Scientia Africana, Vol. 18 (No. 3), December, 2019. Pp 29-38
 ISSN 1118 – 1931

ECONOMIC EVALUATION OF OIL WELL: A SIMPLE RULE OF THUMB APPROACH

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Received: 08-10-19
Accepted: 01-11-19

ABSTRACT

Proper investment analysis is critical to successful business in well development. However the current approach of attempting to list and cost all the equipment, infrastructure and material requirements have been cumbersome and unreliable. In this paper, we have suggested a step-by-step approach that readily provides a full package of relevant economic indicators on oil well investment appraisal. We have proposed a simple approach in the estimation of capital outlay on well development. This is further applied along with the exponential flow rate predicting model and financial management tools to provide a step-by-step approach that generates the Net Present Value (NPV) of an oil well as well as Internal Rate Of Return (IRR). We have also suggested a simple approach to estimation of break-even flow rate. The approach has been illustrated with a hypothetical oil well with an initial annual flow rate of 200,000 barrels, annual rate of decline of 4% and economic limit flow rate of 73,000 barrels. In the above analysis, 10% cost of capital or alternative return on the investment capital has been assumed. An operating drainage cost of US$30 per barrel and price of US$70 per barrel were applied. The analysis yielded a capital outlay of US$13.34 million a Net Present Value (NPV) of US$6.06 million and Internal Rate Of Return (IRR) of 17% showing the declining rate of level of viability of oil wells in view of declining oil price and high cost of oil drainage in Nigeria.

Keywords: Exponential model, Capital outlay, Capital recovery, Net Present Value, Internal Rate of Return, Breakeven flow rate.

INTRODUCTION

Investors in oil well development are often faced with the problem of making at least a minimum rate of return on investment capital. To ensure that this is achievable, there is the need for proper investment analysis.

Well planners and Petroleum Economists have to provide answers to the crucial questions in the heart of the investors, which include; How much capital do I require to develop this well? Will this well be viable to develop? Will the rate of return on the investment on this well be higher than other investment alternatives? When will the well break even? How long will the well remain on a positive economic business?. In answering these questions the Petroleum Economists and Well Planners are faced with inadequate data. For instance, in answering the question of how much do I need to invest on the well development, some Well Planners attempt to list out the equipment and infrastructure required. But many Well Planners discover to their dismay that no matter how detailed their list may be, at the end of the development of the well, the actual capital outlay eventually differ substantially from the initial estimate. Therefore there is the need to suggest a short but straight forward method that readily gives answers to the above questions without a long listing of requirements in infrastructure and equipment etc.

METHODOLOGY

The stages in economic evaluation of an oil well can be divided into three:

i) Production Scheduling
ii) Cash flow development
iii) Investment analysis

Production Scheduling

At the onset of development of an oil well, the flow rate is usually high due to high gas pressure. With time, the flow rate begins to diminish as pressure is reduced. The challenge among well planners is how to develop mathematical model that can accurately predict the flow rate into the future considering the reduction in gas pressure and consequently flow rate with time. If the flow rate for each year of operation of the well can be accurately predicted throughout the economic life of the well, then economic evaluation and investment analysis of the well becomes a lot easier.

Several well planners have proposed various decline curve model to predict well flow rate.

Three major decline model and their modification were suggested by Arps (1945). They include;

1. The exponential decline
2. The hyperbolic decline model
3. The harmonic decline model

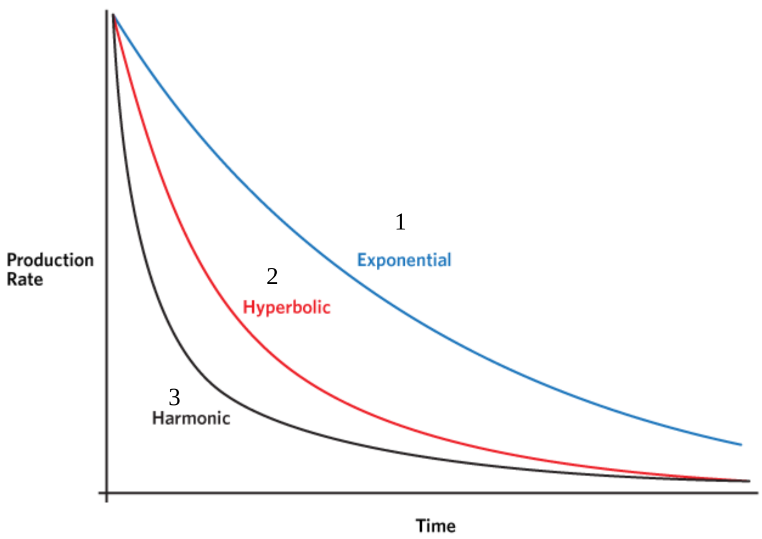

Fig 1: Showing exponential decline curve 1, hyperbolic decline curve 2 and harmonic decline curve 3.

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The three models and their curves are shown in Fig 1 above

Despite criticism of being conservative to flow rate prediction (Agbi, 1987), the exponential decline model has the advantage of showing the relationship between production rate and time especially when drainage and mechanical factors are constant (Faruk, 2007). Doublet (1994) stated that the independence of the decline curve analysis from the size and shape of reservoirs or drainage mechanism is the highest advantage of the exponential model in flow rate prediction.

This explains why it has found wider applications in industry than other models. Consequently in our analysis of X-well we shall apply the exponential model for predicting the flow rates of the well as suggested by Donohue (1983). Thus flow rate at time t,

$$q_t = q_i e^{-Dt} \qquad (1)$$

Where:
q_t = flow rate at time t
q_i = initial flow rate
D = rate of decline (in fraction or %)

Cash Flow Development

Cash flow development requires the following;

1. Estimation of annual cash flow throughout the well’s life utilizing the annual flow rates and drainage cost per barrel.
2. Estimation of annual cash inflow throughout the well’s life using annual flow rates and price per barrel of crude oil.
3. Estimation of annual gross profit throughout the well’s life.
4. Estimation of royalty in line with agreed percentage between the government and the oil industry.
5. Estimation of profit before tax throughout the well’s life.
6. Estimation of tax throughout the well’s life.
7. Estimation of annual net profit throughout the well’s life.

Investment Analysis

After the development of the cash flow table, investment analysis can now commence. The first step towards investment analysis of the oil well is to discount annual cash outflow and annual net cash flows to their present values. This will be utilized in the estimation of capital outlay and net present value of the oil well.

Investment analysis section of this evaluation involves the estimation of the following techno-economic parameters:

1. Capital outlay on the development of the oil well
2. The net present value (NPV) of the project
3. Internal Rate of Return (IRR) of the project
4. The breakeven flow rate of the oil well

Capital Outlay Estimation

Arsentiev, (1972) has proved with statistical data that capital outlay is usually 25% of overall expenditure in heavy industries such as petroleum, mining and metallurgy.

But the total expenditure in any establishment can be captured in the following equation.

$$T = T_c + T_o \qquad (2)$$

Where T = total expenditure in project
T_c = capital outlay in the project
T_o = operating cost of project

But $T_c = 25\%$ of T

or $T_c = 0.25T$

$\Rightarrow T = T_o + 0.25T$

or $T = T_o$ (3)

But the costs in equation (2) can only be compared or added when the expenditures are made within the same time frame, that is, in their present values.

Hence "T_o" represents sum of the operating annual cash outflow discounted to the present day.

Net Present Value

The net present value (NPV) of an oil well can be estimated using the well known formula for net present value estimation in Financial Management (Pandey, 2006). That is,

$$NPV = \sum_{i=1}^{t} N_p - T_c \quad (4)$$

Where;

$N_p \longrightarrow$ sum of the discounted annual net cash outflows

The discounting technique is the usual compound interest technique in Financial Management ie

$$P = \frac{F}{\left(1 + \frac{r}{100}\right)^t} \quad (5)$$

Where;

P $\longrightarrow$ present value of future cash outflows
F $\longrightarrow$ cash flow at time t
r $\longrightarrow$ discount rate

Internal Rate of Return

The internal rate of return (IRR) of the oil well is estimated by the usual trial and error method applied in Financial Management where a discount rate is chosen to compute the NPV. If the NPV is positive, a higher discount rate is chosen. The discounting and NPV estimation is repeated until NPV becomes negative. A graph of NPV against discount rate is then drawn to estimate the discount rate where the NPV equals zero. This discount rate then becomes the internal rate of return as usual.

Break-even Flow Rate

The breakeven flow rate here is the flow rate in which annual revenue coming from the oil well just equals operating cost and annual capital recovery.

The breakeven flow rate is estimated using standard method used in Financial Management (Farrow, 1994).

$$\text{Breakeven flow rate} = \frac{\text{Fixed Cost}}{\text{Contribution}} \quad (6)$$

The fixed cost here is the capital recovery on the development of the well.

The simple technique of estimating capital recovery in Financial Management is applicable here also ie

Fixed cost (Capital recovery) A

$$= T_c\left(\frac{1}{PVFA}\right) \quad (7)$$

Where;

PVFA = Present value factor of annuity

$$PVFA = \frac{1}{i} - \frac{1}{i(1+i)^t} \quad (8)$$

Where;

$$i = \frac{r}{100}$$

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RESULTS AND DISCUSSION

In order to carry out the production scheduling the basic data required for the X-well are tabulated below:

Table 1: Basic data on production scheduling of X-well

Initial flow rate, barrels	Economic limit flow rate	Decline rate, in fraction
200,000	73,000	0.04

The production scheduling can now be done using the exponential model which is the most popular flow rate prediction model in industry.
By this method, the flow rate of the well at time t,
$q_t = q_i\ e^{-Dt}$
Consequently, for the first year ending

- ⇨ $q_1 = 200{,}000\ e^{-0.04 \times 1}$
  $= 192,\ 000$ barrels

- ⇨ $q_2 = 200{,}000\ e^{-0.04 \times 2}$
  $= 184{,}000$ barrels

- ⇨ $q_3 = 200{,}000\ e^{-0.04 \times 3}$
  $= 177{,}000$ barrels

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- ⇨ $q_{24} = 200{,}000\ e^{-0.04 \times 24}$
  $= 77{,}000$ barrels
- ⇨ $q_{25} = 200{,}000\ e^{-0.04 \times 25}$
  $= 74{,}000$ barrels

- ⇨ $q_{26} = 200{,}000\ e^{-0.04 \times 26}$
  $= 70{,}691$ barrels

Consequently beyond the 25th year of production, the well will be operating at a loss since the flow rate is less than economic limit flow rate. The life span of the well is therefore 25 years. The flow rate and year of production from year one to the last production year (25th year) have been tabulated below:

Table 2: Showing projected flow rate of the well for 25 years lifespan.

Year of production	Flow rate, barrels
1	192,000
2	184,000
3	177,000
4	170,000
5	165,000
6	157,000
7	151,000
8	145,000
9	140,000
10	134,000
11	129,000
12	124,000
13	119,000
14	114,000
15	110,00
16	106,000
17	101,000
18	97,000
19	94,000
20	90,000
21	86,000
22	83,000
23	80,000
24	77,000
25	74,000

Cash Flow Development

Before producing the cash flow table, let us first itemize the basis for the cash flow table.

1. Annual cash flow ie total annual production cost of the well

   = Annual flow rate multiplied by drainage cost per barrel.

2. Annual cash inflow

   = Annual flow of oil multiplied by the price per barrel of oil

3. Gross profit = Annual cash inflow less annual cash outflow
4. Royalty = 60% of gross profit
5. Profit before tax = gross profit less royalty
6. Tax = 10% of profit before tax
7. Net profit = profit before tax less corporate tax on profit

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Having defined the basis for the cash flow table, the cash flow table is now presented below:

Table 3: Cash flow development

Year of Produc-tion	Cash outflow in Million US$	Cash inflow in Million US$	Gross income in Million US$	60% Royalty in Million US$	Net profit before tax in Million US$	Tax 10% in Million US$	Net profit in Million US$
1	5.76	13.44	7.68	4.61	3.07	0.31	2.76
2	5.52	12.88	7.36	4.42	2.94	0.29	2.65
3	5.31	12.39	7.08	4.25	2.83	0.28	2.55
4	5.10	11.90	6.80	4.08	2.72	0.27	2.45
5	4.92	11.48	6.56	3.94	2.62	0.26	2.36
6	4.71	10.99	6.28	3.77	2.51	0.25	2.26
7	4.53	10.57	6.04	3.62	2.42	0.24	2.18
8	4.35	10.15	5.80	3.48	2.32	0.23	2.09
9	4.20	9.80	5.60	3.36	2.24	0.22	2.02
10	4.02	9.38	5.36	3.22	2.14	0.21	1.93
11	3.87	9.03	5.16	3.10	2.06	0.21	1.85
12	3.72	8.68	4.96	2.98	1.98	0.20	1.78
13	3.57	8.33	4.76	2.86	1.90	0.19	1.71
14	3.42	7.98	4.56	2.74	1.82	0.18	1.64
15	3.30	7.70	4.40	2.64	1.76	0.17	1.58
16	3.18	7.42	4.24	2.54	1.70	0.17	1.53
17	3.03	7.07	4.04	2.42	1.62	0.16	1.46
18	2.91	6.79	3.88	2.33	1.55	0.15	1.40
19	2.82	6.58	3.76	2.26	1.50	0.15	1.35
20	2.70	6.30	3.60	2.16	1.44	0.14	1.30
21	2.58	6.02	3.44	2.06	1.38	0.14	1.24
22	2.49	5.81	3.32	1.99	1.33	0.13	1.20
23	2.40	5.60	3.20	1.92	1.28	0.13	1.15
24	2.31	5.39	3.08	1.85	1.23	0.12	1.11
25	2.22	5.18	2.96	1.78	1.18	0.12	1.06

Investment Analysis

As stated earlier in our methodology, two main parameters are required to assess the viability of an oil well: the Net Present Value (NPV) and the Internal Rate of Return (IRR).

In Table (4), the annual cash outflows have been discounted at 10% (cost of capital) to the present value while the annual net profit were discounted at various discount rates (10%,15%,20%) in order to estimate the NPV and IRR.

Table 4: Showing discounted cash outflow and discounted net profit.

Year of production	Discounted cash outflow at 10% in million US$	Discounted net profit at 10% in million US$	Discounted net profit at 15% in million US$	Discounted net profit at 20% in million US$
1	5.24	2.50	2.40	2.30
2	4.56	2.19	2.00	1.84
3	4.00	1.92	1.68	1.47
4	3.50	1.67	1.40	1.18
5	3.05	1.46	1.17	0.95
6	2.66	1.27	0.98	0.76
7	2.32	1.12	0.82	0.61
8	2.03	0.95	0.68	0.49
9	1.78	0.97	0.57	0.39
10	1.55	0.86	0.47	0.31
11	1.36	0.68	0.40	0.25
12	1.19	0.57	0.33	0.20
13	1.03	0.49	0.28	0.16
14	0.90	0.43	0.23	0.13
15	0.79	0.38	0.19	0.10
16	0.69	0.33	0.16	0.08
17	0.60	0.29	0.13	0.06
18	0.52	0.25	0.11	0.05
19	0.46	0.22	0.09	0.04
20	0.40	0.19	0.08	0.03
21	0.35	0.17	0.06	0.03
22	0.31	0.15	0.05	0.02
23	0.27	0.13	0.05	0.01
24	0.24	0.11	0.04	0.01
25	0.21	0.10	0.03	0.01
Sum	**40.01**	**19.40**	**14.40**	**11.48**

Net Present Value

$NPV = \sum_{t=1}^{25} N_p - T_c$

$T_c \longrightarrow$ Capital outlay

$\sum_{t=1}^{25} N_p \longrightarrow$ Sum of discounted annual net profit at 10%

$\sum_{t=1}^{25} N_p = \$19.40$ million

$T_c = 0.25T$

$T = \frac{T_o}{0.75}$

$T_o = \$40.01$ million. Table (4)

$T = \frac{40.01}{0.75} = \$53.35$ million

$\therefore$ $T_c = 0.25 \times 53.35$

= US$13.34 million

Consequently, the capital outlay T_c on the development of the oil well is

US$13.34 million

Therefore Net Present Value

NPV = 19.40 – 13.34

= US$6.06 million

Now as explained earlier, in order to estimate IRR, NPVs are estimated using the sum of annual net present values discounted at various discount rates and plotting the graph of NPV versus discount rates.

At 10% discount rate, NPV is 6.06 as already estimated.

At 15% discount rate

NPV = 14.4 – 13.34

= US$1.06 million

At 20% discount rate

NPV = 11.48 – 13.34

= US$-1.86 million

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Now that the NPV is negative, we plot the graph of NPV against discount rates as shown in Fig 2.

From Fig (2) it can be seen that NPV values intersect the discount rate axis at 17% which is the Internal Rate of Return (IRR) of the oil well investment

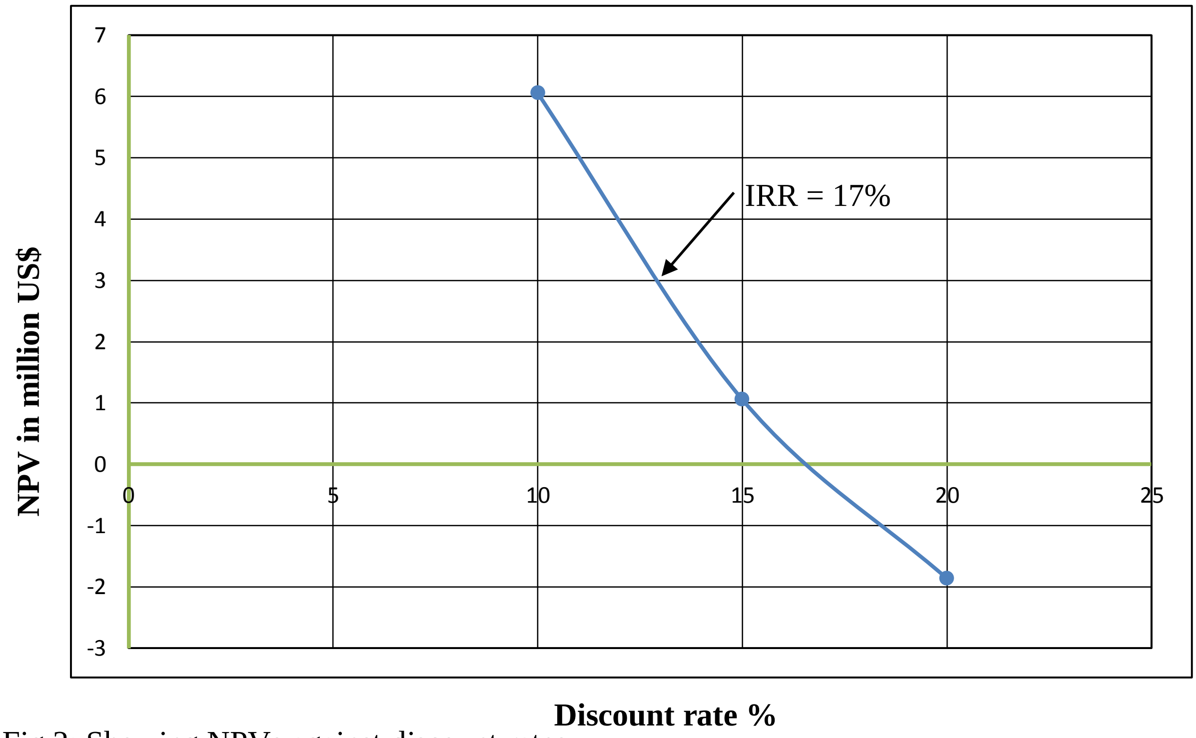

Fig 2: Showing NPVs against discount rates

The breakeven flow rate

$q_{even} = \frac{Fixed\ cost}{Contribution}$

Fixed cost = $[\frac{1}{PVFA}]$

(annual recovery of capital)

Where;

PVFA = Present value factor of annuity

PVFA = $\frac{1}{i} - \frac{1}{i(1+i)^{t}}$

$i = \frac{r}{100} = \frac{10}{100} = 0.1$

$= \frac{1}{0.1} - \frac{1}{0.1(1.1)^{25}}$

= 9.078

□ Fixed cost = 13.34 $[\frac{1}{9.078}]$

= US$1.47 million

Contribution = price per barrel of oil – cost of drainage per barrel of oil

= 70 – 30

= US$40

Breakeven flow rate = $\frac{1470000}{40}$

= 36750 barrels

Cross check

Income = 36750 barrels x US$70

= 2572500

Expenditure

Fixed cost + operating cost

= 1470000 + (36750 x US$30)

=2572500

Note: This flow rate is not the economic limit flow rate which is the flow rate below which the well closes down. It is simply the flow rate at which well property owner ceases to fund the project from his investment capital. At this flow rate, the well can generate funds for its operation; and above the flow rate, the well begins to bring profit.

CONCLUSION

This paper has provided a concise but straight forward approach in well investment analysis. Our proposed methodology of estimating capital outlay on well development as well as breakeven flow rate has simplified the problem of well investment analysis. We have also successfully applied the exponential method and financial management tools to offer a step-by-step approach in well investment analysis.

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