level of associated risks, is very important. The process of screening is simply a means whereby an organization carries out an economic feasibility study of an investment possibility and rates its investment opportunity, while ranking is the process by which acceptable projects are prioritized with respect to the available funds, corporate policy and objectives [1, 2].

Purchase proposals, buy or lease alternatives, properties appraisal, drilling exploration activities, and secondary and tertiary recovery mechanisms, are just a few types of project evaluations conducted in the Oil industry. These projects are often mutually exclusive alternatives, which means that they cannot both exist or be true at the same time. For one to be done another must be forgone, therefore an objective analysis is required to select the best alternative.

In making investment decisions on relative profitability of projects, management has to look at some important parameters. These parameters are used to screen projects and then rank them in order of profitability and how best they meet the organizations goals.

Again, the general assumption is that the alternate projects all have the same level of risk and uncertainty associated with them.

Many research works are available on risk and decision analysis [3, 4, 5, 6]. However, one of the major problems facing management in most organizations is the inability to apply effectively risk analysis tools [7]. This is highly evident in the Oil exploration and production projects which are associated with numerous risk and uncertainties. These risks include, storm damage to offshore installations, risk relating to future oil and gas prices, risk of exploration or development of dry hole, environmental risk etc.

The outcome of this study will be of great significance to management decisions. It will assist the Engineer in selecting the most economically viable project amidst projects competing for limited investment resources. Besides, the computer software presented will facilitate the decision by reducing the period and tediousness of analysis involved.

2. Methodology

2.1. Sources of data

Data on the petroleum field development, capital cost, operating costs, field life and other data were collected from Devcon Exploration and production Inc. located around South Texas and South America.

2.2. Method of analysis

Two methods, Net Present Value (NPV) and the Expected Monetary Value (EMV), were applied for the comparison of the economic viability of the projects selected. First, the net present value of the cash inflows and the present value of the cash outflows generated by the investment and discounted at the hurdle rate [8]. Secondly, the expected monetary value which is the sum of the mathematical product of the probability of each outcome times the value of that outcome for all the possible outcomes [8, 3].

The use of expected value has been found to be more effective in projects with high repetitions of operations. The expected value obtained from this calculation is not to be seen as final or absolute value but instead as a management tool to evaluate alternatives and can only be used effectively by any organization if applied consistently over several projects. The expected value analysis requires the identification of at least two outcomes for each alternative. Each of the possible outcomes must have a finite chance of happening, but none can be certain of happening. The assigned probabilities must be proportional to the likelihood of that individual events occurrence, and the sum of all such probabilities must be equal to one.

The expected value theorem can also be used to create value plots to visually investigate the actual comparison between competing projects. These plots could create what is known as efficient frontiers so that management can get the best value for their investment.

3. Analysis and Discussion

3.1. Risk assessment- Devcon E & P INC.

A basic problem facing Devcon Exploration and production Inc is presented. The projects they are considering include Cuulon, Kilmaro, Bellanak, Bustamante, Vaquillas, and Magnolia fields, all located around South Texas and South America.

All these projects are excellent fields in their own merit but since the company has limited funds it can be exposed to risk, it has to distribute these funds to the most viable projects in such a way that the risk is spread across the projects that have potentially higher value, and at the same time minimizing exposure.

No method can be claimed to be the best, the main issue is that of consistency. If fifty projects are evaluated, they must be subjected to the same process so that there will be no basis for biases. Notably, the results obtained at the end of these process directly result from the input of the planning group who provided the information on the field life i.e. stock tank oil originally in place (STOOIP), the operating costs, estimated capital, working interest and taxes associated with each project or area.

A simple program in Excel and Visual Basic is created to enable easy comprehension of a step-by-step operation to arrive at a good recommendation for management. There are more robust software for doing this evaluation like Peep software from Schlumberger but the major difference is that they have a larger data base and can run up to 30,000 problems at a time. Doing this with this program will require a computer backed up with a server [9].The source code for the program is available on request.

3.2. Application of the developed program

3.2.1. Cuulon problem

The field has an estimated ten years life span as determined by the reservoir engineers. The oil production estimates for maximum reservoir draw down is given and the operating cost is determined from the development experience in that area. If the company does not have any producing asset in this area this information can be estimated from figures received from consultants and other operators. The capital investment, working interest, depreciation rate, taxes accruable and hurdle rate are known. The accurate tax and hurdle rate are 39% and 15% respectively.

From experience the planning group provides the best estimates for oil and gas prices from which before tax cash, taxes and after tax income can be calculated. Using the program the Net Present Value of the after tax is calculated by discounting the total cash as shown in Table 1.

The next step is the analysis section. From Table 1, it is observed that those parameters, which if altered slightly will throw a lot of the calculation off balance, (the critical parameters) should be considered. For the Cuulon project, the predicted Net Present Value (NPV) is $363,644M. For the other projects namely Kilmaro, Bellanak, Bustamante, Vaquilas and Magnolina, the predicted NPV are shown in Tables 2, 3, 4, 5 and 6 respectively.

Looking at Table 7, fluctuations in production, price, operating cost and capital will greatly affect the NPV.

So what the program does is to use triangular probability and scalar factors and are assigned to the parameters based on experience. That is if production, price, operating cost and capital increases or decreases by a factor, what will be the overall effect on the predicted NPV value. This is done by comparing the NPV with the base calculation. For this oil field, the base NPV is $363,644M and if the overall production increases by 1.5 (High production), the NPV will be $552,390M and if it decreases by 0.8(Low production), the NPV will be $288,145M.

Now if the price of oil records an overall increases of 1.2 times the predicted value(High price),then the NPV will be $439,142M and if it decreases by 0.55 times the predicted value(Low price), the NPV will be $193,772M.

Now consider operating cost, if the operating cost(Opcost) increases by 1.3 times the predicted value(High Opcost), the NPV will decrease to $362,773M and if it decreases by 0.9 (Low Opcost),then the NPV will increase to $363,934M. This is in contrast to that of production and price, where an increase leads to an increase in NPV and vice versa. Hence, if there is a decrease in operating cost required to run the project this will positively affect the overall project and if the operating cost required increases this will negatively affect the NPV.

The other index to look at is the capital required to start the project. If there is an increase of 1.1 in the value of capital required(High Capital), the NPV will drop to $362,549M and if the capital required decreases to 0.95(Low Capital), an increase in NPV of $364,191M will be recorded. This pa-

Table 1: Available Data for the Cuulon Project.

Time	**Oil Production**	**Gas Production**	**Oil Price**	**Revenue**	**Opcost**	**Capital**	**Working Interest**	**Operating Income**	**Depreciation**	**Bt Cash**	**Taxes**	**At Cash**
Yrs	MSTB	MMSCF	$/Bbl	M$	M$	M$	%	M$	M$	M$	M$	M$
2003	12,918	113	18	232,524	1,200	18,000	100	231,324	3,600	213,324	88,812	124,512
2004	10,061	106	18	181,086	1,100		100	179,986	3,600	179,986	68,796	111,190
2005	7,836	99	18	141,030	850		100	140,153	3,600	140,153	53,266	86,877
2006	6,102	93	19	116,936	850		100	116,086	3,600	116,086	43,480	72,606
2007	4,752	87	19	90,298	850		100	89,448	3,600	89,448	33,477	55,971
2008	3,701	82	19	70,319	850		100	69,469		69,469	27,093	42,376
2009	2,882	77	17	48,994	850		100	48,144		48,144	18,776	29,368
2010	2,245	72	17	38,156	850		100	37,306		37,306	14,553	22,753
2011	1,748	67	17	29,716	850		100	28,866		28,866	11,256	17,610
2012	1,362	63	18	24,516	850		100	23,666		23,666	9,230	14,436
											Total	577,699
											NPV	363,644

Table 2: Available Data for the Kilmaro Project.

Time	**Oil Production**	**Gas Production**	**Oil Price**	**Revenue**	**Opcost**	**Capital**	**Working Interest**	**Operating Income**	**Depreciation**	**Bt Cash**	**Taxes**	**At Cash**
Yrs	MSTB	MMSCF	$/Bbl	M$	M$	M$	%	M$	M$	M$	M$	M$
2003	1,000	200	18	18,000	1,000	8,000	100	17,000	1,600	9,000	6,006	2,994
2004	900	200	18	16,200	1,000		100	15,200	1,600	15,200	5,304	9,896
2005	850	200	18	15,300	1,000		100	14,300	1,600	14,300	4,953	9,347
2006	720	200	19	13,680	1,000		100	12,680	1,600	12,680	4,321	8,359
2007	600	200	19	11,400	1,000		100	10,400	1,600	10,400	3,432	6,968
2008	500	200	19	9,500	1,000		100	8,500		8,500	3,315	5,185
2009	425	200	17	7,225	1,000		100	6,225		6,225	2,428	3,797
2010	300	200	17	5,100	1,000		100	4,100		4,100	1,599	2,501
2011	200	200	17	3,400	1,000		100	2,400		2,400	936	1,464
2012	100	200	18	1,800	1,000		100	800		800	312	488
											Total	50,999
											NPV	29,499

Table 3: Data for the Bellanak Project.

Time	**Oil Production**	**Gas Production**	**Oil Price**	**Revenue**	**Opcost**	**Capital**	**Working Interest**	**Operating Income**	**Depreciation**	**Bt Cash**	**Taxes**	**At Cash**
Yrs	MSTB	MMSCF	$/Bbl	M$	M$	M$	%	M$	M$	M$	M$	M$
2003	29,773	120	18	535,914	2,500	145,000	100	533,414	61,400	388,414	184,085	204,329
2004	24,376	113	18	438,768	2,100	112,000	100	436,668	61,400	324,668	146,355	178,313
2005	19,958	100	18	359,244	1,970	50,000	100	357,274	61,400	307,274	115,391	191,883
2006	16,340	76	18	310,460	1,900		100	308,560	61,400	308,560	96,392	212,168
2007	13,378	70	19	254,182	1,900		100	252,282	61,400	252,282	74,444	177,838
2008	10,953	61	19	208,107	1,800		100	206,307		206,307	80,460	125,847
2009	8,968	50	17	152,456	1,800		100	150,656		150,656	58,756	91,900
2010	7,342	42	17	124,814	1,800		100	123,014		123,014	47,975	75,039
2011	6,011	37	17	102,187	1,800		100	100,387		100,387	39,151	61,236
2012	4,922	30	18	88,596	1,800		100	86,796		86,796	33,850	52,946
											Total	1,371,498
											NPV	792,379

Table 4: Data for the Bustamante Project.

Time	**Oil Production**	**Gas Production**	**Oil Price**	**Revenue**	**Opcost**	**Capital**	**Working Interest**	**Operating Income**	**Depreciation**	**Bt Cash**	**Taxes**	**At Cash**
Yrs	MSTB	MMSCF	$/Bbl	M$	M$	M$	%	M$	M$	M$	M$	M$
2003	19,849	114	18	357,282	5,000	123,500	100	352,282	24,700	228,782	127,757	101,025
2004	16,251	110	18	92,518	3,500		100	289,018	24,700	289,018	103,084	185,934
2005	13,305	110	18	239,490	2,200		100	237,290	24,700	237,290	82,910	154,380
2006	10,893	84	19	206,967	1,750		100	205,217	24,700	205,217	70,402	134,815
2007	8,919	79	19	169,461	1,200		100	168,261	24,700	168,261	55,989	112,272
2008	7,302	77	19	138,738	1,000		100	137,738		137,738	53,718	84,020
2009	5,978	68	17	101,626	950		100	100,676		100,676	39,264	61,412
2010	4,895	68	17	83,215	950		100	82,265		82,265	32,083	50,182
2011	4,007	68	17	68,119	950		100	67,169		67,169	26,196	40,973
2012	3,281	66	18	59,058	950		100	58,108		58,108	22,662	35,446
											Total	960,460
											NPV	559,073

Table 5: Data for the Vaquillas Project.

Time	Oil Production	Gas Production	Oil Price	Revenue	Opcost	Capital	Working Interest	Operating Income	Depreciation	Bt Cash	Taxes	At Cash
Yrs	MSTB	MMSCF	$/Bbl	M$	M$	M$	%	M$	M$	M$	M$	M$
2003	18,195	99	18	327,510	3,500	115,000	100	324,010	23,000	209,010	117,394	91,616
2004	14,897	90	18	268,146	3,000		100	265,146	23,000	265,146	94,437	170,709
2005	12,196	90	18	219,528	1,500		100	218,028	23,000	218,028	76,061	141,967
2006	9,986	86	19	189,734	1,100		100	188,634	23,000	188,634	64,597	124,037
2007	8,175	80	19	155,325	1,000		100	154,325	23,000	154,325	51,217	103,108
2008	6,694	83	19	127,186	1,000		100	126,186		126,186	49,213	76,973
2009	5,480	80	17	93,160	1,000		100	92,160		92,160	35,942	56,218
2010	4,487	75	17	76,279	1,000		100	75,279		75,279	29,359	45,920
2011	3,673	68	17	62,441	1,000		100	61,441		61,441	23,962	37,479
2012	3,008	60	18	54,144	1,000		100	53,144		53,144	20,726	32,418
											Total	880,445
											NPV	512,364

Table 6: Data for the Magnolia Project.

Time	Oil Production	Gas Production	Oil Price	Revenue	Opcost	Capital	Working Interest	Operating Income	Depreciation	Bt Cash	Taxes	At Cash
Yrs	MSTB	MMSCF	$/Bbl	M$	M$	M$	%	M$	M$	M$	M$	M$
2003	10,586	232	18	190,548	900	19,000	100	189,648	3,800	170,648	72,481	98,167
2004	8,667	190	18	156,006	650		100	155,356	3,800	155,356	59,107	96,249
2005	7,096	155	18	127,728	650		100	127,078	3,800	127,078	48,078	79,000
2006	5,810	127	19	110,390	650		100	109,740	3,800	109,740	41,317	68,423
2007	4,757	104	19	90,390	650		100	89,733	3,800	89,733	33,514	56,219
2008	3,894	85	19	73,986	650		100	73,336		73,336	28,601	44,735
2009	3,188	70	17	54,196	650		100	53,546		53,546	20,883	32,663
2010	2,611	57	17	44,387	650		100	43,737		43,737	17,057	26,680
2011	2,137	47	17	36,329	650		100	35,679		35,679	13,915	21,764
2012	1,750	38	18	31,500	650		100	30,850		30,850	12,032	18,819
											Total	542,719
											NPV	328,336

rameter behaves in the same way as the operating cost. The program can be used to vary these parameters as much as is needed to observe the impact of different scenarios. Table 7 also contains the variance measure. The value of the variance from the mean NPV is obtained by determining the high and low values of NPV for production. Using the base NPV of price for the Cuulon field, when price increases by 1.2 the NPV increases to $439,142M. This is assigned the variable X_{high}. When it decreases to 0.55 the NPV is $193,772M. This is assigned the variable X_{low}. The mean NPV is the variable X. Thus, the variance distribution for price is obtained as $(X_{high} - X)^2 + (X - X_{low})^2$. This same process is repeated for production, operating cost and capital. The value of variance distribution for each is obtained by dividing the sum of $(X_{high} - X)^2 + (X_{low} - X)^2$ for all the parameter by $(X_{high} - X)^2 + (X_{low} - X)^2$ for each individual parameter. This is clearer from the source code for the program. The sum of the variance distribution must always equal to unity. Finally, for the

$$EMV = \sum NPV * Pr \qquad (1)$$

Where, Pr is the probability.

The calculation is done by summing the multiplication of the probabilities, Pr(0.6 for Base and 0.1 for High and Low productions as well as 0.1 for High and Low prices) and the various NPV for the base, high and low production together with high and low prices. For the cuulon project, the calculated EMV is $365,531. The values are then the final value for making comparison with the other projects. The same triangular probability values used for cuulon projects and procedures were applied to other projects for EMV calculations.

The EMV was used to make a decision in this case because all the other uncertainties were adjudged to be roughly the same effect since these fields are all situated in the same region. The EMV calculations for other projects are shown in Tables 8, 9, 10, 11 and 12 respectively.

From the EMV values obtained, it is very easy to pick the viable projects to be executed based on available fund. Thus the best project is Bellanak, followed by Bustamante and Vaquillas in that order. If about 200 fields

Table 7: Risk Analysis, Variance and EMV calculations for Cuulon Project.

	Scalar Factor			**NPV**			**Variance Distribution**	**Risked NPV**		
	High	Base	Low	High	Base	Low		High	Base	Low
Production	1.5	1	0.8	552,390	363,644	288,145	0.54	55,239	218,186	28,815
Price	1.2	1	0.55	439,142	363,644	193,722	0.46	43,914		19,377
Opcost	1.3	1	0.9	362,773	363,644	363,934	0.00	-	-	-
Capital	1.1	1	0.95	362,549	363,644	364,191	0.00	-	-	-
							Sum = 1.00	**Sum = 365,531**		

Table 8: Risk Analysis, Variance and EMV calculations for Kilmaro Project.

	Scalar Factor			**NPV**			**Variance Distribution**	**Risked NPV**		
	High	Base	Low	High	Base	Low		High	Base	Low
Production	1.6	1	0.6	51,954	29,499	14,529	0.68	5,195	17,699	1,453
Price	1.2	1	0.55	36,984	29,499	12,658	0.32	3,698		1,266
Opcost	1.3	1	0.9	28,581	29,499	29,805	0.00	-	-	-
Capital	1.1	1	0.95	29,013	29,499	29,742	0.00	-	-	-
							Sum = 1.00	**Sum = 29,311**		

Table 9: Risk Analysis, Variance and EMV calculations for Bellanak Project.

	Scalar Factor			**NPV**			**Variance Distribution**	**Risked NPV**		
	High	Base	Low	High	Base	Low		High	Base	Low
Production	1.6	1	0.6	1,369,527	792,379	407,614	0.68	136,953	475,427	40,761
Price	1.2	1	0.55	984,761	792,379	359,518	0.32	98,476		35,952
Opcost	1.3	1	0.9	790,533	792,379	792,994	0.00	-	-	-
Capital	1.1	1	0.95	776,041	792,379	800,548	0.00	-	-	-
							Sum = 1.00	**Sum = 787,569**		

Table 10: Risk Analysis, Variance and EMV calculations for Bustamante Project.

	Scalar Factor			**NPV**			**Variance Distribution**	**Risked NPV**		
	High	Base	Low	High	Base	Low		High	Base	Low
Production	1.55	1	0.72	911,774	559,073	379,516	0.61	91,177	335,444	37,952
Price	1.2	1	0.55	687,328	559,073	270,499	0.39	68,733		27,050
Opcost	1.3	1	0.9	556,942	559,073	559,783	0.00	-	-	-
Capital	1.1	1	0.95	551,563	559,073	562,828	0.00	-	-	-
							Sum = 1.00	**Sum = 560,356**		

Table 11: Risk Analysis, Variance and EMV calculations for Vaquillas Project.

	Scalar Factor			**NPV**			**Variance Distribution**	**Risked NPV**		
	High	Base	Low	High	Base	Low		High	Base	Low
Production	1.4	1	0.6	747,501	512,364	277,228	0.57	74,750	307,418	27,723
Price	1.2	1	0.55	629,933	512,364	247,836	0.43	62,993		24,784
Opcost	1.3	1	0.85	510,701	512,364	513,196	0.00	-	-	-
Capital	1.1	1	0.95	505,371	512,364	515,861	0.00	-	-	-
							Sum = 1.00	**Sum = 496,668**		

Table 12: Risk Analysis, Variance and EMV calculations for Magnolia Project.

	Scalar Factor			**NPV**			**Variance Distribution**	**Risked NPV**		
	High	Base	Low	High	Base	Low		High	Base	Low
Production	1.4	1	0.7	533,544	328,336	225,732	0.65	53,354	197,002	22,573
Price	1.2	1	0.55	396,739	328,336	174,430	0.35	39,674		17,443
Opcost	1.3	1	0.9	327,699	328,336	328,548	0.00	-	-	-
Capital	1.1	1	0.95	327,181	328,336	328,914	0.00	-	-	-
							Sum = 1.00	**Sum = 330,046**		

were to be evaluated in addition to other processes, the EMVs would have been plotted against capital to ensure that projects with varying amount of risk can compensate one another resulting in an optimum investment portfolio.

4. Conclusion and Recommendations

Oil exploration and production is a capital-intensive business and over the years the activities have recorded success in dealing with the uncertainty associated with its operations. In this work, the Net Present Value (NPV) and Expected Monetary Value (EMV) were applied to actual field problems in the Oil field exploration and productions. A computer programme using spread sheet and visual Basic was developed for selecting the best alternatives in making investment decisions among various Oil fields selected for study. Although cost of operation in Oil well exploration and production has fallen and success rates increased considerably due to improved technology, the average rate of return is still low. Greater utilization of risk analysis is necessary so as to give the investor a good return on his investment.

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