“Economic Evaluation of Oil & Gas Fields”

A DISSERTATION REPORT

Submitted by

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in partial fulfillment for the award of the degree

Of

MBA (Upstream Asset Management)

To

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CERTIFICATE

This is to certify that the dissertation project report on "Economic Evaluation of Oil & Gas Fields" completed and submitted by Abhishek Kumar Gupta in partial fulfilment of the requirements for the award of degree of Masters of Business Administration (Upstream Asset Management), is a bonafide work carried out by him under my supervision and guidance.

To the best of my knowledge and belief the work has been based on investigation made, data collected and analyzed by him and this work has not been submitted anywhere else to any other University or Institution for the award of any degree/diploma.

Mandira Agarwal 30.04.08

Dr. Mandira Agarwal
Astt. Professor

<u>**DECLARATION**</u>

I, **Abhishek Kumar Gupta,** student of **M.B.A. (Upstream Asset Management)** at UPES declare that work done on "***Economic Evaluation of Oil & Gas Fields***" is original.

Any references made in this project are duly acknowledged.

To the best of my knowledge and belief the subject matter here is original and has not been submitted to any other university till date.

Abhishek Kumar Gupta.

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INTRODUCTION

Oil and gas producing industry, which is extractive in nature, involves activities relating to acquisition of mineral interests in properties, exploration (including prospecting), development, and production of oil and gas. Oil and Gas companies consist of many types of activities before it starts its operation in the field. It involves bidding procedure, acquiring mining lease, petroleum exploration license (PEL). It consists of high risk and uncertainties which may cause financial distress for the company. The aforesaid activities are collectively referred to as upstream operations and form the 'Upstream Petroleum Industry'. The industry is commonly referred to as the 'E&P' industry.

In order to assure the receipt of fair market value for oil and gas asset Economic Evaluation is performed. Economic Evaluation consists of the assessment of oil and gas resources the valuation of resources in the market and the use of evaluation in considering the bid, exchange offer or other action. Full development of all three components of economic evaluation is essential if it is to be successful evaluation. Evaluation process embraces a range of procedures which, when applied to available data leads to an estimation of the rights or property's value. So to quantify the risk and uncertainties a good economic evaluation process is needed. There are many economic evaluation processes. Among the existing evaluation processes, which one is the best, is the main motto of our study.

This report discusses different method of economic evaluation like Accounting Rate of Return (ARR), Payback Period, Discounted Payback Period, Net Present Value (NPV), Internal Rate of Return (IRR), NPV per barrel of Oil, Maximum Sustainable Risk (MSR), Net Incremental Cost of Exploration, Net Incremental Cost of Development, Profit Investment Ratio (PI) and Terminal Value (TV). This report also consist some example on various methods.

These methods does not account for risk and uncertainties. A trivial change in prediction alters the whole calculation of profit and loss and may compel the company to be great loser. Now to analyze the risk and uncertainties, Risk Analysis is necessary. In this report we have included Sensitive Analysis, Decision Tree and Monte Carlo stimulation. At the end of the report the analysis is broadly given in support of the best method of economic evaluation.

1. STEPS FOR ECONOMIC EVALUATION PROCESS

The initial step of an economic evaluation is the gathering of the technical data, which include the following:

- An annual forecast of the oil and gas production that is expected to be generated by the project, where the project may be a single well, a field, an onshore license, an offshore block, or any other type of asset or group of assets. These forecasts are prepared by the geologists furnishing the amount of estimated oil and gas reserves and the engineers who then convert the reserves to annual production figures.
- An annual forecast of the oil and gas prices at which the production is expected to be sold. In larger oil companies, there are usually "company approved" forecasts that must be used for all economic evaluations, especially for oil prices. By doing this, companies strive to maintain consistency among all economic evaluations. If this is not done, then sponsors of individual projects can easily manipulate the economics in their favor through more optimistic price assumptions.
- An annual forecast of the capital expenditures that will be required to explore and develop a project. These are typically pro-vided by engineers who have evaluated the optimum methods for developing and/or producing the oil and gas (in terms of field exploiting strategies and facilities development). For the purposes of economic evaluations, a great deal of breakdown of the capital expenditures into subcategories is usually not required, although separating them into exploration capital and development capital is typical so that the decision maker can clearly see how much capital is at risk vs. the capital that is only required once a discovery is made (development capital). Any further separation into subcategories is necessary only when the tax laws or contract terms specify different treatment of these capital subcategories for income tax or contractual issues.
- An annual forecast of the operating expenses required to maintain the production of the oil and gas (e.g., costs associated with the maintenance of the plant). This is also typically provided by the engineers and is usually split into fixed costs that will be incurred each year and variable costs that will vary with the amount of production. The costs of transporting the oil or gas from the wellhead to the point of sale (e.g., tariffs paid for use of a pipeline system) are also usually entered here.
- The working interest ownership also needs to be supplied because it represents the share of the project that is being evaluated.

1.1. Modeling of the Fiscal System

Each country has a set of tax laws and/or contract terms that govern the methods by which oil and gas companies must pay a portion of their proceeds to various government agencies. Collectively, these are referred to as the fiscal system of a country. A model must be constructed that will ultimately calculate the annual after-tax cash flow that the oil company will receive over the life of the project. It is this determination of cash flow that is always the goal of an economic evaluation because, from this, many types of economic indicators may be derived to aid in the decision process. Thus, from the economic evaluation point of view, there are two fundamental types of fiscal systems.

1.1.1. Royalty/tax regimes. These types of systems are found in countries such as the United States, United Kingdom, Norway, and Australia and have the following common characteristics:

The oil company "owns" the reserves and thus receives their revenues by selling the oil and gas.

Out of the proceeds of the sales, the oil company must pay a royalty to the government, which is generally a specified percentage of the revenues. The oil company must then pay an income tax based on the profits of the project (i.e., the revenues less the royal-ties less all costs). There is a single source of cash inflow - the revenues from the sales of production - and four sources of cash outflow: royalty, capital expenditures, operating costs, and taxes.

1.1.2. Production Sharing Contracts. The derivation of the after-tax cash flow is very different in production-sharing contracts, which are used most often, but not exclusively, in emerging markets (e.g., Angola, Indonesia, Malaysia, and China).

- Unlike royalty/tax systems, the oil company does not "own" all of the reserves. Rather, the government may be considered the original owner.
- The government allocates a portion of each year's actual production (cost recovery) to be used by the oil company to recover their costs of exploration, development, and operating.
- The value of the production remaining in a given year after cost recovery is deemed to be the profit of the project. This profit is then shared between the oil company and the government.
- There are two sources of cash flow inflow to the oil company - cost recovery and profit share - and two sources of cash outflow: capital expenditures and the operating costs.

1.2. Calculation of Economic Indicators

The final step in the economic evaluation process is to summarize the future cash flow projections from Step 2 into various economic indicators that will allow you to make a decision on whether to proceed with the project. One of the key concepts upon which many economic indicators are based is the time value of money.

The time value of money can best be illustrated by asking a question. Would you rather have USD 100 today or USD 100 a year from today? The answer is today and the reason is that you could take that USD 100 today, put it in the bank for 1 year, and earn interest on it. Assuming a 5% interest rate at the bank, this means that you would have USD 105 at the end of the year, which is better than the USD 100 offer.

Working this concept backwards, if there is a projection that USD 105 will be earned from a project 1 year from now and we have the same bank, then that USD 105 is only worth USD 100 today. This process of converting future cash flows into today's value is called discounting, and the amount of equivalent value today of a future cash flow is called its present value. If each year of a future cash flow projection is converted into today's value and then all of these present values are added together, the result is what is commonly referred to as the net present value (NPV).

The NPV is the best measure of the actual value in monetary terms of any individual project. The interest rate at the bank referenced in the preceding example is commonly called the discount rate, and it generally represents the oil company's alternative earnings rate. There are various methods used to derive the company discount rate, but most companies have a standard one that must be used for all new projects to maintain consistency of results among multiple projects.

Besides NPV, there are three other economic indicators:

- Rate of return is mathematically derived as the only discount rate that forces the NPV to be exactly zero.
- Payout (or payback) is a meaningful indicator of how long it takes a project to recoup its capital expenditures from the profits.
- A profitability index is a measure of the earning power of each dollar of capital and is calculated by taking the total after-tax cash flow for the life of the project and dividing it by the total capital expenditures. This indicator may be done on either an undiscounted or a discounted basis.

Many other economic indicators may be used, each with its own strengths and weaknesses. When viewed together, though, they usually give a very good indication of whether or not the project should proceed.

2. DIFFERENT APPROACHES FOR ECONOMIC EVALUATION

2.1. NPV Methods:

NPV may be described the summation of prescribed values of gas proceeds in each year minus the summation of present values of net cash outflows in each year. Symbolically the NPV for projects having conventional cash flows would be:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+K)^t} + \frac{S_n + W_n}{(1+K)^n} - CO_o$$

If cash outflow is also expected to occur at some times other then at initial investment-(Non Conventional Cash flow), the formulae would be:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+K)^t} + \frac{S_n + W_n}{(1+K)^n} - \sum_{t=0}^{n} \frac{CO_t}{(1+K)^t}$$

The decision rule for the project under NPV is to accept the project if the NPV is positive and reject if NPV is negative. Symbolically,

1. NPV > 0, Project accept
2. NPV < 0, Project reject.

Zero NPV implies that the firm is indifferent to accepting or rejecting the project. However, in practice it is rare if ever such project will be accepted, as such a situation simply implies that only the original investment has been recovered.

Merits:

1. NPV explicitly recognizes the time value of money.
2. It considers total benefit arising out of the proposal over its life time.
3. A changing discount rate can be built into the NPV calculations by altering the denominator. This feature becomes important as this rate normally changes because the longer the time span, the lower is the value of money and the higher is the discount rate.
4. This method is particularly useful for the selection of mutually exclusive projects.

5. This method of asset selection is instrumental in achieving the objective of financial management which is the maximization of the share holder's wealth. The rationale behind this contention is the effect on the market price of the shares as a result of acceptance of a proposal having present value exceeding the initial outlay or, as a variation having NPV greater than zero. The market price of shares will be affected by the relative force of what the investors expect and what actual return is earned on the funds. The discount rate that is used to convert benefits into present values is the minimum rate or the rate of interest is that when the present values of cash inflows is equal to the initial outlay or when the NPV is equal to zero, the return on investment equals the expected or required rate by investors. There would, there fore, be no change in the market price of the shares when the present values exceeds the outlay or the NPV > 0, the return would be higher than expected by the investor. It would, therefore, lead to an increase in share prices.

Limitations:

1. It is difficult to calculate as well as understand and use in comparison with the payback method or even the ARR method, but this can be taken minor flaw.
2. A more serious problem associated with the present value method, involves the calculation of required rate of return to discount the cash flows. The discount rate is most important element used in the calculations of the present values because different discount rates will give different present values. The related desirability of a proposal will change with a change in the discount rate.
3. Another shortcoming of the present value method is that it is an absolute measure. Prima facie between two projects, this method will favor the project which has higher present value (or NPV). But it is likely that this project will also involve larger initial outlay. Thus in case of project involving different outlays, the present value method may not give dependable results.
4. This method may also not give satisfactory result incase of two project having different effective lives. In general, the project with a shorter economic life would be preferable, other things being equal. A project with a higher present value may also have larger economic life so that the fund will remain invested for a longer period, while the alternative proposal may have shorter life but smaller present value. In this situation the present value method may not reflect the true worth of the alternative proposals.

2.2. Internal Rate of Return Method:

This technique is also known as yield on investment, marginal efficiency of capital, marginal productivity of capital, rate of return, time adjusted rate of return and so on. Like the present value method the IRR method also consider the time value of money at discounting the cash streams. The basis of the discount factor, however, is different in both cases. In the case of net present value, the discount rate is the required rate of return and being the predetermined rate, usually the cost of capital, its determinants is external to the proposal under consideration. The IRR, on the other hand is based on the fact which are internal to the proposal. In other words, while arriving at the required rate of return for finding out present values the cash flows (inflows and outflows) are not considered. But the IRR depends entirely on the initial outlays and the cash proceeds of the project which is being evaluated on acceptance or rejection. It is, therefore, appropriately refer to as internal rate of return.

The **Internal Rate of Return** is the discount rate that equates the present value of cash inflows with the initial investment associated with a project, thereby causing NPV of project zero.

Assuming conventional cash flows, mathematically the IRR is represented by the rate, r, such that

$$CO_o = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} + \frac{S_n + W_n}{(1+r)^n}$$

$$Zero = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} + \frac{S_n + W_n}{(1+r)^n} - CO_o$$

For unconventional cash flows, the equation would be:

$$= \sum_{t=0}^{n} \frac{CF_t}{(1+r)^t} + \frac{S_n + W_n}{(1+r)^n} - \sum_{t=1}^{n} \frac{CO_o}{(1+r)^t}$$

$$= \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} + \frac{S_n + W_n}{(1+r)^n} - \sum_{t=0}^{n} \frac{CO_t}{(1+r)^t} = Zero$$

where, r= The internal rate of return
CF_t= Cash Inflows at different time period
S_n= Salvage Value
W_n= Working capital adjustment
CO_t= Cash Outlay at different time periods

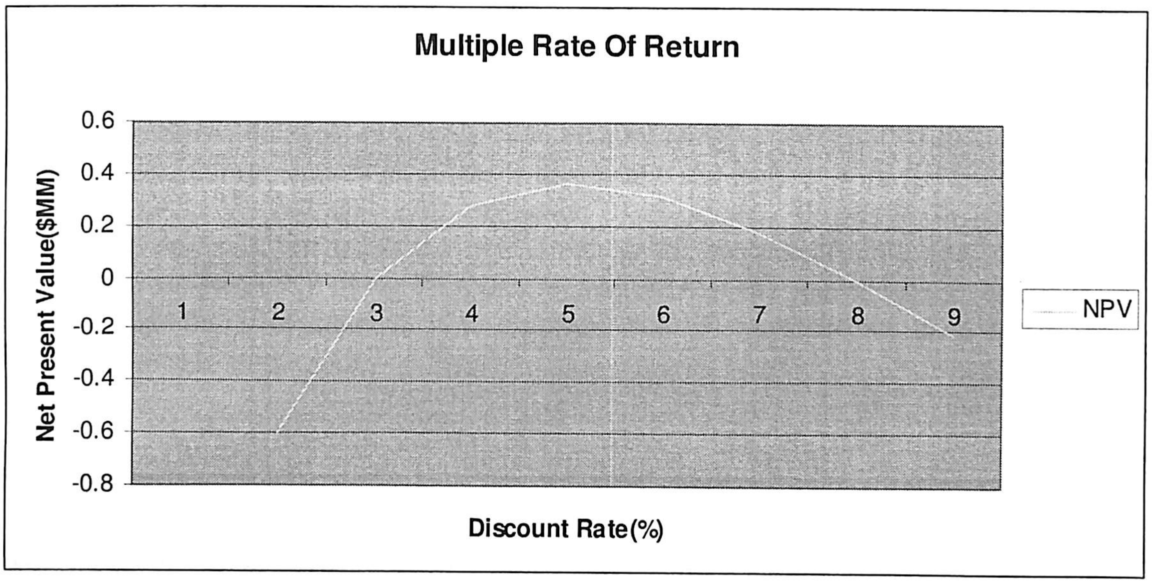
The use of IRR, as a criterion to accept capital investment decision involves a comparison of the actual IRR with the required rate of return also known as Cut Off or hurdle rate. The project would be qualified to be accepted if the IRR exceed the cut off rate. If the IRR and the required rate of return are equal the firm is indifferent as to whether to accept or reject the project.

2.2.1. Multiple Rate of Return:

In some cash flows profile there are multiple IRRs. In general, the number of IRR will be the same as the number of times that the sign of the net cash flows changes. We will show this by an example.

In this example a petroleum project has an initial capital investment of $10 million in year 1, gives a net cash flow of $27 million in year 2 but is uneconomic in year 3 and must be abandoned at a cost of $17.6 million. The NPV of this project at different discount rate is shown below.

			Time=0		End Yr1		End Yr2	
Net Cash Flow($MM)			($10.00)		$27.00		($17)	
Discount Rates	0%	10%	20%	30%	40%	50%	60%	70%
NPV	-0.6	0	0.28	0.36	0.31	0.18	0	-0.21



Merits of IRR

The IRR method is theoretically correct technique to evaluate capital expenditure decision. It has the advantages which are offered by the NPV criterion such as time value of money and also it account for all the project cash inflows and outflows. In addition following are the advantages:

1. It is easier to understand. Business executives and non technical people understand the concept of IRR much more readily than they understand the concept of NPV. They may not be following the definition of IRR in terms of the equation but they are well aware of its usual meaning in terms of rate of return on investment. For instance, business executives will understand the investment proposal in a better way if told that IRR of Oilfield B is 21% and k = 10% instead of saying that the NPV of Oilfield B is Rs.15,396.

2. It is consistent with the over all objective of maximizing shareholder wealth. According to IRR, as a decision criterion, the acceptance or otherwise of a project is based on comparison of the IRR with the required rate of return. The required rate of return is, by definition, the minimum rate which investors expect on there investment. In other words, if the actual IRR of an investment proposal is equal to rate expected by the investors, the share price will remain unchanged. Since, with IRR, only such projects are accepted as have IRR > required rate, the share price will tend to rise. This will naturally lead to the maximization of shareholders wealth.

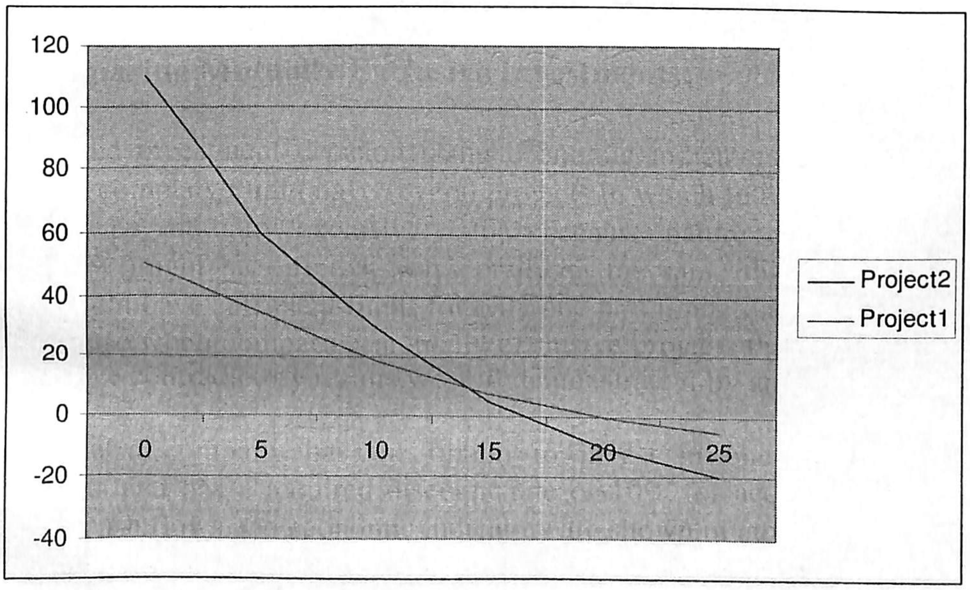
Limitations

1. It involves tedious calculations.
2. It produces multiple rate which can be confusing.
3. In evaluating mutually exclusive proposals, the project with the highest IRR would be picked up to the exclusion of all others. However, in practice, it may not turn out to be the one which is the most profitable and consistent with the objective of the firm that is, maximizing the shareholders' wealth.
4. Under the IRR method, it is assumed that all intermediate cash flows are reinvested at the IRR.

2.2.2. Comparing Mutually Exclusive Investments:

We can make investment decision using economic indicators NPV and IRR. In practice, the company might have several projects in which to invest. Some or all of these might be mutually exclusive, either because nature of the projects (for instance, they might be different ways of doing the same thing), or because the company might have sufficient funds for only one or a limited number of projects. It can be the case when comparing mutually exclusive projects that the NPV and IRR indicators give contradictory results we will demonstrate it by an example.

Suppose that a company has the option to invest in one of two petroleum developments and has a required discount rate of 10% for accessing their relative merits. The cash flows and economic indicators are shown in table below.



	End Yr1	End Yr2	End Yr3	End Yr4	End Yr5	End Yr6
Project 1 NCF	-100	50	40	30	20	10
Project 2 NCF	-100	1	2	10	20	175

Project 1 NPV at 10% = $19 million
Project 1 IRR = 20.3%

Project 2 NPV at 10% = $29.5 million
Project 2 IRR = 16.8%

When comparing the NPVs of the project, project 2 should be selected since it has a higher NPV. In contrast, when comparing the IRR project 1 should be selected. The two criterions give contradictory result.

However, in this example, assuming a 10% discount rate, project 2 is clearly the one which adds more to the value of company. The problem with IRR measure is that is a percentage. Although project 2 gives a lower rate of return than a project 1 the return is based on a larger total cash flow in money terms. This illustrates the problem with any percentage figure, namely that it tells us nothing about the absolute magnitudes involved. In contrast, the NPV measure does.

2.3. Terminal Value Method

The Terminal Value approach (TV) even more distinctly separates the timing of cash inflows and outflows. The assumption behind the TV approach is that each cash inflow is reinvested in another asset at a certain rate of return from the moment it is received until the termination of the project.

Accept-Reject Rule

The decision rule is that if the present value of the sum total of the compounded reinvested cash inflows (PVTS) is greater than the present value of the outflows (PVO), the proposed project is accepted otherwise not. Symbolically,

PVTS > PVO accept
PVTS < PVO reject

Merits

1. These methods explicitly incorporate the assumption about how the cash inflows are reinvested once they are received and avert any influence of the cost of capital on the cash inflow stream itself.
2. It is mathematically easier, making simple the process of evaluating the investment worth of alternative capital projects.
3. This method would be easier to understand for business executives who are not trained in accountancy or economics than NPV for IRR, as the 'compounding technique', appeals more than 'discounting'.
4. It is better suited to cash budgeting requirements. The NPV computation in spite of being a cash flow approach does not explicitly show all the cash inflows. It does not take into account cash inflows in respect of interest earnings.

Demerits

1. The major practical problem of this method lies in projecting the future rates of interest at which the intermediate cash inflows received will be reinvested.

2.4. Profitability Index (PI) or Benefit Cost Ratio (B/C Ratio):

This method is similar to the NPV approach. The Profitability Index approach measures the present value of returns per rupee invested, while the NPV is based on the difference between the present value of future cash inflows and present values of cash outlays. A major short coming of the NPV method is that, being an absolute measure, it is not a reliable method to evaluate projects requiring different initial investments.

It may be defined as the ratio which is obtained dividing the present value of future cash inflows by the present value of cash outlays. Symbolically,

$$PI = \frac{\text{Present Value Cash Inflows}}{\text{Present Value of Cash Outflows}}$$

Accept – Reject Rule

When PI is greater than, equal to or less than 1, the net present value is greater than, equal to, or less than zero respectively. In the other words, the NPV will be positive when the PI is greater than 1; will be negative when the PI is less than 1. Thus, the NPV and PI approaches give the same results regarding the investment proposals.

The selection of projects with the PI method can be done on the basis of ranking. The highest rank will be given to the project with the highest PI, followed by others in the same order.

It is common to define PI as the ratio of the PV of cash inflows divided by PV of cash outflows, the PI may also be measured on the basis of net benefit of a project against its current cash outlay rather than measure its gross benefits against its total cost over the life of the project. This aspect becomes very important in situation of capital rationing. In such situation the decision rule would be to accept the project if the PI is positive and reject the project if it is negative.

3. COMPARISON AMONG THE ECONOMIC INDICATORS

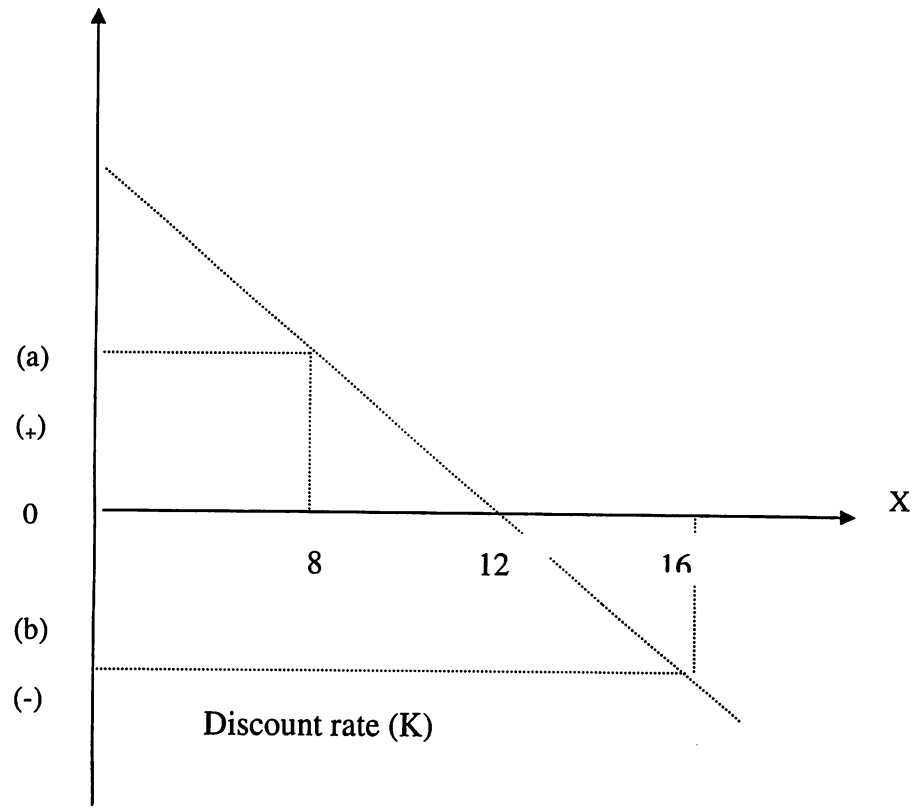
NPV, IRR, Profitability Index Methods- A Comparison:-

3.1. NPV vs. IRR Methods –

The NPV & IRR methods would in certain situations give the same accept – reject decision. But they may also differ in the sense the choice of an asset under certain circumstances may be mutually contradictory. The comparison of these methods, therefore, involves discussions of (i) The similarities between them, and (ii) their differences, as also the factors which are likely to cause such differences.

3.1.1. NPV and IRR similarities:

The two methods- IRR & NPV - would give consistent results in terms of acceptance or rejection of investment proposals in certain situations. That is, if a project is sound, it will be indicated by both the methods. If, however, it doesn't qualify for acceptance, both the methods will indicate that it should be rejected.
The situation in which the methods would give a concurrent accept-reject decision will be in respect of conventional and independent projects. A conventional investment is one in which the cash flow pattern is such that an initial investment (outlay or cash outflow) is followed by a series of cash inflows. Thus, in the case of such investments, cash outflows are confined to the initial period. The independent proposals refer to investments the acceptance of which doesn't preclude the acceptance of the others so that all profitable proposals can be accepted and there are no constraints in accepting all profitable projects. The reason why both the methods are equivalent and support or reject a proposal is simple. The decision criteria with these methods may be recalled here. According to the NPV method, the decision rule is that a project will be accepted if it has a positive NPV, that is, NPV exceeds zero. The IRR method would support projects in which case the IRR is more than the required rate of return (r exceeds k). When the NPV equal to zero or the IRR = k, the project may be accepted or rejected. The projects which have positive NPVs will also have an IRR higher than the required rate of return.



Thus, the above figure portrays NPV as (i) Positive, (ii) Zero, and (iii) Negative corresponding to three situations (a) IRR > K (b) IRR = K (c) IRR < K.

Figure above shows the relationship between the NPV of a project and the discount rate. If there is no K, or discount rate is zero (a very unreal situation), NPV is maximum. As the value of K increases, the NPV starts declining. At 12 per cent rate of discount, the NPV is zero. This is the IRR also because by definition it is that rate of discount which reduces the NPV to zero. Assuming cost of capital to be 8 per cent, we find that NPV is positive by amount (a) and the project is acceptable and so is it under IRR as its value is > K (0.12 > 0.08). If we assume K to be 16 per cent, the project is unacceptable as the NPV is negative by amount (b) and so is it under IRR as IRR < K (0.12 < 0.16). The two approaches lead to identical results with regard to the accept-reject decision.

3.1.2. NPV and IRR Methods: Differences

Thus, in the case of independent conventional investments, the NPV and IRR methods will give Concurrent results. However, in certain situations they will give contradictory results such that if the NPV method finds one proposal acceptable, IRR favours another. This is so in the case of mutually exclusive investment projects. If there are alternative courses of action, only one can be accepted. Such alternatives are mutually exclusive. The mutual exclusiveness of the investment projects may be of two types: (i) technical, and (ii) financial. The term technical exclusiveness refers to alternatives having different profitability's and the selection of that alternative which is the most profitable. Thus, in the case of a purchase or lease decision the more profitable out of the two will be selected. The mutual exclusiveness may also be financial. If there are resource constraints, a firm will be forced to select that project which is the most profitable rather than accept all projects which exceed a minimum acceptable level (say, k). The exclusiveness due to limited funds is popularly known as capital rationing.

The different ranking given by the NPV and IRR methods can be illustrated under the following heads:

a. Size-disparity problem;
b. Time-disparity problem; and
c. Unequal expected lives.

3.1.2(a). Size-disparity Problem

This arises when the initial investment in projects under consideration, that is, mutually exclusive projects, is different. The cash outlay of some projects is larger than that of others. In such a situation, the NPV and IRR will give a different ranking.

When faced with mutually exclusive projects, each having a positive NPV, the one with the largest NPV will have the most beneficial effect on shareholders wealth. Since the selection criterion under the NPV method is to pick up the project with the largest NPV, the NPV is the best operational criterion. As long as the firm accepts the mutually exclusive investment proposal with the largest NPV, it will be acting consistently with the goal of maximizing shareholders' wealth. This is because the project with the largest NPV will cause the share price and shareholders' wealth to increase more than will be possible with any of the other projects.

Incremental Approach- The conflict between the NPV and IRR in the above situation can be resolved by modifying the IRR so that it is based on incremental analysis. According to the incremental approach, when the IRR of two mutually exclusive projects whose initial outlays are different exceeds the required rate of return, the IRR of the incremental outlay of the project requiring a bigger initial investment should be calculated.
This involves the following steps:

1. Find out the differential cash flows between the two proposals.
2. Calculate the IRR of the incremental cash flows.
3. If the IRR of the differential cash flows exceeds the required rate of return, the project having greater investment outlays should be selected, otherwise it should be rejected.

The logic behind the incremental approach is that the firm would get the profits promised by the project involving smaller outlay plus a profit on the incremental outlay. In general, projects requiring larger outlay would be more profitable if IRR on differential cash outlays exceeds the required rate or return. The modified IRR for mutually exclusive proposals involving size-disparity problem would provide an accept-reject decision identical to that given by the NPV method.

To summarize the above discussion, the NPV method is superior to the IRR because the former supports projects which are compatible with the goal of maximization of shareholders' wealth while the latter does not. On modifying the IRR method by adopting the incremental approach, IRR would give results identical to the NPV method. The modified IRR method has other merits also. It is easier to interpret and apply than the NPV measure. However, it requires additional computation, whereas the NPV method provides the correct answer in the first instance itself.

3.1. 2(b). Time-disparity Problem

The mutually-exclusive proposals may differ on the basis of the pattern of cash flows generated, although their initial investments may be the same. This may be called the time-disparity problem. The time-disparity problem may be defined as the conflict in ranking of proposals by the NPV and IRR methods which have different patterns of cash inflows. In such a situation, like the size-disparity problem, the NPV method would give results superior to the IRR method.

3.1.2(c). Projects With Unequal Lives

Another situation in which the IRR and NPV methods would give a conflicting ranking to mutually exclusive project is when the projects have different expected lives.

Reinvestment Role Assumption The preceding discussions have revealed chat in the case of mutually exclusive projects, the NPV and IRR methods would rank projects differently where (a) The projects have different cash outlays initially, (b) the pattern of cash inflows is different, and (c) the service lives of the projects are unequal. It has also been found that the ranking given by the NPV method in such cases is theoretically more correct.

The conflict between these two methods is mainly due to different assumptions with regard to the reinvestment rate on funds released from the proposal. The assumption underlying the IRR method seems to be incorrect and deficient. The IRR criterion implicitly assumes that the cash flow generated by the projects will be reinvested at the internal rate of return, that is, the same rate as the proposal itself offers. With the NPV method, the assumption is that the funds released can be reinvested at a rate equal to the cost of capital, that is, the required rate of return. The crucial factor is which assumption is correct. The assumption of the NPV method is considered to he superior theoretically because it has the virtue of having a rate which can consistently be applied to all investment proposals. Moreover, the rate of return (k) represents an opportunity race of investment. In contrast to the NPV method, the IRR method assumes a high reinvestment rate for investment proposals having a high IRR and a low investment rate for investment proposals having a low IRR. The implicit reinvestment rate will differ depending upon the cash flow stream for each investment proposal. Obviously, under the IRR method, there can be as many rates of reinvestment as there are investment proposals to be evaluated unless some investment proposals turn out to have an IRR which is equal to that of some other project(s).

However, the IRR can be modified assuming the cost of capital to be the reinvestment rate. The intermediate cash inflows will lie compounded by using the cost of capital. The compounded sum so arrived at and the initial cost outflows can be used as the basis of determining the IRR. The limitation of IRR arising out of the inconsistency in the reinvestment rate assumption can be obviated through the modified approach.

Thus, the assumption regarding the reinvestment rate of the cash inflows generated at the intermediate stage is theoretically more correct in the case of NPV as compared to the IRR. This is mainly because the rate is a consistent figure for the NPV but it can widely vary for the IRR according to the cash flow patterns.

To conclude the discussion relating to the comparison of NPV and IRR methods, the two methods would give similar accept-reject decisions in the case of independent conventional investments. They would, however, rank mutually exclusive projects differently in the case of the (i) size-disparity problem, (ii) time-disparity problem, and (iii) unequal service life of projects. The ranking by the NPV decision criterion would lie theoretically correct as it is consistent with the goal of maximization of shareholders' wealth. Further, the reinvestment rate of funds released by the project is based on assumptions which can be consistently applied. The IRR can, of course, be modified by adopting the incremental approach to resolve the conflict in ranking. But it involves additional computation. Another deficiency of (he IRR is that it may be indeterminate and give multiple rates in the case of a non-conventional cash flow pattern. In sum, therefore, the NPV emerges as a superior evaluation technique.

3.2. Net Present Value Vs. Profitability Index

In most situations, the NPV and PI, as investment criteria, provide the same accept and reject decision, because both the methods are closely related to each other. Under the PI method, the investment proposal will be acceptable if the PI is greater than one; it will be greater than one only when the proposal has a positive net present value. Likewise, PI will be less than one when the investment proposal has negative net present value under the NPV method. However, while evaluating mutually exclusive investment proposals, these methods may give different rankings.

The reasons for the superiority of NPV method are the same as given in comparing NPV and IRR techniques. The best project is the one which adds the most, among available alternatives, to the shareholders' wealth. The NPV method, by its very definition, will always select such projects. Therefore, the NPV method gives a better mutually exclusive choice than PI. The NPV method guarantees the choice of the best alternative.

4. RISK IN THE PETROLEUM INDUSTRY

4.1. Risk in Petroleum Industry

We have deliberately ignored a key consideration in assessing the economic merits of investment alternatives. That is, risk and uncertainty. So far, the analyses have implicitly assumed that everything about a proposed petroleum project is known with complete certainty. Almost all variables we might choose to put in our cash flow projections are subject to risk - reserves, production profiles, oil and gas prices, capital and operating costs, and sometimes even royalty, tax and production sharing regimes. In this chapter we discuss risk and uncertainty and show how it can be incorporated into economic analyses.

4.2. Categories of risks

The risks and uncertainties inherent in oil and gas investments are not only larger than in many other industries, but have many components. Figure 4.1 shows that uncertainties are largest at the exploration stage. Probabilities of success on drilling a wildcat well are usually in the vicinity of 10% worldwide.

This means that typically 9 out of 10 wells will be dry.

Once a discovery has been made, the uncertainties are reduced considerably by comparison with the uncertainties of exploration, but they are still very significant. At the stage of appraising the discovery, it is still far from certain that the discovery will be developed and provides a return to shareholders. Even following a decision to develop, there are significant risks associated with development: - cost blowouts, unexpected development drilling results etc. The production stage is associated with the lowest level of risk, but the potential for unexpected reservoir performance problems, accidents, equipment failures etc always remains. Figure 4.1 describes risk and uncertainly in terms of what might be called project risk and uncertainty. That is risk and uncertainty which relates to the new oil or gas development itself. There are also general company or industry risks which are equally if not more significant. These include:-

(a). **Price risk** - the uncertainties associated with oil and gas price volatility.

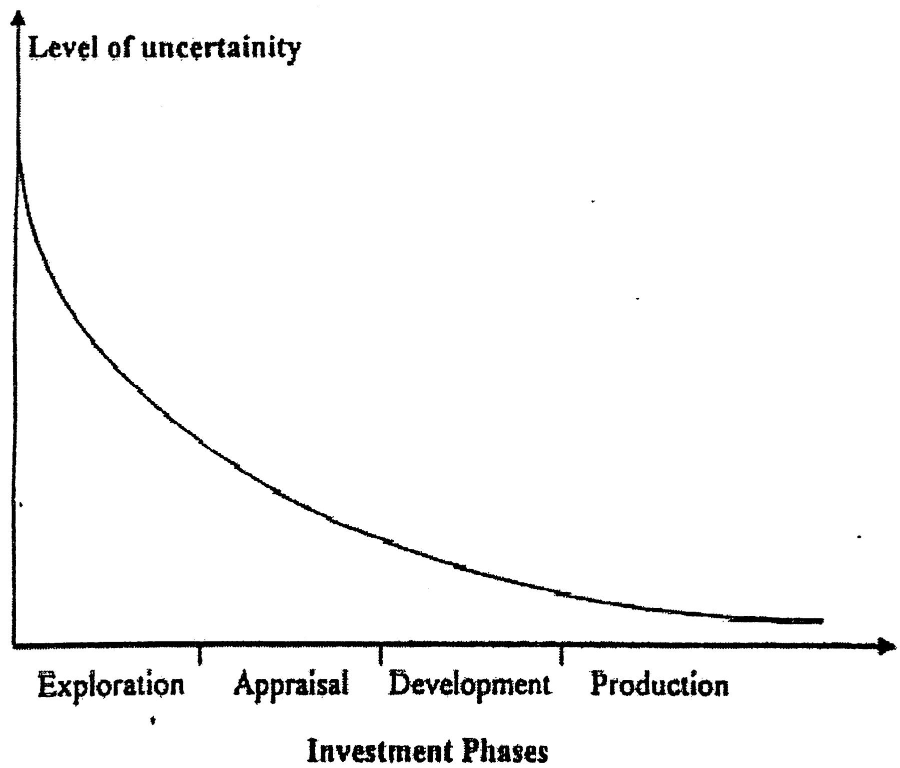
(b). **Political risk** - the uncertainties associated with political and military disturbances in any particular country.

(c). **Macro-economic risk** - the uncertainties associated with exchange rate fluctuations, interest rates, inflation rates, share market collapses etc.

(d). **Business environment risk** - the uncertainties associated with changes in commercial business practices in any particular country.

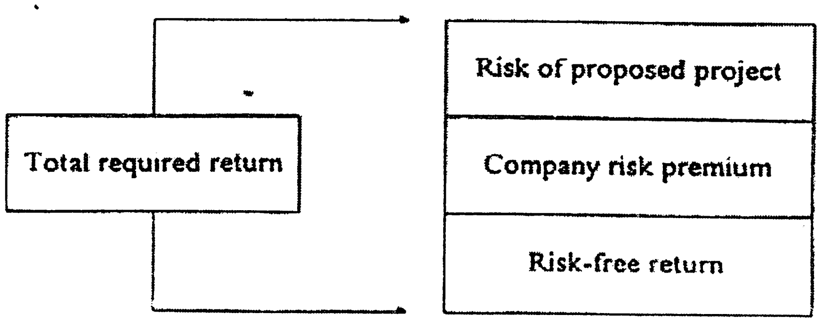
(e). The **project** and **asset risks** of all the existing projects and assets of the company.

Figure 4.1- Degrees of uncertainty in oil and gas projects



We need to take all different kinds of risk into account when making oil industry investment decisions. In theory this is reasonably easy to do, but it presents several practical problems. In theory, we can classify the risks associated with decision to invest in an oil or gas field development project in terms of different components of the return required from the project as shown in Figure 4.2 (later we will modify this view of the required return).

Figure 4.2 - Risk and required return



This diagram can be interpreted as telling us that the total required return from a project should cover:-

(a)Risk-free return

The risk-free return is the interest which shareholders could earn by investing in "safe" long term investments such as term deposit accounts treasury bonds etc. These are associated with a low level of risk because they are bank-backed or government-backed. They are referred to as "risk-free", although, in practice, they might not be completely free of risk (banks have been known to fail). However, these investments typically offer the highest security of all kinds of investment.

(b) Company risk premium

This is measured by the extra return which shareholders of the company expect (that is, have historically received) on their shares. This risk covers the normal/average risks associated with the industry and the particular company - oil price fluctuations, political risk, macro-economic risk, business risks on existing projects and assets etc. These are not only the type of risks which the oil industry as a whole must face, but also they take into account aspects of a company which are peculiar to that company. These include that company's portfolio of assets, the perceived calibre of its management, its financial structure etc.

The difference between the return which shareholders have historically received on their shares and the risk-free rate is one measure of company risk. As discussed later, the risk/return can be described as a function of general fluctuations in the share market and the volatility of the company's shares by comparison with the share market as a whole. Company risk is to be distinguished from proposed project risk (described below), since it includes aspects of the company's overall performance (including its past and existing projects) rather than aspects of any proposed project.

(c) Risk of proposed project

This is the total of the project risks of the particular investment which we are evaluating. This covers exploration, appraisal and development risks about which, typically, the shareholders of the company might not have complete information. However, the company's engineers, geologists and other technical and financial personnel will have the most complete data on the project and would therefore be in the best position to appraise and quantify its risks.

4.3. Treatment of risks in project appraisal

Among the most difficult aspects of investment or project appraisal in the oil and gas exploration and production industry are how to treat and quantify the different aspects of risk.

One way of tackling the problems starts by treating the two main components of risk and uncertainty (that is, company risk and project risk) in different ways as discussed in the following: -

Treatment of company risks

Those risks which can be classified as company risks can be taken into Account by selecting an appropriate required discount rate for our net present value calculations. This discount rate will be equal to the risk free rate plus a risk premium which reflects what shareholders require to cover anticipated company risk. We can to some extent rely on historical statistics to tell us what this premium is. The measurement of the appropriate company risk premium is discussed in the next section.

Treatment of risk for proposed new project

The risks associated with the project under evaluation cannot be handled in a similar way precisely because the particular project being appraised is a potential investment which is, by definition new, and therefore has no history. Moreover, the new project's technical risks and uncertainties are best appraised by the company's technical and financial staff who arc likely to be better informed about the project than its shareholders. Therefore, technical project risks are appropriately incorporated by risk-weighting and expected value techniques, which effectively reduce the project risks to those of the average of existing projects of the company. These average existing project risks are already effectively incorporated in share prices and are therefore incorporated in company risks which in turn are determinants of the discount rate selected.

We can now modify our definition of the required return and summarize the methodology for the treatment of risk as shown in Table 4.1:-

Table 4.1 - Treatment of risks in project appraisal

Risk?	Treatment
Risk of proposed project	Use risk-weighted variables to reduce "average" company levels.
Company risk premium and risk - free return	Select required discount rate for NPV calculation.

It is important in this system not to double-count the risks involved, particularly when choosing or risk-weighting project variables such as reserves.

For instance, we could assume that reserves for a new project at the proven-plus probable level might be generally categorized as "average" risk and would therefore be included with company risk which is taken into account by the selection of the discount rate. In contrast, the use of proven reserves would be effectively eliminating reserves risk and thereby lowering potential cash flows below what is considered to be included in average company risk. We should also ensure, for instance, that market-accepted oil price projections exchange rates and inflation rates are incorporated in the analyses.

4.4. Company risk and the choice of discount rate

The logic behind selecting a required discount rate for discounting net cash flows for new project evaluation is that it establishes the "opportunity cost of capital" for the company. The opportunity cost of capital is the return lost by not investing in the "average" project. If a new project can generate a positive net present value at the required discount rate, then, by definition, it can provide a return to the company above the return from "average" project and therefore should be accepted. If the net present value is zero when discounted at the opportunity cost of capital, then we have just covered that cost. If the net present value is negative, then the project has not covered that cost and has not therefore matched the required return to the company which shareholders expect.

As stated earlier, the cost of capital or the required or expected return is composed of a risk free rate plus a premium which takes into account company risk (see Table 4.2);

Table 4.2 - Required return

$r = r_f$ + company risk premium

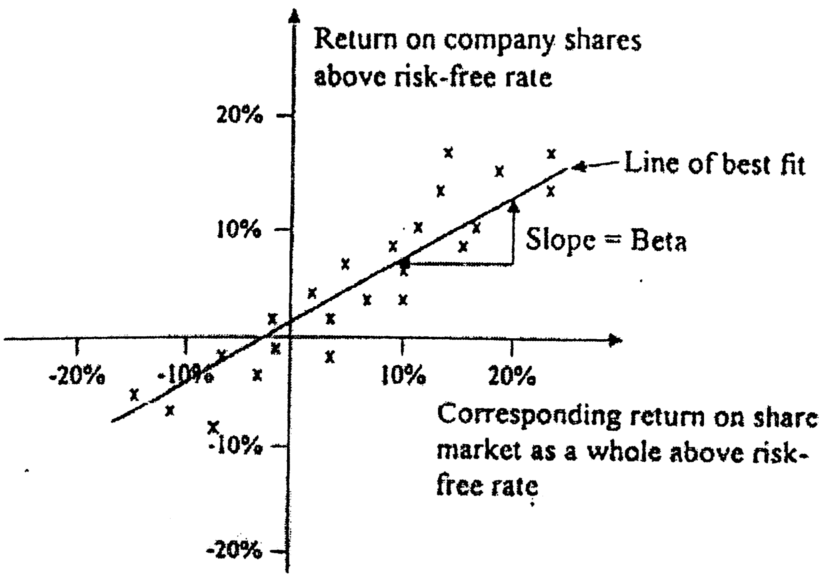
where: - r = expected return = required discount rate

r_f = risk-free rate

Estimating the company's risk premium

The company risk premium can be assessed by examining the past behavior of the returns to company shareholders. These returns can be calculated from published historical share price and financial statistics of the individual companies. The statistics can be used to compare the return from holding a share as compared 10 the return from the sharemarket as a whole (that is holding a portfolio composed of all shares). A measure of total sharemarket performance can be represented by movements in a share market index (for example, the Dow Jones or the Hang $eng indices). Pictorially, we could set up a diagram as shown in Figure 4:3.

Figure 4.3 - Variability of returns on company's shares



The slope of the line is best fit in Figure 4.3 tells us by how much, on average, an individual company's return to shareholders has varied by comparison to the return obtained from a share market index. If they move together, then the slope of the line will be 1. If the return on the company's share varies Jess than the sharemarket as a whole, the slope will be less than 1. If the return on the company's share varies more than the market as a whole, then the slope will be more than 1.

The slope of the line is called the company's "Beta". Beta is therefore a measure of the historical volatility of the return on the company's shares by comparison with the share market as a whole.

"High risk" companies might be expected to out-perform the sharemarket as a whole in bull markets and to under-perform the market as a whole in bear markets. $uch companies would have a Beta greater than 1 because they are more volatile than the market. This might be the case with oil and gas companies which often have a higher level of risk by comparison with many other companies. Conversely, "low risk" companies might under - perform the market in bull markets and out - perform the market in bear markets. Such companies would have a Beta less than 1.

A company's Beta is measured from historical sharemarket statistics. In most cases, we do not have to measure it ourselves. It can normally be obtained from the $tock Exchange in the country in which the company is listed.

Taking company debt into account

The above analysis assumes that the company has no debt, and that return from a project is attributable to shareholders. If we wish to incorporate the fact that we must also provide a return to the company's financiers - then we must modify the discount rate applicable to future cash flows.

Assuming that the company's capital is composed of 60% equity and 40% debt and assuming also as a first approximation that the return into debt is the same as the risk free rate, then the required, or expected, discount rate would be as shown in Table 4.5 :-

---

Table 4.5 - Required discount rate with debt

$$r = (r_e * 60\%) + (r_f * 40\%)$$

return on equity   return on debt

where: -
r = required discount rate
r_e = required return to equity (assuming no debt using Beta factor analysis)
r_f = risk free rate

Taking the example used earlier in this section, the required discount rate would be calculated as shown in Table 4.6

Table 4.6 - Example calculation of discount rate for company with debt

r = (17.5% x 60%) + (7% x 40%)

= 10.5% + 2.8%

= 13.3%

This example shows that the required discount rate has been reduced from 17.5% to 133% because the return from the project is required to compensate both shareholders (who require 17.5%) and financiers (who require 7%). The weighted average required return lies in between these extremes - at 13.3%.

Problems with Beta methodology

The above discusses the methodology involved in deriving a suitable discount rate which incorporates a company risk premium. The method relies on historical statistics of company arid market returns. This is a potential weakness of the method since we wish to use it to apply to future cash flows. History might not be a reliable basis on which to measure the future. For instance, if we look a measure of Beta from an oil company's past 5 year's returns, then those returns could be affected by large fluctuations in international oil prices and a high value of Beta might have been the result. However, we might view the future of oil prices to be by comparison relatively stable and therefore we might expect a lower Beta than was applicable over the past 5 years.

We might have similar difficulties with present -day risk free rates and market risk premiums as far as applying them to future long term oil and gas projects is concerned. These are basically the problems associated with the use of any present-day data to apply to the future. In this context, (here is a school of thought which believes that the correct rates to apply are the rate quoted and applicable at the present time. In other words, the "market knows best".

4.5. Project risk

In earlier sections of this chapter we discussed how the general company/ industry aspects of petroleum risk can be taken into account in deriving net present values. This was done by selecting a required discount rate higher than the rate obtainable or "risk-Free" investments {such as the bank).

However, the risk associated with particular potential projects cannot be easily incorporated in this way. Project risk is more appropriately assessed by the company and its employees who are likely to have sufficient knowledge of a particular prospect or development to be in a position to assess those project risks.

4.6. Expected value - definitions

While sensitivity analyses implicitly recognize the existence of risk and uncertainty, they do not take them into account quantitatively and explicitly. We must rely on risk-weighting and expected value concepts and probability theory in general to allow us to assess the quantitative effects of risk. Expected value analysis is a good place to start.

There are several concepts used in Expected Value analysis which require definition at the outset. These are:-

Decision alternative

A decision alternative is an option, or choice, open to the decision maker. The choice might be, for instance, to drill or not to drill an exploration well, to develop a discovery, or to gamble on a coin tossing game. It is important to note that we cannot avoid making decisions even the decision to do nothing is effectively a decision. A decision to do nothing might not be consciously made, but nevertheless, in effect, it is a decision because alternatives to it were not adopted.

Outcome or event

An outcome or an event is something which could occur once a decision is made (even if the "decision" is to do nothing). Risk analysis recognizes that, in general, there will be more than one outcome to a decision alternative. There may be an infinite number of possible outcomes.

Conditional value of an outcome

When considering the economic or financial effects of a decision, the value of an outcome measured in monetary terms is critical to the analysis. However, in general, the value of an event can be measured in any units (barrels of oil or cubic feet of gas, for instance). The value if an event occurs is called the conditional value of the event, as distinct from its expected value, which is discussed below.

Expected value of an outcome

The expected value of an outcome is the conditional value of the outcome multiplied by the probability that it will occur. For instance, we might, as part of a gamble, win $2.00 if a coin falls heads up. Given that the probability of the coin falling heads up is 50%, then the expected value would be +$2.00 times 50% equals +$1.00. We use the expression expected value or its abbreviation "EV" to refer to the expected value of an outcome which has conditional values described by anything quantifiable - reserves of oil, reserves of gas, money values, production rates, porosity, net pay etc. In contrast, the expression, "expected monetary value" or its abbreviation, "EMV", is used when we are referring to the expected value of an event which has a conditional monetary value.

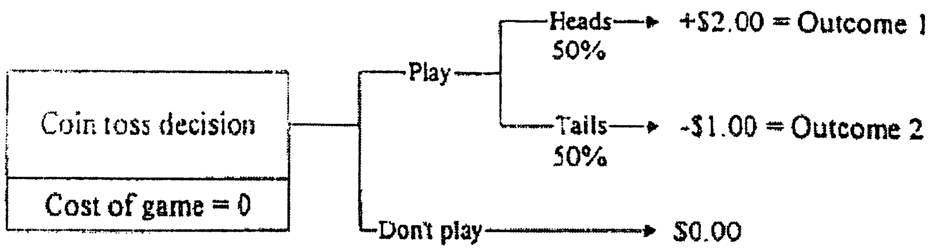
Expected value of a decision alternative

Since a decision alternative recognizes the possibility of several outcomes, the expected value of the alternative is the sum of the individual expected values of each possible outcome.

As an example of the use of expected value analysis, suppose we are invited to gamble on a coin tossing game in which we win $2.00 if the coin lands heads up, but we lose $1.00 if it lands tails up. Assume that we pay nothing to play the game.

The diagram in Figure 4.5 illustrates the different decision alternatives, their possible outcomes and the conditional values of those outcomes.

Figure 4.5 - Expected value of coin toss



We can calculate the expected value of taking part in the game as follows:-

Outcome 1 - coin lands heads up

Expected value = Conditional Value * probability
= +$2.00 * 50%
= +$1.00 (positive because we would win)

Outcome 2 - coin lands tails up

Expected value = Conditional Value * probability
=$1.00* 50
= $0.50 (negative because we would lose)

Expected value of decision to take part

= expected value of Outcome 1 + expected value of Outcome 2

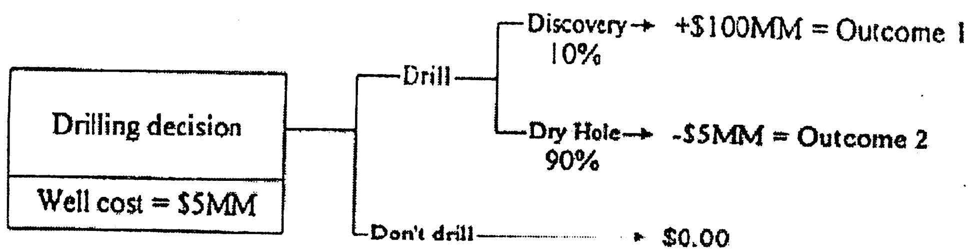
We need one more calculation to complete the analysis. That is the calculation of the expected value of not taking part in the game of doing nothing. In this case the result of the calculation is simply zero. The game still has two outcomes - heads up and tails up – but this time we win nothing and lose nothing for each outcome.

The results of our expected value calculations are $0.50 if we take part in the game, and zero if we don't. Following expected value concepts, our decision should therefore be to take part.

4.7. Expected value of example drilling decision

We are now in a position to apply expected value concepts to the decision to drill or not to drill an exploration well. Suppose, for example, we have the opportunity to drill a well on a prospect which, if successful, is expected to lead to a development with an estimated net present value ("NPV") of $100 million (net of the exploration well cost). Suppose the well costs $5 million and the estimated probability of success is 10%. The different outcomes and their conditional values arc shown in Figure 4.6:-

Figure 4.6 - Expected value of drilling decision



Based on the above, we can calculate the expected value ("EV") of the decision to drill as follows:-

EV = Conditional Value of success * probability of success

plus

Conditional value of failure * probability of failure

Therefore:- EV = ($100MM * 10%) + (-$5MM * 90%)
= $10MM - $4.5MM
= $5.5MM

Of course, the EV of the alternative decision, which is not to drill the well (that is, to do nothing) is zero.

When selecting among mutually exclusive alternatives, the expected value decision rule is to select the decision alternative which has the highest positive EV In this example, the alternatives are mutually exclusive (we can't take both alternatives in this case) and the alternative which gives the highest EV is the decision to drill the well.

4.8. Meaning, properties and implications of expected value

There are several principles and properties of expected value which is important to recognize when using the concept in practice.

Meaning of Expected Value

When we loss a coin, we know that the probability of it landing heads up is 50%. We know this because if we repeated the process many times, 50% of the time it would land heads up and 50% of the time it would land tails up. While in the first few tosses there might be an uneven number of heads and tails, after many tosses the cumulative number of times it lands heads up will be the same as the cumulative number of limes it lands tails up.

In the drilling situation, it is more difficult to interpret probabilities of success and failure in a similar way because we are unable to repeat the process. Once we have drilled the well, in practice we can't do exactly the same again as we can when tossing a coin. However, expected value can still be illustrated if we examine a simplified example.

The example is illustrated in Table 4.7 and Figure 4.7. In this table and figure we assume that a hypothetical basin contains identical prospects each of which costs $5 million to drill and has a 20% probability of success (i.e. one in five). If successful, the value of each development is $100 million Table 4.7 shows a possible sequence of events in which drilling is successful one in five limes on average in a drilling program of 40 wells (giving 8 successes in all). Table 4.7 shows the calculation of the cumulative gain per well. This statistic is plotted in Figure 4.7. It is clear that after the first few successful wells, the cumulative gain per well tends to settle to a level of $16 million. This is the expected value in this example. The more wells drilled, the cumulative gain per well becomes closer to $16 million.

The calculation of expected value for each drilling decision in this example is:-

EV = $100MM * 20% - $5MM * 80
= $20MM - $4MM
=$16MM

Expected value is not Most Likely Value

Expected value is not the same as most likely value. For example, in most drilling decisions the most likely value is that the well will be dry and thereby will have a negative monetary value. However the expected value (the risk-weighted value of success and failure) could well be positive. In the coin tossing example, there is no most likely value, yet there is always an expected value.

4.9. Decision tree analysis

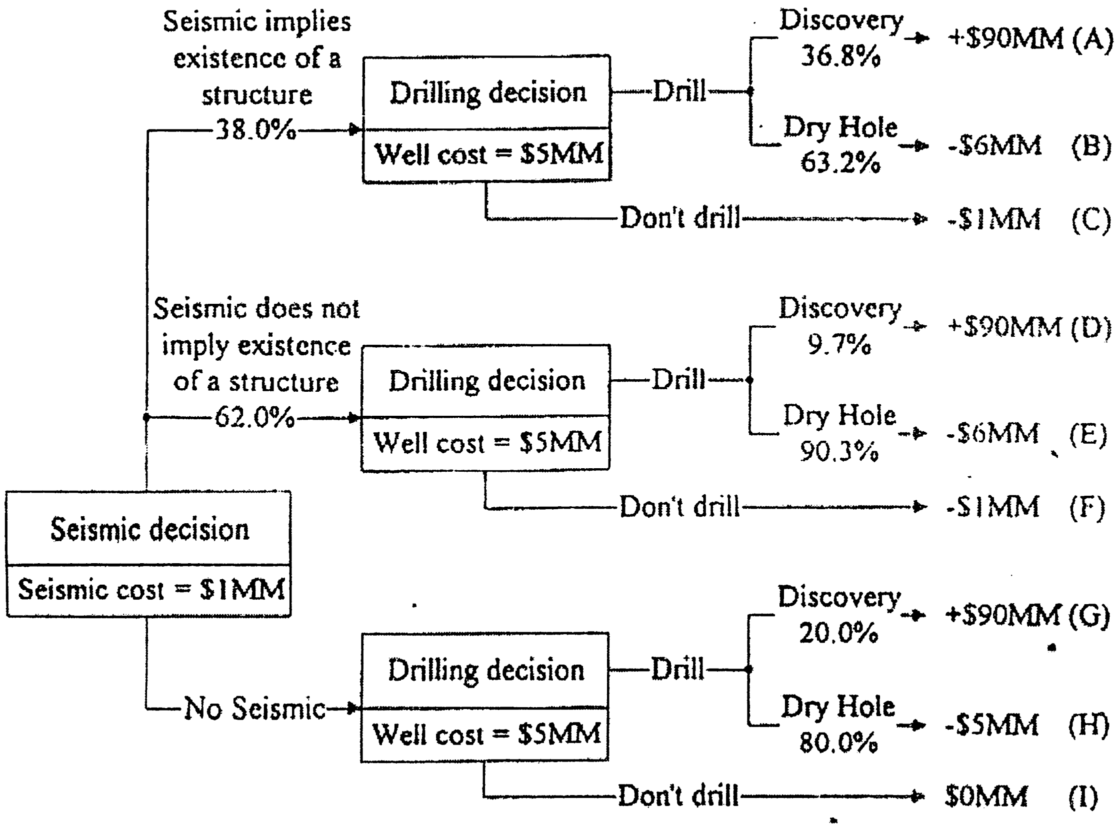
In earlier sections we discussed the use of expected value analysis and gave examples of its use in deciding whether or not to drill an exploration well, in deciding whether or not to farm out a well or how much of it to farmout. These examples are all based on a single decision with only two possible outcomes. However, expected value analysis can easily be extended to cover more complicated problems which involve a series of connected decisions and more than two outcomes. The analysis of series of connected decisions is called "decision-tree analysis. The logic and philosophy remains the same as in expected value analysis, but can handle problems-which are more complicated.

A decision tree is simply a diagram showing a sequence of decision points and their possible outcomes.

In the simplified, example which follows there arc two decision points. A company is considering conducting an exploration programme which involves deciding whether or not to conduct a seismic survey and also whether or not to drill a well. The company believes that, if the well is successful, the discovery would have an estimated net present value of $96 million. The company has estimated that the present value of the cost of the seismic survey is $1 million and the present value of cost of the well is $5 million.

If the seismic is carried out, we assume that it will either imply the existence of a structure or it will not. In this example, there is a 38% probability that the seismic will imply the existence of a structure and a 62% probability that it will not. Probabilities are also assigned to each drilling outcome. The decision tree diagram representing these different outcomes is shown in Figure 4.10.

Figure 4.10 - Decision tree for seismic decision



Note that in Figure 4.10 the values of the different outcomes are placed at the end of the decision tree branches. Each value takes into account the present value of the costs and revenues up to that point. For instance, the present value of a dry hole at branches (B) and (E) ($6 million-consists of the present value of the costs of the seismic survey ($1 million) plus the present value of the costs of the well ($5 million). The present value of a discovery at branches (A) and (D) is $90 million and this consists of the present value of the development itself ($96 million) less the present value of the costs of seismic ($1 million) and the discovery well ($5 million).

Each decision node in the decision tree is represented by a square box and each chance node (over which the company has no control) is represented by a the symbol.

The conditional probabilities associated with each chance node add up to 1. No probabilities are assigned to the outcomes which are direct results of decisions (for example, the don't drill decisions) because if that decision is taken, then that will be the outcome - there are no other possibilities.

Solution of decision tree

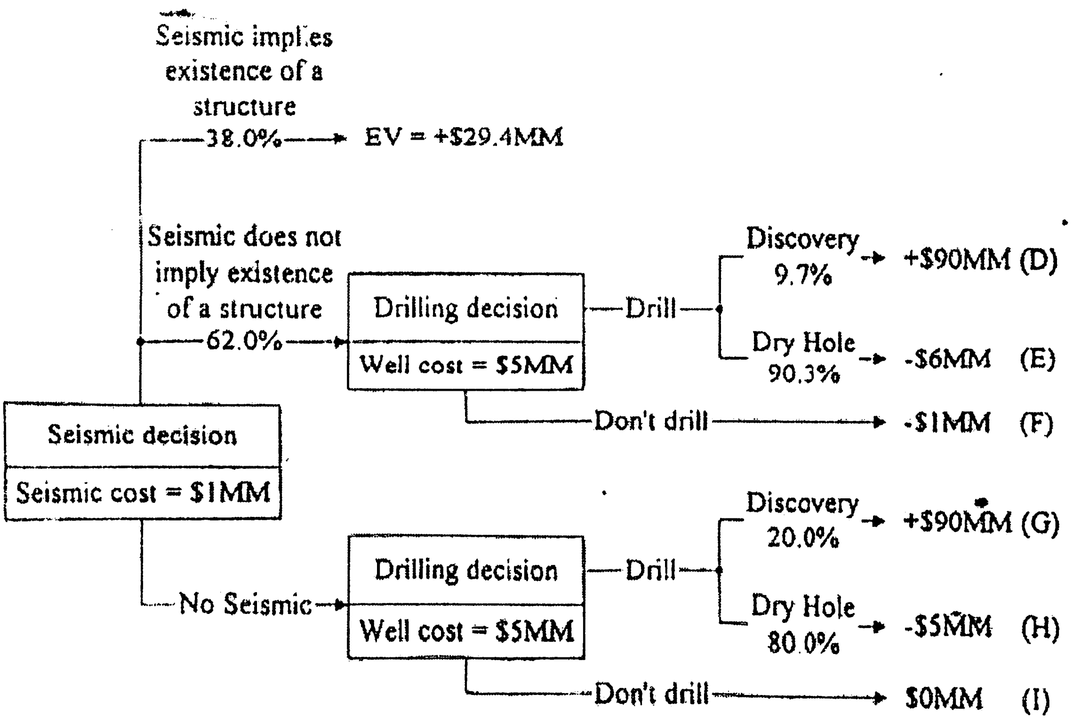
We can now proceed to solve the decision tree to determine what the company's best course of action should be. In order to do this, we must start at the end points of the branches of the decision tree and work backwards to the beginning.

Starting at the top right hand side of the tree, we can calculate the expected value of the decision to drill the well based on earlier seismic which has implied the existence of a structure. This involves calculating the expected value of the outcomes (A) and (B) in the diagram. The calculation is as follows:-

$$\text{EV of (A) and (B)} = +\$90MM*36.8\% - \$6\ MM*63.2\% = +\$29.4MM$$

For the decision note at the top right hand side of the diagram, we can compare this EV with the alternative of not drilling the well, which has a value of -$1 million. Since +$29.4 million is greater than -$1 million, the decision should be taken to drill the well. Therefore we can cross out the "don't drill" branch and then simplify the diagram by substituting the drilling decision box and everything to its right hand side by a single outcome which has a value of $29.4 million as shown in Figure 4.1.1.

Figure 4.11 - Solving branches A, B and C

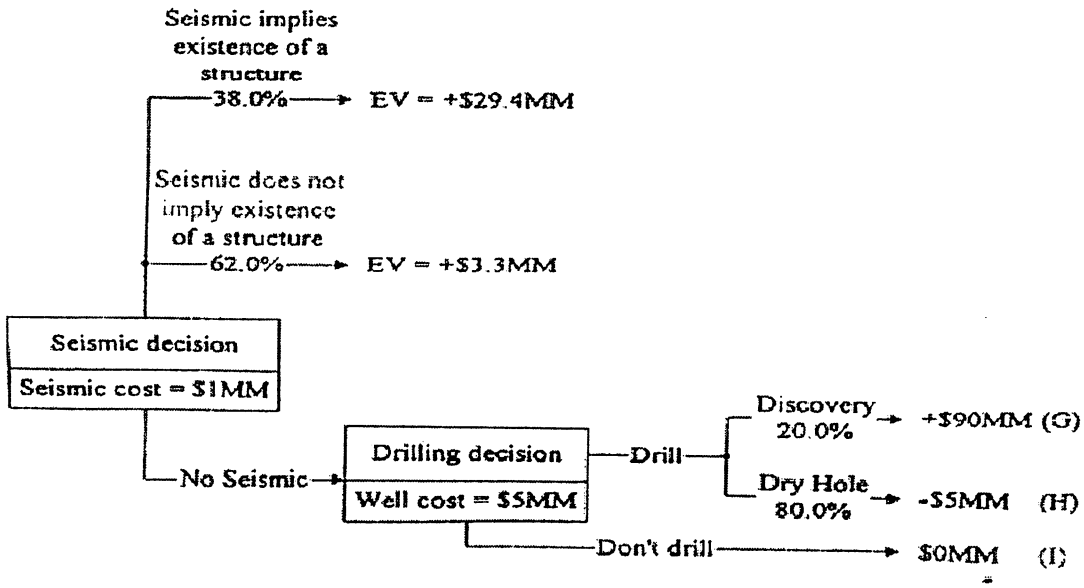


We can carry put a similar process for outcomes (D) and (E) to decide whether or not we should drill following a weak confirmation of the existence of a structure. The calculation is the same as for branches (A) & (B) as follows:-

EV of (D) and (E) = +$90MM*9.7% - $6MM*90.3% = +$3.3 MM

Again, since $3.3 million (the expected value of drilling the well) is greater than -$1 million (the value of not drilling the well), then we should drill the well. The "don't drill" branch can be eliminated and the diagram can be simplified as shown in Figure 4.12.

Figure 4.12 - Solving branches D, E and F



Repeating this process for outcomes (G) and (H) (which result from not running seismic) gives an expected value as follows :-

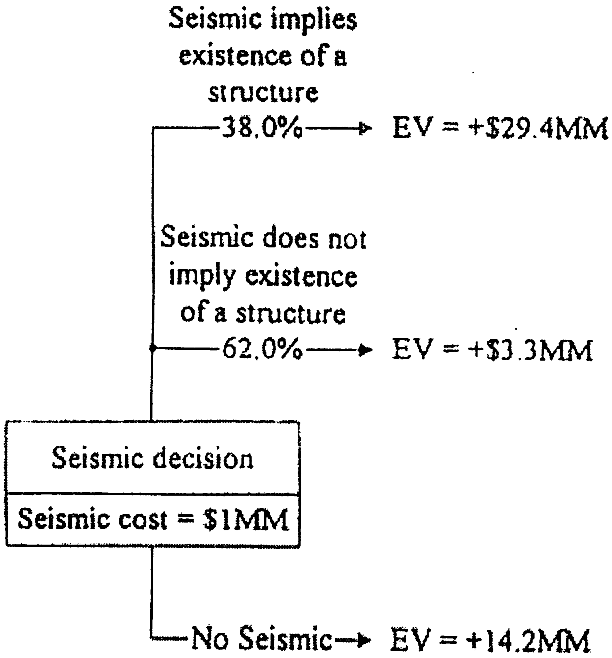
EV of (G) and (H) = +$91MM*20% -$5MM*80% = +$14.2MM

In this case, since this EV is more than the value of not drilling (zero), we should decide to drill the well. We can then cross out the "don't drill" branch and substitute the drilling decision box with a single outcome with a value of +$14.2 million. The decision tree can then be simplified further as shown in Figure 4.13.

This now much simplified decision tree can be easily solved. The expected value of running a seismic survey is given by:-

EV of running seismic = +$29.4MM*38% + $3.3MM*62% = $13.2MM

Figure 4.13 - Solving branches G, H and I



This can be compared with the value of not running seismic, which is +$14.2 million. Since +$14.2 million is greater than +$13.2 million, we should take the decision to drill the well without running the seismic survey beforehand.

What the decision tree has told us:

The construction and solution of the decision tree has told us the following:-

(a) First, drawing the decision tree has forced us to think logically about the decisions the company is faced with and to set out these decisions and all possible outcomes in a systematic and consistent way.

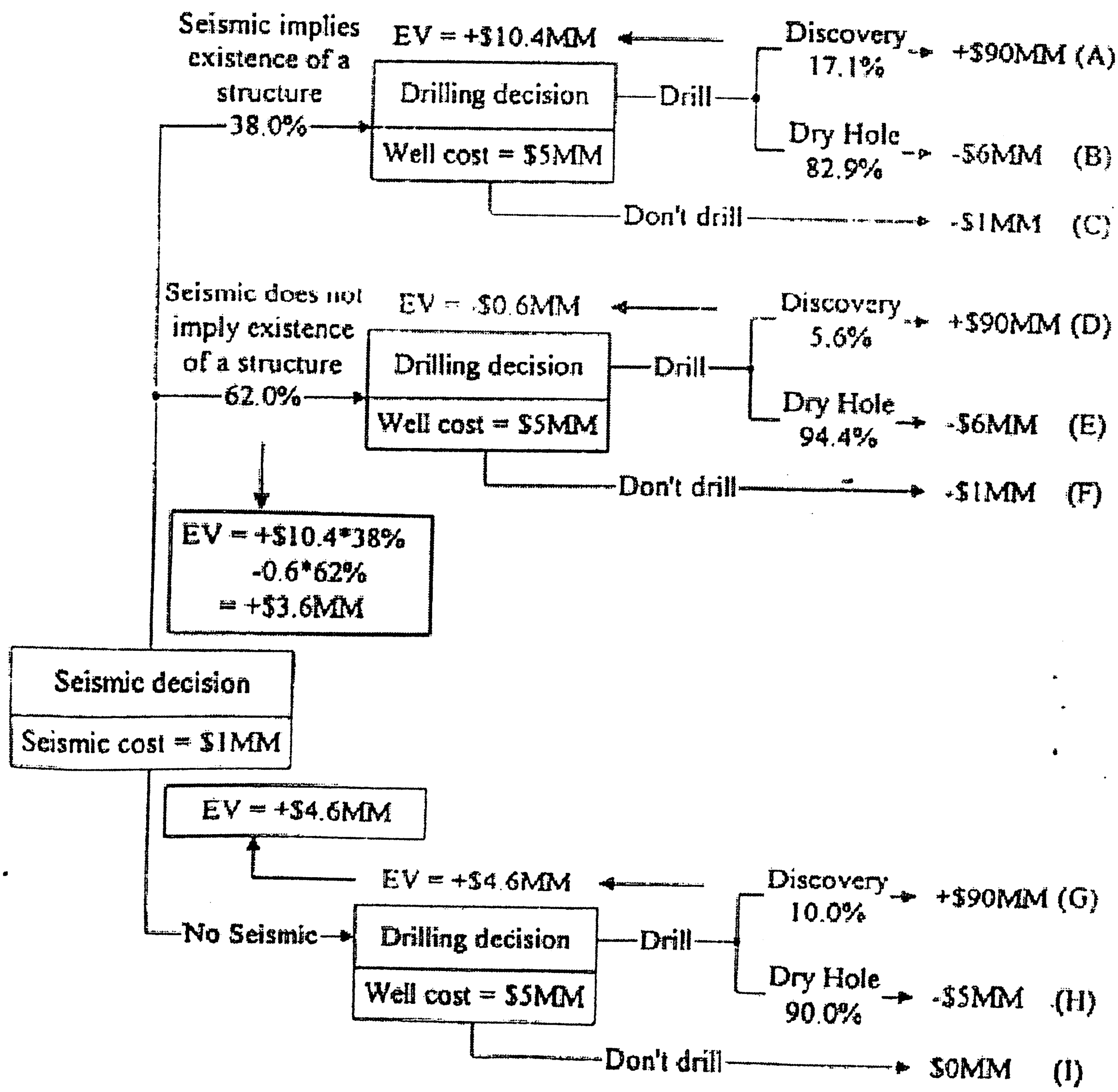
(b) Second, it has provided us with the solutions to the decisions which must be taken. Based on the data supplied, the analysis has laid us that the well should be drilled without conducting the seismic survey. The reason is that, given the risks and rewards involved, it is not worth the expense of running seismic. This is because, in this example, even though we spend an extra $1MM on the seismic, the seismic does not allow us to increase our probabilities of drilling success.

(c) Third, it has given us a means to analyze easily the effects of changing our perceptions of the possible outcomes and their associated probabilities of success and examining the sensitivity of the result to these changes. Sensitivity analyses such as this are best carried out using a computerized version of the decision tree. Spreadsheets can be used for this purpose. A sensitivity analysis based on the above example is shown below.

Sensitivity analysis

The example decision tree discussed above is repeated below, except that, this time, the probabilities of success have been changed. This time, the results of the analysis are shown in Figure 4.14.

Figure 4.14 - Seismic decision sensitivity analysis



results of the surveys showed that 80% of those surveys conducted over what eventually turned out to be commercial fields reliably suggested that an oil bearing structure existed (that is, a correct interpretation). However, the remaining 20% of surveys conducted over commercial fields erroneously suggested that an oil bearing structure did not exist (that is, an incorrect interpretation).

The analysis of the detailed seismic survey over those leads which did not become fields showed that 90% of the surveys reliably suggested that no oil bearing structure existed. "However, the other 10% of the surveys were unreliable and incorrectly suggested that a field was there.

Exploration decision

We are now considering whether or not to conduct another detailed seismic survey over another lead in the basin. We use the analysis of previous exploration to help to make the decisions. The probabilities are derived as shown in Figure 4 1 6.

4.10. Sensitivity Analysis

One way in which we can assess the effects of risk and uncertainty in project appraisal is by sensitivity analyses. These are particularly useful when looking at project risk in field development decisions, and in exploration decision making.

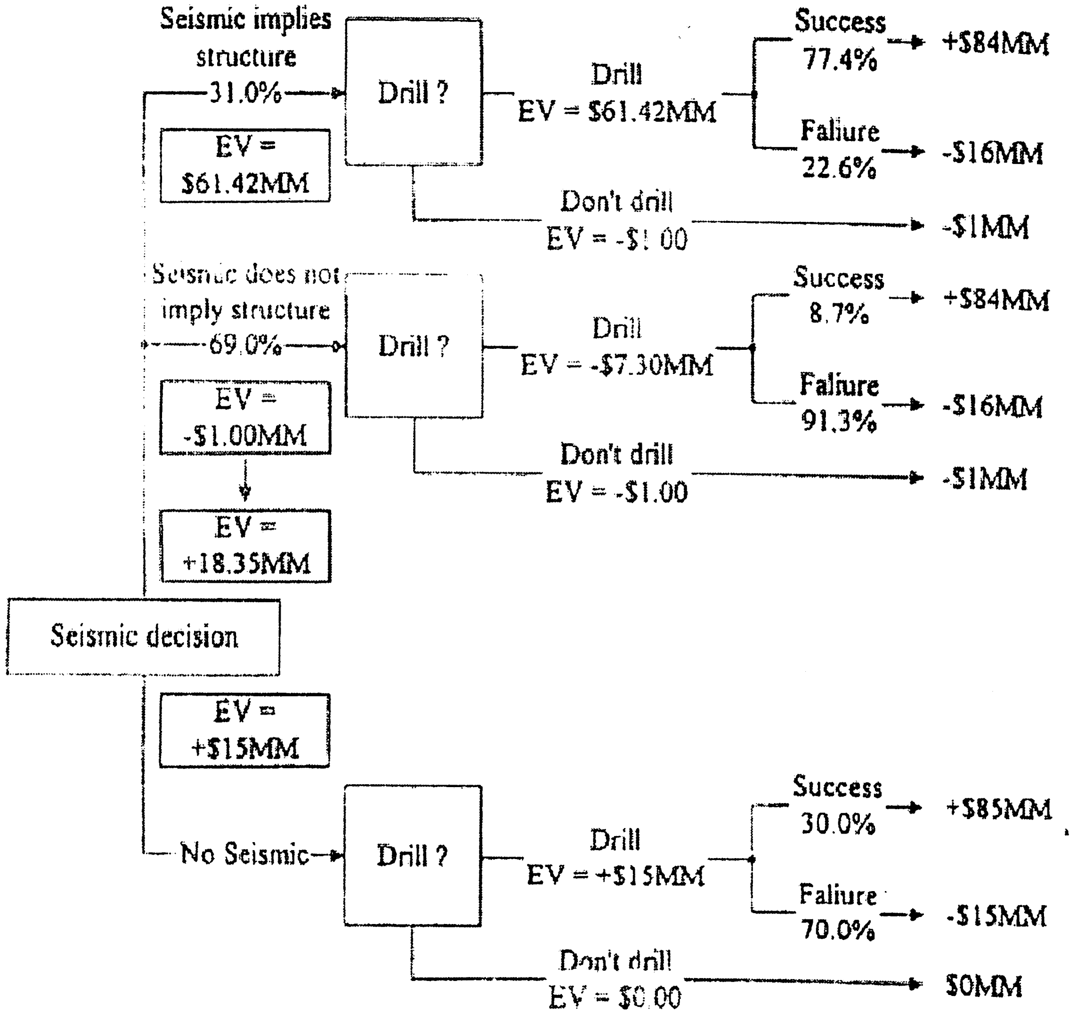
The principle behind sensitivity analyses is simple. Starting from a "base case" analysis which contains all our central or most likely assumptions, we change one assumption at a time keeping all other assumptions the same as in the base case.

For instance, suppose a base case economic analysis of a potential field development establishes that it has a net present value ("NPV") of $100 million. Varying the capital costs of the development by plus 20% and minus 20% might give the NPVs as shown in Table 4.11.

Table 4.11 - Sensitivity of changes in capital costs

Percentage of base case variable	NPV in $MM
120%	$50MM
110%	$75MM
100%	$100MM
90%	$125MM
80%	$150MM

Figure 4.17 - Decision tree to assess the value of seismic



This example sensitivity analysis shows that the project is very sensitive to variations in capital costs. For instance, a 10% increase in capital costs results in a 25% reduction in the project's NPV.

We can carry out similar analysis by varying other inputs to the NPV calculation. The results can be depicted on a so-called "spider diagram" an example of which is shown in Figure 4.18.

The spider diagram shows that the steeper the "legs" of the spider the more sensitive is the project to changes in that variable. As shown in Figure 4.18, projects are typically most sensitive to variations in capital costs (because they are front end costs) and oil prices (because they determine the revenue of the project) and not so sensitive to operating costs (because they occur later in the project and are small in relation to other costs, such as taxes etc.

Spider diagrams can also indicate how economically robust a project is to changes in assumptions. This is illustrated in Figure 4.19. Figure 4.19a shows a robust project in which significant variations in the assumptions results in only small changes in the project's NPV. In contrast, Figure 4.19b shows a sensitive project in which small changes in the assumptions result in large variations in the project's NPV. Such changes may make the project uneconomic.

Therefore, sensitivity analyses can assist us in showing what happens to the project if the assumptions are different to our original assumptions. However, sensitivity analyses do "not take into account the probability of different assumptions applying. We must turn to risk assessments to help us in this aspect of economic analysis.

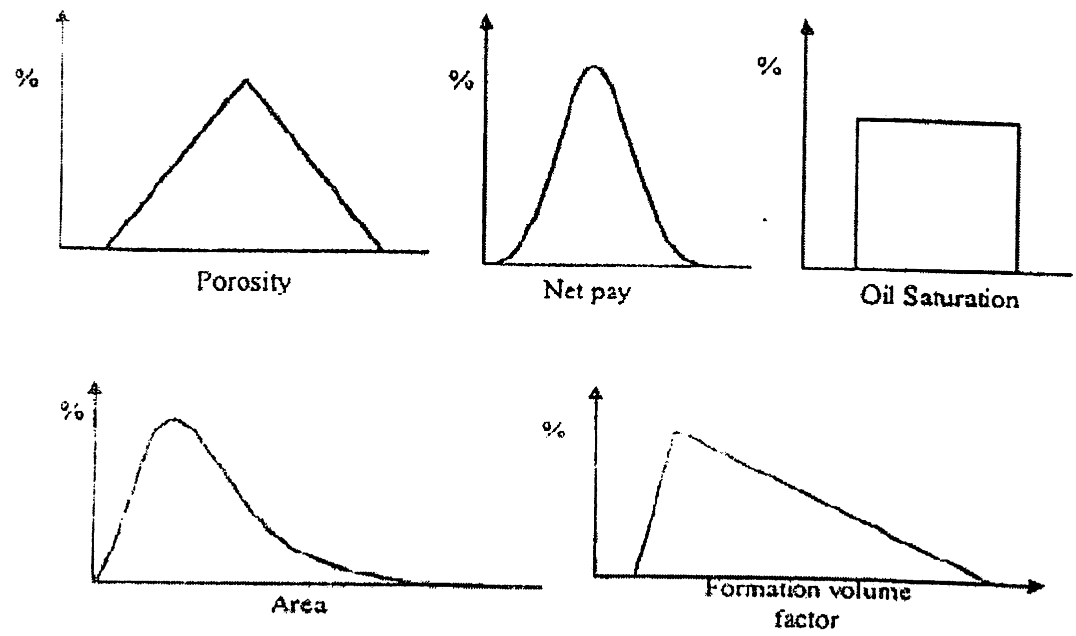
4.11. The mechanics of Monte Carlo simulation

The first stage in carrying out a Monte Carlo simulation is to estimate or select an appropriate probability distribution for each input variable in the analysis. The nature of the distribution might be different for each input variable. An example is shown in Figure 4.28 in which inputs for reserves estimation are probability distributions and the output is a probability distribution of reserves.

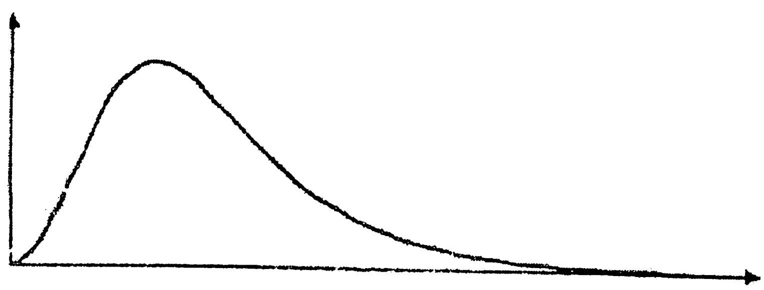
For instance, in the volumetric reserves estimation problem, we might estimate that the effective area of the reservoir could be anything between 2,500 acres and 12,500 acres and that the probability is best described by a lognormal probability distribution. Alternatively, we might feel that the effective area is best described by a histogram, a triangular distribution, any one of the mathematically defined distributions, or simply a distribution for which we define each individual point. In practice, we can use *any* type of probability distribution which best suits our estimate of the likely range of possibilities. If we use Monte Carlo simulation software on a computer to help us carry out the analysis, the computer will generate the input probability distributions for us, depending on our specifications.

Figure 4.28 - Monte Carlo simulation

Input



Output



Having defined all our input variables by probability distributions, we can now proceed with the Monte Carlo analysis. The method involves a series of steps as shown below. To make the explanation easier, we assume that we are carrying out a Monte Carlo analysis to determine a probability distribution of reserves. However, the mechanics of the analysis are the same no matter what the particular task is. In the following explanation, it is assumed that a computer is being used to carry out the analysis.

Step 1

The computer generates a random number between zero and one (or 0% to 100%).

Step *2*

The random number generated in step 1 is used to select a point on the cumulative probability distribution for one of the input variables. Assume that the variable is the area of the reservoir and that the random selection is 10,000 acres. This selection is then stored in the computer.

Step 3

The computer generates another random number between zero and one (or 0% to 100%).

Step4

The random number generated in step 3 is used to select a point on the cumulative probability distribution for another input variable. We assume that this is the distribution for the average net pay of the reservoir and that the random selection is 20 feet. This is stored in the computer.

Further steps

Further random numbers are selected, namely one for each additional cumulative probability distribution (porosity, oil saturation, oil formation volume factor and finally recovery factor). The corresponding selections of values from each of the distributions are made and stored in the computer.

When selections for each input variable have been made, then a calculation of reserves can be carried out using those values. If, for instance, in this first "pass" we selected the input value; given as shown in Table 4.25, then reserves of 59.7 million barrels would be derived.

Having calculated the reserves, the computer stores the result and the whole process is repeated many times for many "passes" of the analysis to ensure that sufficient results are obtained to give a smooth probability distribution of reserves. Under normal circumstances, the number of passes needs to be between 1,000 and 2,000.

Once a reasonable number of passes have been made, the results are separated into individual groups and the number of results in an individual group are counted precisely because of the way in which the sampling has been carried out there will be more results in some groups than in others. This will give a probability distribution of reserves which will reflect the probability distributions of ail the input parameters.

Table 4.25 - Calculation of reserves for first selection

Variable	Selection of value
A	10,000 acres
h	20 feet
Φ	22%
S_o	70%
RF	25%
B_o	1

Reserves ($A*h*\Phi*S_o*RF*B_o * 7{,}758/10^6$) = 59.7 Mmbbl

4.12. The method of sampling in Monte Carlo simulation

The reason that there are more results in some groups than in other relates to the method of sampling. The sampling is of the cumulative probabilities on the vertical axis of each input distribution is and is uniformly random. That is, the selections are spread evenly along the vertical axis. This means that one cumulative probability is as likely to be selected as any other. In other words, if many selections are made, there will be as many between the cumulative probabilities 0% to 30% (for instance) as there will be between the limits 60% to 90% (for instance). However, this even set of selections on the vertical axis only results in an even selection of values on the horizontal axis under special circumstances (namely, if the probability distribution is rectangular and therefore the cumulative distribution is a straight line). Otherwise, the set of selections will be uneven and will follow the shape of the cumulative probability curve.

The selection procedure is illustrated in Figure 4.34. The distribution in this figure is a rectangular distribution, which therefore is associated with a straight line cumulative distribution. A random (even) selection on the vertical axis of this distribution would produce a correspondingly random (even) selection on the horizontal axis.

In contrast; the distribution in Figure 4.34 is a discrete distribution with only one value. This is associated with a cumulative distribution which is step function. In this case, a random (even) selection of probabilities on the vertical axis would not result in an even selection of values on the horizontal axis. In fact, all of the selections would yield only one value (as it should).

To take another example, a triangular distribution has a cumulative probability distribution which is steep in the middle and gently sloping at each end as shown in Figure 4.36. In this case, a random (even) selection on the vertical axis results in the selection of few values at the ends of the range, but most elections are made near the middle because, by definition, this is where the more probable outcomes lie.

Because of the use of cumulative probability distributions in this way, a random (even) set of selections on the vertical axis will result in a number of selections on the horizontal axis which precisely honors the shape of the cumulative distribution curve.

4.13. Practical aspects of Monte Carlo analysis

Several aspects of the use of Monte Carlo analysis in practice are worthy of mention:-

(a) Define input Probability Distributions with Care

The definition of input distributions which suitably describe the explorationist's judgment about the different variables is critical. Monte Carlo analysis only produces results which are as good as the input data.

Figure 4.36a - Triangular distribution

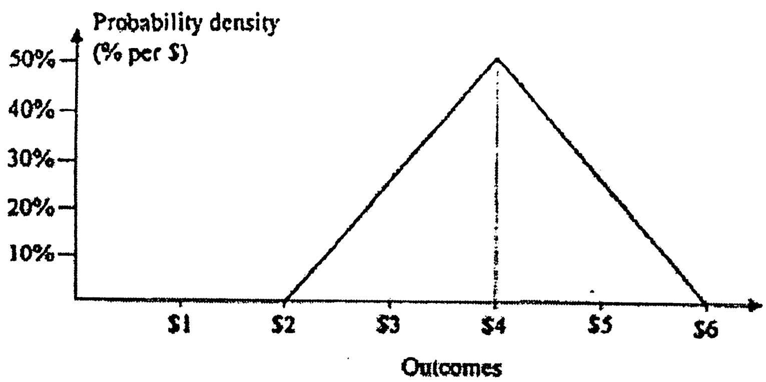
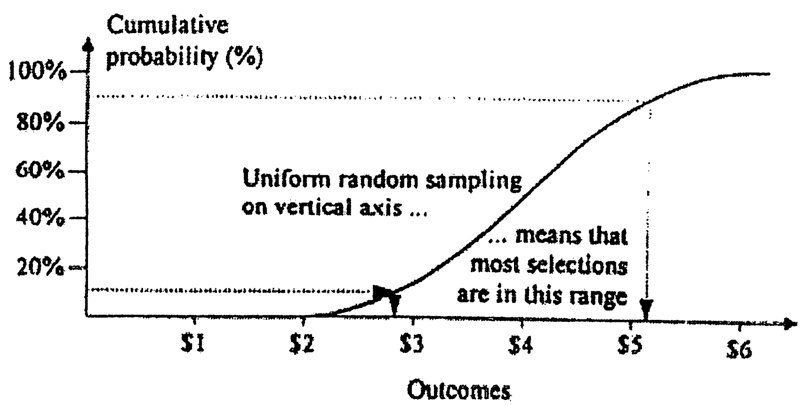


Figure 4.36b - Cumulative distribution



(b) Avoid single values for uncertain variable

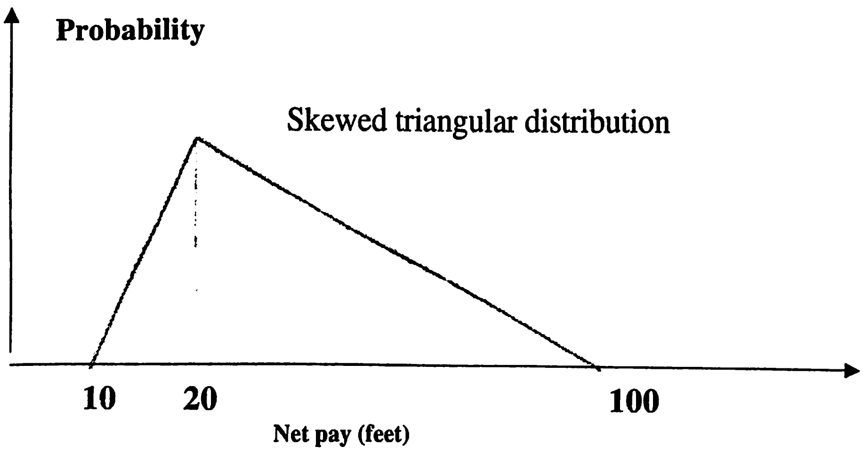
It may be difficult in some circumstances to define an input probability distribution. However, the solution to the difficulty should not be to describe the input by a single best guess. The very fact that the variable is difficult to define implies that it is subject to a large degree of uncertainty. If this is the case, then the choice of a single value is the least suitable solution to the problem. The variable would be more faithfully described by a probability distribution with wide limits (that is, a large standard derivation).

(c) Used skewed triangular distributions with care

The description of input variables by skewed triangular distributions should be done with caution. It is often tempting, for instance, to describe a skewed triangular distribution the situation in which we feel we know the lower and upper limits of a variable are far apart, but also feels that the most likely value is near the lower value.

Suppose, for example, that we put a lower limit on the net pay of a reservoir of 10 feet and an upper limit of 100 feet because we feel that it has large upside potential but with a low probability. The most likely value however, is, in our view, more like 20 feet. We might therefore describe the area by the distribution shown at the top of Figure 4.37.

Figure 4.37 - Skewed distributions



The skewed triangle fit to these three points gives a low probability that the net pay lies between 10 feet and 20 feet and a much higher probability that the net pay lies between 20 feet and 100 feet. In other words, by far the majority of the area lies in the top section of the distribution; this might not accurately represent our feelings about the variable and could have a distorting effect on the final answer. It might be that we actually feel that the probability of the net pay being between 10 feet and 20 feet is greater than it being between 20 feet and 100 feet. In other words, then a better way of filling a distribution to the points might be to use a distribution defined by more points such that the curve has shape more like that shown at the bottom of Figure 4.37.

In many cases, a lognormal distribution similar to that shown at the bottom of Figure 4.37 might fit the situation ideally.

(d) Check for dependency between variables

In some cases there may be a dependency between variables which, if not recognized in the Monte Carlo analysis, can lead to inaccurate results. Under normal circumstances, when the selection of a point on an input distribution is made, it is done randomly. However, if two input variables are mutually dependent, then this process would be incorrect. Instead of the selection from each dependent variable being at random, the selections ought to be related to reflect the fact that the variables are related. In other words, if one variable is directly related to another, then the selection of a high value from one distribution ought to be followed by a corresponding high value from the other.

Most computerized Monte Carlo simulators have the facility for defining any relationship between two variables to allow such interdependencies (or "auto correlation") to be handled correctly.

ANALYSIS

We have the data of XYZ field in the table below and we have considered **Base Production** And **Base Price** as the case.

Assumptions:-

2) Tax Holiday of 7 Years.

3) Income Tax Rate 35%

4) Straight Line Depreciation for 10 Years from the year of production.

5) Royalty at the rate of 10%

6) Discount Rate of 10%

Now we have analyzed the project for nine different combinations of High, Base and Low Price and High, Base and Low Production. For these different combinations, following are calculated value of NPV of Company, Undiscounted Government Take, Discounted Government Take and Investment Multiples.

Production	Price	NPV Of The Company	Government Undiscounted	Government Discounted
High	High	25.97	327.25	66.8
Base	High	19.69	247.92	49.62
Low	High	12.06	172.33	33.75
High	Base	20.43	244.19	48.88
Base	Base	13.63	183.41	36.1
Low	Base	7.16	117.93	22.98
High	Low	12.06	172.33	33.75
Base	Low	7.16	117.93	22.98
Low	Low	1.96	64.3	12.52

Base Production Base Price : Preferred Case

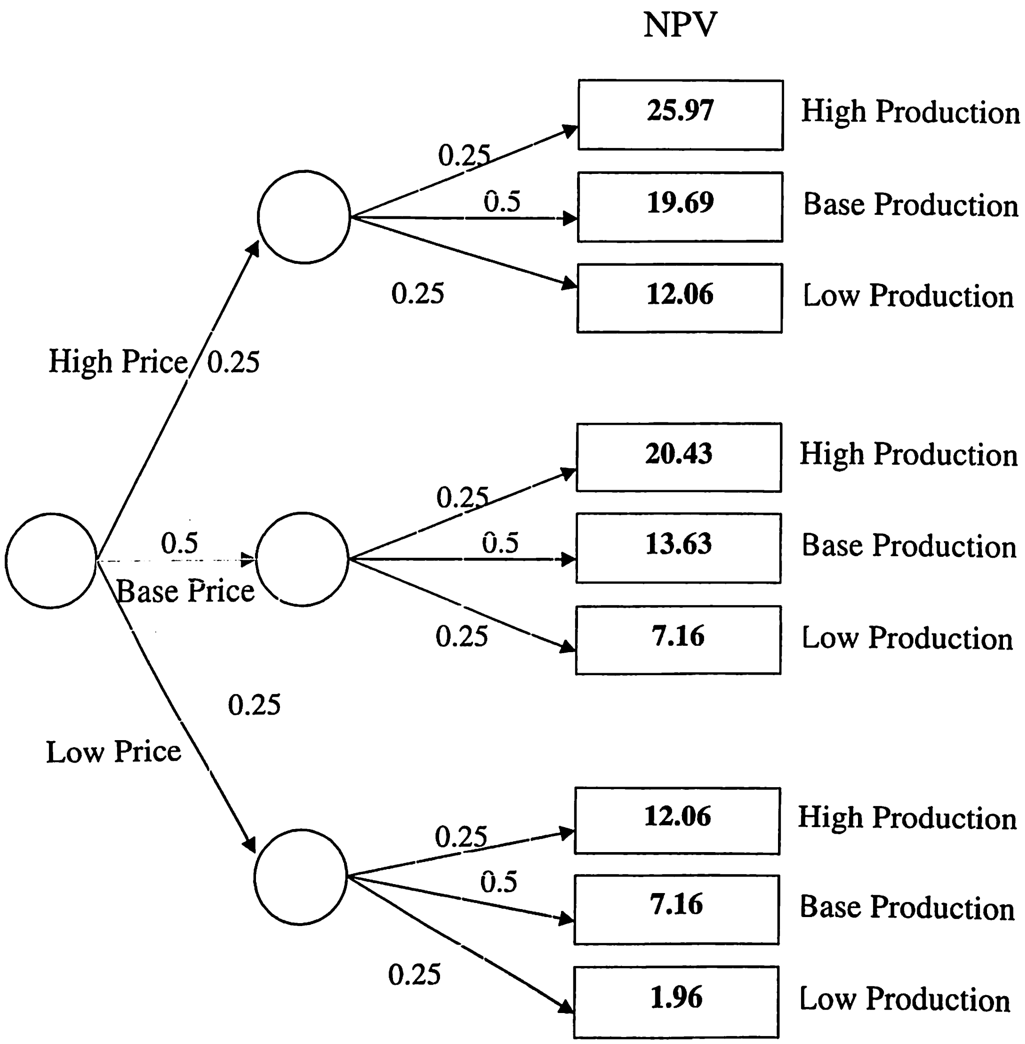
S.No.	Year	Oil Price $/bbl	Annual Production (MM bbl)	Gross Revenue	Royalties @10%	Capital Costs	Accumulated Net Investment	Operating Costs	Net Cash Income Of Contractor	Depriciation Straight Line 10 Years	C/R C/F	Profit Oil
1	1960	2.88	0	0	0	2.5	2.5	0	0	0	0	0
2	1961	2.88	0	0	0	0	2.5	0	0	0	0	0
3	1962	2.88	0	0	0	0	2.5	0	0	0	0	0
4	1963	2.88	0	0	0	0.5	3	0	0	0	0	0
5	1964	2.88	0	0	0	13	16	0	0	0	0	0
6	1965	2.86	0.9	2.574	0.2574	15.5	31.5	0.5	1.8166	5.7	0	0
7	1966	2.86	3.3	9.438	0.9438	16	47.5	1.8	6.6942	5.7	3.8834	0
8	1967	2.86	5	14.3	1.43	3	50.5	2.8	10.07	5.7	2.8892	1.4808
9	1968	2.86	5.6	16.016	1.6016	0.8	51.3	3.2	11.2144	5.7	0	5.5144
10	1969	2.86	6.7	19.162	1.9162	1	52.3	3.6	13.6458	5.7	0	7.9458
11	1970	3.18	5.6	17.808	1.7808	0	52.3	3.5	12.5272	5.7	0	6.8272
12	1971	3.39	5	16.95	1.695	0	52.3	3.2	12.055	5.7	0	6.355
13	1972	3.39	5.5	18.645	1.8645	0.4	52.7	3.6	13.1805	5.7	0	7.4805
14	1973	3.96	4.8	19.008	1.9008	0.2	52.9	3.8	13.3072	5.7	0	7.6072
15	1974	6.88	6	41.28	4.128	0	52.9	3.9	33.252	5.7	0	27.552
16	1975	7.67	4.1	31.447	3.1447	0	52.9	6.2	22.1023	0	0	22.1023
17	1976	8.19	3.9	31.941	3.1941	0	52.9	5.8	22.9469	0	0	22.9469
18	1977	8.57	3.2	27.424	2.7424	0	52.9	5.4	19.2816	0	0	19.2816
19	1978	9	3.1	27.9	2.79	0	52.9	2.8	22.31	0	0	22.31
20	1979	13.99	2.4	33.576	3.3576	0	52.9	3.6	26.6184	0	0	26.6184
21	1980	22.49	1.8	40.482	4.0482	2	54.9	8	28.4338	0	0	28.4338
22	1981	31.13	1	31.13	3.113	2.1	57	6	22.017	0	0	22.017
23	1982	28.52	0.2	5.704	0.5704	0	57	3	2.1336	0	0	2.1336
24	1983	26.19	0.3	7.857	0.7857	0	57	1.5	5.5713	0	0	5.5713
25	1984	25.88	0.1	2.588	0.2588	0	57	0.4	1.9292	0	0	1.9292
26	1985	23.95	0.1	2.395	0.2395	0	57	0.3	1.8555	0	0	1.8555
27	1986	11.36	0	0	0	0	57	0.3	-0.3	0	0	0
28	1987	15.4	0	0	0	0	57	5.2	-5.2	0	0	0
			68.6	416.79	72.37	57		83.4	297.4625			245.9625

1. ANCF = Annual Net Cash Flow 2.1960 = 100.0

1)Tax holiday of first 7 years
2)We are examining as a company XYZ
3)Taking the discount rate @15%
4)Government Cash flow is undiscounted

Accumulated Net Cash Income	Investment Multiple	Government Take (Profit Oil)	Company Take	Taxes @35%	Net Cash Flow Of Company	Present Value of Company Cash Flow @10%	Undiscounted Total Government Take	Discounted Government Take
0	0	0	0	0	-2.5	-2.272727273	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	-0.5	-0.341506728	0	0
0	0	0	0	0	-13	-8.0719772	0	0
0	0	0	0	0	-13.6834	-7.723922574	0.2574	0.145296
0	0	0	0	0	-9.3058	-4.775346817	0.9438	0.484319
1.4808	0.029322772	0.14808	1.33272	0.466452	6.455468	3.011523465	2.044532	0.953789
6.9952	0.136358674	0.55144	4.96296	1.737036	8.125924	3.446185015	3.890076	1.649772
14.941	0.285678776	0.79458	7.15122	2.502927	9.348293	3.604171634	5.213707	2.01011
21.7682	0.416217973	0.68272	6.14448	2.150568	9.693912	3.397657018	4.614088	1.61721
28.1232	0.537728489	0.6355	5.7195	2.001825	9.417675	3.000761486	4.332325	1.380412
35.6037	0.67559203	0.74805	6.73245	2.3563575	9.6760925	2.802819332	4.9689075	1.439316
43.2109	0.81684121	0.76072	6.84648	2.396268	9.950212	2.620201807	5.057788	1.331874
70.7629	1.337672968	2.7552	24.7968	8.67888	21.81792	5.223036582	15.56208	3.725438
92.8652	1.755485822	4.42046	17.68184	6.188644	11.493196	2.501254313	13.753804	2.993228
115.8121	2.18926465	6.88407	16.06283	5.6219905	10.4408395	2.065664434	15.7001605	3.106193
135.0937	2.553756144	7.71264	11.56896	4.049136	7.519824	1.352506445	14.504176	2.608704
157.4037	2.975495274	8.924	13.386	4.6851	8.7009	1.422666677	16.3991	2.681384
184.0221	3.478678639	13.3092	13.3092	4.65822	8.65098	1.285913053	21.32502	3.169828
212.4559	3.869870674	17.06028	11.37352	3.980732	5.392788	0.728730521	25.089212	3.39032
234.4729	4.113559649	13.2102	8.8068	3.08238	3.62442	0.445245404	19.40558	2.383897
236.6065	4.150991228	1.28016	0.85344	0.298704	0.554736	0.061951895	2.149264	0.240026
242.1778	4.248733333	3.34278	2.22852	0.779982	1.448538	0.147063687	4.908462	0.498335
244.107	4.282578947	1.15752	0.77168	0.270088	0.501592	0.046294934	1.686408	0.155649
245.9625	4.315131579	1.1133	0.7422	0.25977	0.48243	0.040478508	1.61257	0.135303
245.9625	4.315131579	0	0	0	-0.3	-0.022883305	0	0
245.9625	4.315131579	0	0	0	-5.2	-0.360585417	0	0
		85.4909	160.4716	56.16506	98.80654	13.6351769	183.41846	36.1004

Decision Tree:-



Expected Monetary Value (EMV)

= (0.25*0.25*25.97)+ (0.25*0.5*19.69) + (0.25*0.25*12.06)
+ (0.5*0.25*20.43) + (0.5*0.5*13.63) + (0.5*0.25*7.16)
+ (0.25*0.25*12.06) + (0.25*0.5*7.16) + (0.25*0.25*1.96)

=13.43

On the basis of the decision tree we have calculated the EMV of the project assigning the probabilities for **P10, P50, and P90** case which has been shown in the figure above.

Conclusion of Analysis:

Since we have calculated the EMV for company which is coming positive after calculation (= **3.47336**). So company can develop this project. On the other hand the NPV for government is also positive so we can consider this project economically feasible.

CONCLUSION

The oil and gas project typically have large cash outlays over several years at the beginning of a project. That is, initially cash flows are negative and revenues are not received until production starts. Revenues are typically at their maximum at or near the start of production and decline in real terms as the field becomes depleted. Therefore net cash flow typically becomes positive as production starts and remains positive until the end of field life. Under PI method, the investment proposal will be acceptable only when the PI is greater than one. Likewise evaluating mutually exclusive investment proposal, these methods may have different accept-reject criterion. In such cases as discussed above the NPV criterion is always superior. The reason for the acceptance of NPV method of that project is that it maximizes the shareholders' wealth.

While doing the Sensitivity Analysis, in some cases there may be a dependency between variables which, if not recognized in the Monte Carlo analysis, can lead to inaccurate results. Under normal circumstances, when the selection of a point on an input distribution is made, it is done randomly. However, if two input variables are mutually dependent, then this process would be incorrect. Instead of the selection from each dependent variable being at random, the selections ought to be related to reflect the fact that the variables are related. In other words, if one variable is directly related to another, then the selection of a high value from one distribution ought to be followed by a corresponding high value from the other.

In the economic analysis done above, the NPV of the company is moving both in positive and negative direction for different cases of varying the Production and Price. While for the government the NPV is always positive. This shows a Progressive Fiscal Architecture for the project, taking Base Production & Base Price. Hence we could consider this project as a feasible project in INDIA.

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