SSRG International Journal of Recent Engineering Science
ISSN: 2349–7157 / https://doi.org/10.14445/23497157/IJRES-V8I3P106

Volume 8 Issue 3, 36-44, May-Jun, 2021

Original Article

Relationship between Crude Oil Reserve Size and Portfolio Management

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Received: 29 April 2021 Revised: 30 May 2021 Accepted: 16 June 2021 Published: 30 June 2021

Abstract - *The relationship between crude oil reserve size and portfolio (investment) management was investigated in this paper for different reservoir sizes (small, medium, and large) using portfolio management tools such as the net present value (NPV), profitability index (PI), present value ratio (PVR), payback period (POP), internal rate of return (IRR), and unit technical cost (UTC). The field life performances of the three reserves were also looked into, taking into consideration of the daily production rate, annual production rate, and cumulative production rate. A cash flow analysis was developed showing the cost implications of the gross revenue, variable operating expenditure, fixed operating expenditure, royalty and tax payment, net revenue, profits, discount factor, and cash flows of the large, medium, and small reservoirs. A decision tree that estimates the risk associated with each investment (small, medium, and large) and the expected monetary value of the investment is presented in this work. The net present values (NPV) were all positive for each reservoir: small ($17.29 MM), medium ($4853.80 MM), and large ($6990.28 MM). Profitability index (PI) were all greater than one for each reserve small, medium and large, Present value ratios (PVR) were all greater than zero, and the Payback period (POP) presents a time frame of below two (2) years. It is clear that all reserves are mutually exclusive and can be collectively exhaustive depending on the risk attitude and portfolio size of the investor.*

Keywords *- Relationship, Crude, Oil, Crude oil, Reserve size, Crude oil reserve size, Portfolio management.*

1. Introduction

According to the World Proven Reserves of Oil and Natural Gas (2016), an Oil reserve is defined as an estimate of how much oil can ultimately be recovered. This broad definition is also called oil in place. It includes undiscovered or "yet to find" reserves. It's based on the probability of finding reserves in certain geological areas. It assumes that new types of technology will make it economically feasible to extract the oil. Recoverable reserves are based on how likely it is that oil can be recovered using current technology. They include the proven reserves, which have a greater than 90% chance that the oil will be recovered. The probable reserves are where the chance of actually getting the oil out is greater than 50%, and the possible reserve is where the likelihood of recovering the oil is significant but less than 50%.

According to Daferighe*et al*. (2015), exploration for oil in Nigeria began in 1908, with the first discovery in the Niger Delta in 1956. Nigeria's first refinery began operations in 1965, with a capacity of 38,000 bbl/day, and it was enough to meet domestic requirements at the time. The demand and production of oil in Nigeria have increased tremendously, such that Nigeria's current daily production is estimated at about 2.5 million bbl/day, with a domestic consumption level of 279,000 bbl/day. As of 2010, Nigeria's proven oil reserves were estimated to be 37.2 billion barrels, which amounts to 2.68% of the world's reserves. Key participants in the Nigerian upstream sector include Shell, Mobil, Chevron, Elf, Agip, and Total. The crude oil produced in Nigeria is classified as 'sweet' as it is largely Sulphur-free. Eighty percent (80%) of production wells are located in the Niger Delta region in the southern part of the country, with notable projects, which include the Afam Integrated Oil and Gas Project operated by Shell and the Bonga Deep Water Project.

The oil industry remains the most important income earner for the government, even though oil and gas contribute only 14% to the nation's Gross Domestic Product (GDP). The Nigerian oil industry has had many triumphs and setbacks. Recently, it had emerged from the scourge of militancy in the Niger Delta when the production level was 1.6 million barrels per day in 2009, but the current levels of about 2.5 million barrels per day are attributable to the government's amnesty program. Oil companies are required to report and manage their product through supplemental information on the oil reserve. They tend to use an inappropriate financial management tool for reserves of diverse sizes leading to the early abandonment of projects or late minimal return on investment. Production and exploration companies need to manage their project portfolio by strengthening their decision-making criteria and using the right management tools in order for projects to be properly accounted for. These profitability tools shall be able to give investors optimum results of profit and likely risks associated with the investments. This paper

aims to determine the appropriate portfolio management tools (profitability tools) for different reservoir sizes that ensure optimum returns on investments. This would be achieved through the application of different economic indicators to determine the profitability of the crude oil reserve size and establish a relationship between an oil field size and the portfolio of the oil field operator.

2. Statement of Problem

Oil companies are required to report and manage their product through supplemental information on the oil reserve. They tend to use an inappropriate financial management tool for reservoirs with diverse sizes leading to the early abandonment of projects or late minimal return on investment. Therefore, production and exploration companies need to manage their project portfolio by strengthening their decision-making criteria and using the right management tools in order for project profitability to be clearly stated. These management tools shall be able to give investors optimum results and profit.

This study aims to determine the appropriate portfolio management tools for different reservoir sizes for optimum returns on investments. This would be achieved through the following objectives:

- To determine the profitability of a crude oil field based on the reserve size.
- To study the application of the different economic indicators on crude oil fields.
- To establish a relationship between an oil field size and the portfolio of the oil field operator.

3. Literature Review

3.1. Crude Oil in Nigeria

In Nigeria, the search for crude oil started between 1905 and 1908 by the Nigerian Bitumen Corporation (NBC), who, on their search, found 16 shallow wells, confirming a line of oil seepage in the Eastern Dohomey Basin in Okitipupa, Western Region of Nigeria. NBC could not go far with its search due to the outbreak of the First World War in 1914, which distorted its activities. However, after the war, the Royal/Dutch Company took over and continued with the search from Ondo State to Abia State and finally narrowed down their search to Niger Delta Region, where they first discovered oil in large commercial quantity in 1956 at Oloibiri, specifically in the present Bayelsa State. Nigeria's oil discovery hit nine states of the Federation. (Azaiki and Shagari, 2007). The oil-producing states in Nigeria so far discovered include (Abia, AkwaIbom, Bayelsa, Cross River, Delta, Edo, Ondo, and Rivers) having a common nomenclature known as the "Niger Delta region" (Akinlo, 2012).

The expansion of Nigeria's petroleum exports drained resources from other parts of the economy, brought about a rise in urbanization to the new oil centers, and generated an appreciable exchange rate that culminated in a decline in the competitiveness of non-oil exports and import-competing industries (Akinlo, 2012). This resulted in the Dutch Diseased economy, which in Nigeria's case, is an economy whose original exports were tradable agricultural goods, but shifted to the export of booming sector that consequently led to a real exchange rate appreciation and the near extinction of the original agricultural exporting sector (Hassan, 2016).

3.2. Crude Oil Reserve

DeGolyer and McNaughton (2008) defined oil and gas reserves are the estimated quantities of crude oil, natural gas, and natural gas liquids, which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions, i.e., prices and costs as of the date the estimate is made. Prices include consideration of changes in existing prices provided only by contractual arrangements but not on escalations based upon future conditions.

John (2004) stated that petroleum (or any other natural resource) reserves could not be measured directly. They are estimates of future production under certain conditions which may or may not be well specified but which include economic assumptions, knowledge of the feasibility of projects to extract the resources, and geological information. Most of the parameters that define the reserves of a Reservoir cannot be measured directly and must be determined indirectly through geologic and reservoir engineering analysis and interpretations. As a result, the estimates of oil and gas reserves have an intrinsic uncertainty. The definitions of reserves are designed to promote uniformity and standard measurement of the assets, providing a structure to quantify risk and uncertainty through its categorization.

According to the Society of Petroleum Engineers (SPE) and the World Petroleum Congress (WPC), reserves are those quantities of hydrocarbon expected to be recoverable from known accumulations based on prevailing economic conditions and current technology from a given date forward. The ability to recover a particular reserve is not 100% certain. This is the reason reserves underlying reserves are either proven or unproven reserves. Proven reserves do not include quantities of petroleum being held in inventory or quantities of hydrocarbon whose field economics details are not available or with reasonable doubt in recovery (SPE, 2000).
reservoirs and under prevailing economic conditions, operating methods, and government regulations (SPE, 2000). Proven hydrocarbon reserve is classified as developed and underdeveloped.

3.3. Estimated Proven Hydrocarbon Reserves

Estimated proven hydrocarbon reserves are those quantities of hydrocarbon which geological and engineering data estimates with reasonable certainty to be commercially recoverable, from a given date forward, from known

3.4. Developed Reserves

Developed reserves are expected to be recovered from existing wells. Improved recovery reserves are considered developed only after the necessary equipment has been installed or when the costs to do so are relatively minor. Developed reserves are sub-categorized as producing or non-producing.

3.4.1. Producing

These are reserves recovered from completion intervals that are open and producing at the time the estimate is made. Improved recovery reserves are considered produced only after the improved recovery project is complete.

3.4.2. Non-Producing

Reserves sub-categorized as non-producing include shut-in and behind-pipe reserves. Shut-in reserves are expected to be recovered from completion intervals that are open at the time of the estimate though yet to produce, wells that were shut in for market conditions or pipeline connections, or well not capable of production for mechanical reasons. Behind-pipe reserves are expected to be recovered from zones in existing wells, which will require additional completion work or future recompletion prior to the start of production.

3.5. Undeveloped Reserves

Undeveloped reserves are estimated from:

- From new wells on undrilled acreage
- From deepening existing wells to a different reservoir
- Where a relatively large expenditure is required to (a) Complete an existing well or (b) Install production or transportation facilities for primary or improved recovery projects.

3.6. Unproven Hydrocarbon Reserves

Unproven Hydrocarbon Reserves are reserves based on geologic and engineering data similar to that used in estimates of proved reserves, but practical, contractual, commercial, or regulatory uncertainties make such reserves classified as proved. Unproved reserves may be estimated assuming future economic conditions different from those prevailing at the time of the estimate. Unproved reserves may be further classified as probable reserves and possible reserves.

3.7. Probable Reserves

Probable reserves are those unproved reserves that analysis of geological and engineering data suggests are more likely than not to be recoverable. Probability estimates are for probable reserve estimation, and there is a 50% probability that the estimated hydrocarbon volume would be recovered.

3.8. Possible Reserves

Possible reserves are those unproved reserves that the study of geological and engineering information acclaims as less likely to be recoverable than probable reserves. This definition of reserves is excluded from a study carried out by a study group of the Society of Petroleum Engineers in conjunction with the World Petroleum Congress. These definitions are important both to companies and countries, and they can have a very significant commercial impact. The classification of the reserve as presented by the study group of the Society of Petroleum Engineers and the World Petroleum Congress is presented in Figure 1.

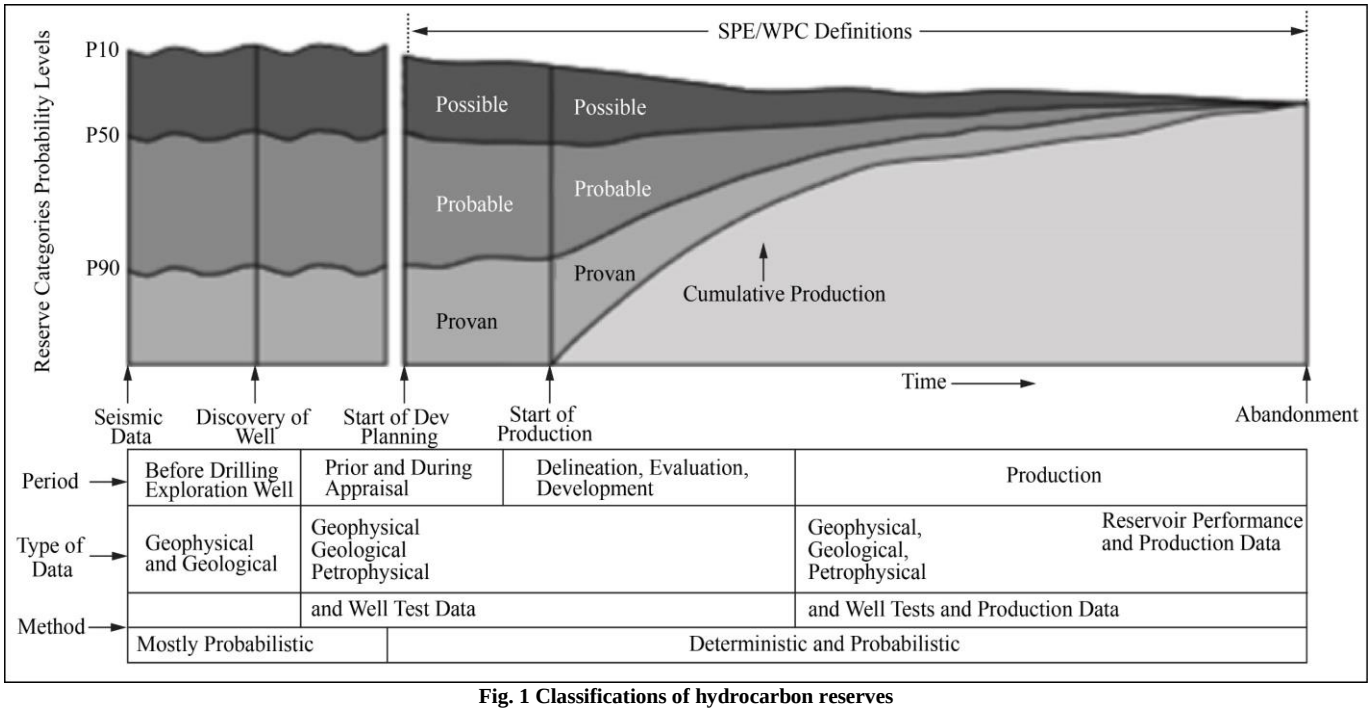

Fig. 1 Classifications of hydrocarbon reserves

There is an estimate of about 159 trillion cubic feet of natural reserves in Nigeria. Thus, Nigeria is regarded as one of the top 10 natural gas-rich countries worldwide.

In Nigeria, an estimate carried out in the year 2003 showed that there were recoverable oil reserves of about a billion barrels. This oil reserve base was projected to increase as a result of more appraisal drilling and oil explorations. More than 900 million barrels of recoverable crude oil reserves have already been identified in the country. The Nigerian government set a target to achieve an oil reserve of 40 billion barrels in the year 2010.

Table 1. Crude oil reserve estimates in nigeria 1988-2005

Years	Crude Oil Reserves (Billions of barrels)	Years	Crude Oil Reserves (Billions of barrels)
1988	16.0	1997	25.0
1989	16.0	1998	27.0
1990	17.5	1999	28.0
1991	18.5	2000	20.0
1992	19.0	2001	30.5
1993	20.5	2002	32.0
1994	21.0	2003	33.0
1995	23.0	2004	33.5
1996	23.5	2005	35.0

Source: Olalekan (2010)

Table 1 above shows the increase of crude oil reserves in the country between the years 1988 to 2005. This increase is a result of the discovery of new oil wells over the years.

3.9. Portfolio Management

Portfolio management is the key skill that one requires to manage investment effectively. According to Borad (2018), the portfolio is a collection of investment instruments like shares, mutual funds, bonds, and other cash equivalents, etc. Portfolio management is the art of selecting the right investment tools in the right proportion to generate optimum returns with a balance of risk from the investment made. In other words, a portfolio is a group of assets. The portfolio gives an opportunity to diversify risk. Diversification of risk does not mean that there will be an elimination of risk; even an optimum portfolio cannot eliminate market risk but can only reduce or eliminate the diversifiable risk. As soon as risk reduces, the variability of return reduces (Brinson *et al.*, 1991). Best portfolio management practice runs on the principle of minimum risk and maximum return within a given time frame. A portfolio is built based on an investor's income, investment budget, and risk appetite keeping the expected rate of return in mind.

4. Methodology

The following materials were used in this study. An onshore field production data for three reservoirs, an Excel worksheet, and questor software by IHS. Economic indicators such as net present value, internal rate of return, profitability index, payback period, and unit technical cost were used to carry out economic analysis. A discounted cash flow (DCF) was built MS Excel platform with equation 1 as the basic principle of the DCF model.

$$Net\ cash\ Flow = Receipts - Disbursements \quad (1)$$

All receipts include all cash inwards especially generated from the sales of oil, while all disbursements include all cash outward beings expenditures and costs of oil field development. Cost objects were generated from the Questor software and inputted into the DCF model. Three different sizes of reservoirs were considered, there are:

- Small reservoir
- Medium reservoir
- Large reservoir

4.1. Production Profile

The production profile defines how the oil and gas flow rates will change with time for a whole field life. The production profile is normally generated by reservoir engineers by performing reservoir simulations. The production profile includes three phases (Build up, Plateau, and Decline phases).

4.2. Build-Up Phase

During this period, production wells are progressively brought on flow. This is the early production line in which the wells are newly drilled and gradually put on flow. The production at the buildup phase begins with an instant flow rate measured in barrels. Crude oil or natural gas is produced at a specific build-up rate (a_i) and period of time (t).

$$a_i = \frac{(q_i/q_p)}{N_p} \quad (2)$$

Where:
q_i= initial flowrate
QP = peak production flow rate
N_p = cumulative production at the build-up phase

Build up rate can also be calculated using:

$$a_i = \frac{ln(q_i/q_t)}{t} \quad (3)$$

Where:
t = time
$q_t = q_{i+1}$or q_{peak} or q at production time

$$q_t = q_i e^{-at} \quad (4)$$

Annual production buildup rate N_a is calculated as:

$$N_a = \left(\frac{q_i - q_{i+1}}{a_i}\right) \times 365 \quad (5)$$

4.3. Plateau/Peak Phase

A constant production rate is maintained. The plateau phase starts as soon as the buildup phase is over; in this phase, all the wells in the field are completed, and production is at its peak. The peak production flow rate is sustained over a number of years until the natural reservoir energy begins to deplete and the production flow rate begins to drop.

Peak production rate q_p = constant
Annual peak production rate $N_p = q_p\, x\, 365$ (6)

4.4. Decline Phase

All producers show declining production rates. This is the last stage in the life of a reservoir. It begins as soon as the peak production is over. At the decline phase, there is a rapid pressure drop. The oil field operator may embark on pressure maintenance projects like the installation of artificial lifts, development and completion of injection wells for either water or gas injection or enhanced oil recovery system.

Decline production rate a_d is calculated as:

$$a_{nd} = -ln(1 - a_d) \quad (7)$$

Annual decline production is calculated as:

$$N_a = \left(\frac{q_i - q_t}{a_{nd}}\right) \times 365 \quad (8)$$

whereq_i = initial peak production rate

4.5. Field Data

The Fields data collected and used in this project are tabulated in Table 2.

Table 2. Field data

Reservoir Size	Small	Medium	Large
Initial production rate (bbl/d)	125	4,000	4,500
Peak production rate (bbl/d)	25,000	90,000	100,000
Decline rate (%)	15	15	15
Build-up phase (years)	6	3	3
Peak phase (years)	5	3	5
Decline phase (years)	5	4	12
Field life (years)	16	10	20
CAPEX ($)	202,064	720,259	1,024,933
PV of CAPEX ($)	21,593.52	178,037.01	62,623.69
NPV ($MM)	17.03	4,853	6,990
Cumulative production (MMSCF)	149	249	500

5. Results and Discussion

5.1. Annual Production Rate

The annual production rates for the three reservoirs (small, medium, and large) are shown in Figures 2, 3, and 4, respectively.

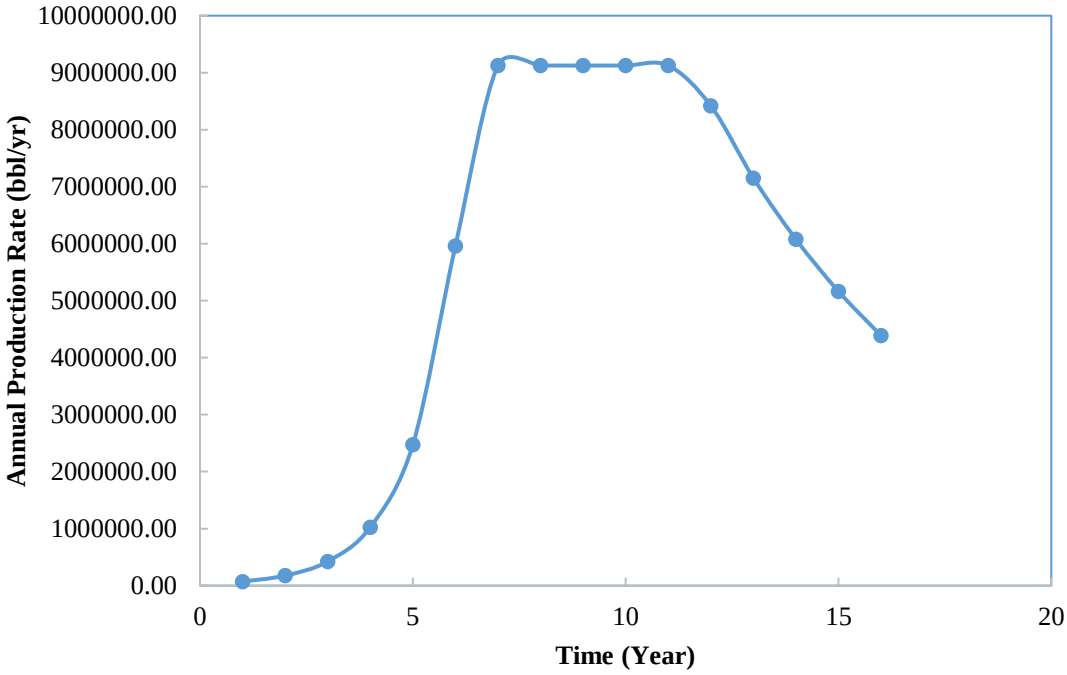

Fig. 2 Graph of annual production rate (bbl/yr) for small reserve

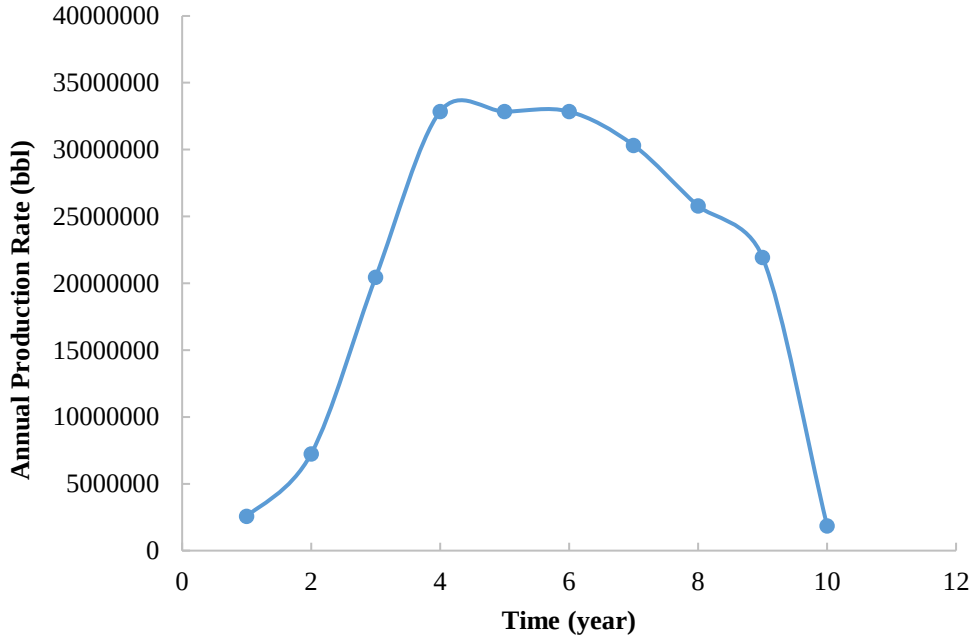

Fig. 3 Graph of annual production rate (bbl/yr) for medium reserve

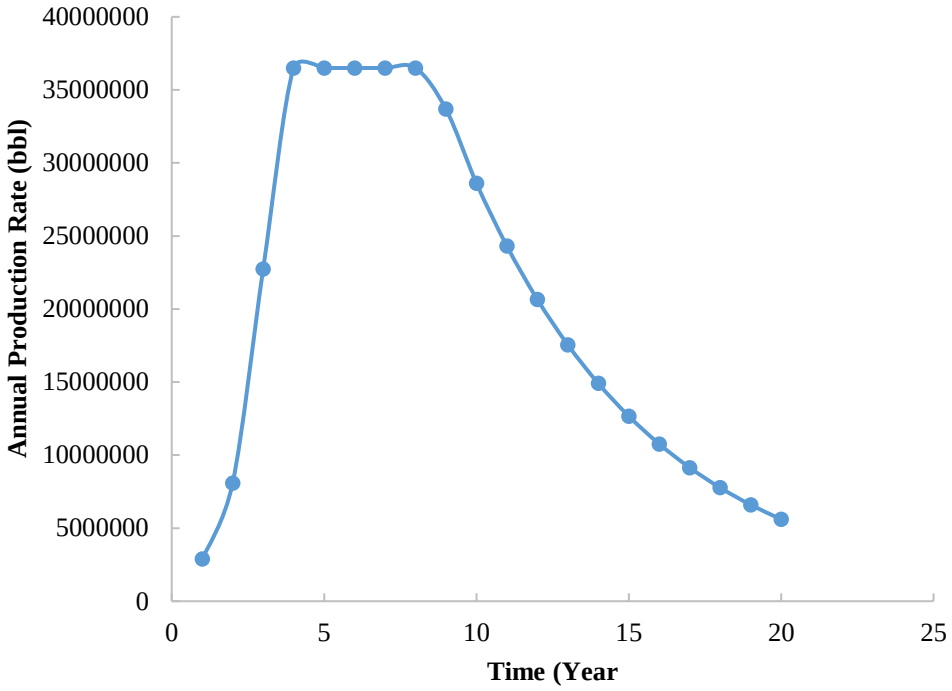

Fig. 4 Graph of annual production rate (bbl/yr) for large reserve

The results displayed in Figures 2, 3, and 4 show that the annual production rate for all three reservoirs increased periodically in the buildup phases of the field life, became constant throughout the plateau or peak phases and reduced spontaneously during the decline phases.

5.2. Cumulative Production Rate

The cumulative production rate for the three reservoirs: small, medium, and large, are shown in Figure 5.

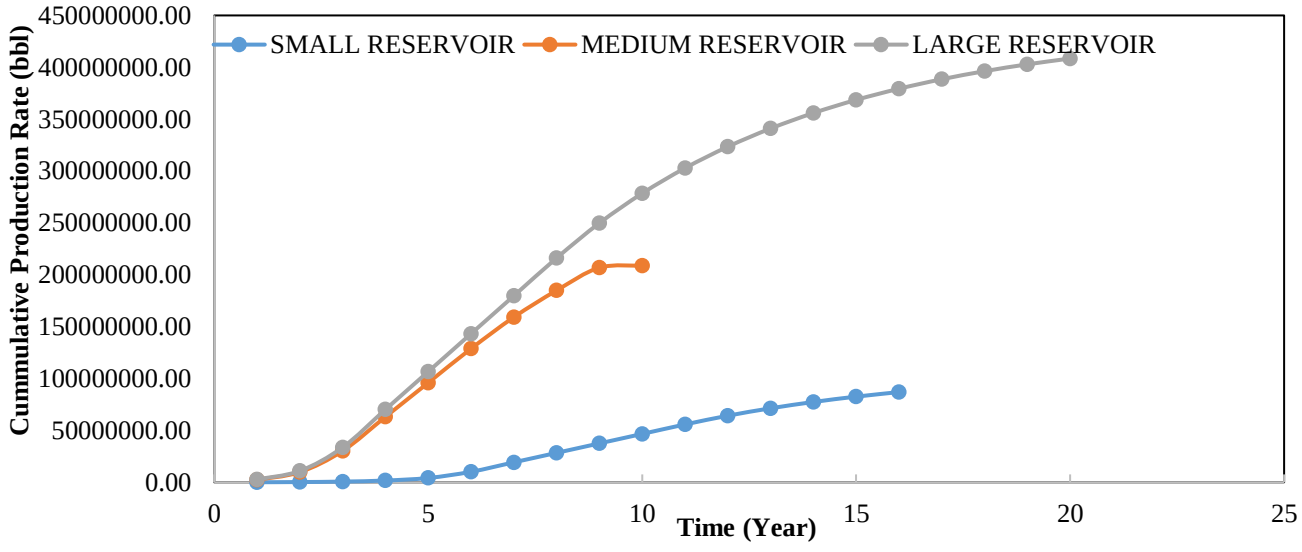

Fig. 5 Graph of cumulative production rate (bbl/yr) for small, medium and large reserve

Table 3. Results of economic analysis

RESERVE SIZE	ECONOMIC INDICATORS			
	NPV ($MM)	PI	PVR	POP (Years)
Small	17.29	800.49	800.52	2
Medium	4853.80	27262.69	27262.84	2
Large	6990.28	111621.72	111623.51	2

The cumulative production rate displayed in Figure 5 shows that, generally, the cumulative volume of crude oil produced increases as the field life increases.

5.3. Economic Tools Analysis

The economic indicators (NPV, PI, PVR, and POP) calculated for the three reservoirs are presented in Table 3.

Table 3 reveals that the net present value (NPV) gives the discounted value (profit or loss) of the investment, and it is positive for all reserve sizes. It indicates that the investment is profitable. The profitability index (PI) is greater than 1; this indicates that the investment's net present value is greater than the capital investment for the three different reserves. The payback period is about two (2) years indicating that the investment's net cash flow turns positive in about 24 months. This is generally favorable and profitable for an oil and gas investment.

5.4. Decision Tree

A decision tree is a tool used to estimate the risk behavior of an investment and the risk associated with every investment. A decision tree is designed for the three reservoirs shown in Figure 6 and assigned equal probabilities.

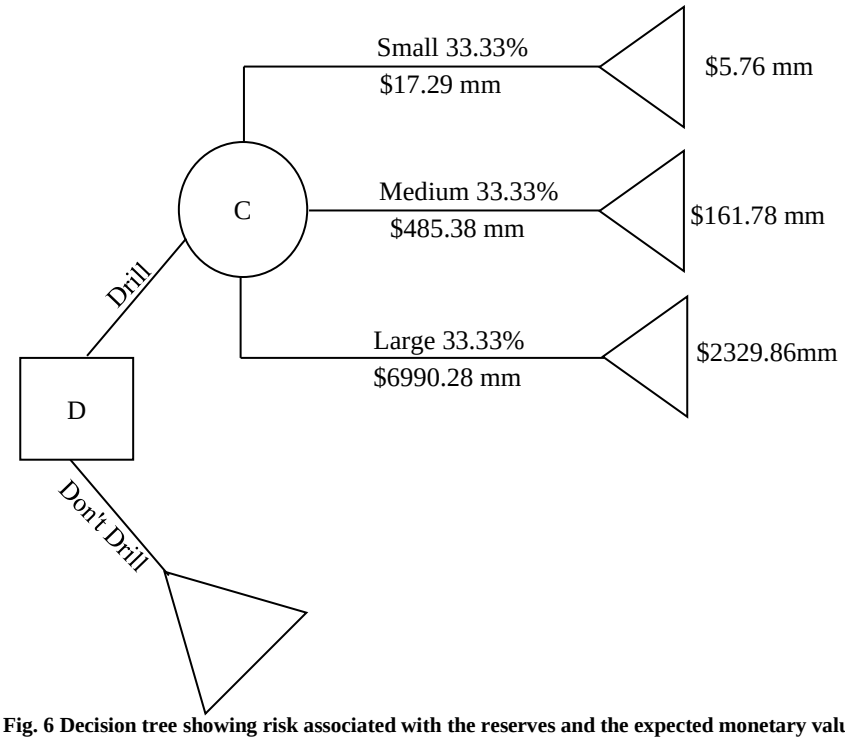

Fig. 6 Decision tree showing risk associated with the reserves and the expected monetary values

The decision tree shows the net present value (NPV) and the expected monetary value (EMV) for the three reserves at a 33.33% probability. The equal probabilities assigned to the three reserves show that all reserves are profitable regardless of the associated risk. The investor may decide to drill, given the chance that outcomes are profitable.

6. Conclusion

The relationship between crude oil reserve size and portfolio (investment) management was investigated in this paper by determining the appropriate portfolio management tools, such as the net present value (NPV), profitability index (PI), present value ratio (PVR), and payback period (POP) for different reservoir sizes (small, medium and large) required for optimum returns on investments. A decision tree that estimates the risk behavior of the investments (the three reservoirs) and shows the expected monetary value of the investment was also designed.

At the end of this study, the value of all the portfolio management tools (decision tools) indicates that the three reserves are profitable investments. The net present values (NPV) were all positive: small ($17.29MM), medium ($4853.80MM), and large ($6990.28MM). Profitability indexes (PI) were all greater than one: small (800.49), medium (27262.69), and large (111621.72); present value ratios (PVR) were all greater than zero, and the Payback period (POP) was about 24 months for all reserves. All reserves are profitable; hence depending on the portfolio size of the investor, the investments may be harnessed as mutually exclusive investments or as collectively exhaustive investments.

Recommendations

Based on the study findings, it is recommended that stochastic analysis be applied to confirm the results generated from the discounted cash flow model and decision tree.

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