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Monte Carlo Simulation and Risk Analysis: Case Study on Libyan Oil Project

محاكاة مونت كارلو وتحليل المخاطر: حالة دراسية عن مشروع النفط الليبي

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Abstract

The oil industry is characterized by the needs of large amounts of money, difficulty of estimating future cash flows, low success rates and increased risk and uncertainty. Since there are several ways to help decision-maker on investment risk analysis and take appropriate decisions, this study focused on illustrating the advantages of using Monte Carlo simulation to assess an investment project in the oil sector, which is one of the most important economic sectors in Libya. Results showed that high proportion of risk according to the current circumstances, which include the sharp decline in oil prices. It has been proven that probability of positive net present value (NPV) is only 20.84%. Therefore, management must focus on controlling expenditures, operational costs, fundamental analysis of relevant agreements, operating excellence and voting and veto rights of cancellation or reduction of capital expenditure. Results also showed that the most important element that must pay more attention and analysis is oil price. Therefore, decision maker can also delay decision because of current situation such as profitability of project, oil price are not as high as expected.

Keywords: Monte Carlo Simulation, Risk Analysis, Oil Project

الملخص

تتميز صناعة النفط باحتياجاتها لكميات كبيرة من الأموال، وصعوبة تقدير التدفقات النقدية المستقبلية، وانخفاض معدلات نجاحها وزيادة المخاطرة وعدم اليقين. وبما أن هناك عدة طرق تساعد متخذي القرار على تحليل مخاطر الاستثمار واتخاذ القرارات الرشيدة، فقد ركزت هذه الدراسة على توضيح مزايا استخدام محاكاة مونت كارلو لتقييم المشروع الاستثمارية بقطاع النفط والذي يعد أحد أهم القطاعات الاقتصادية في ليبيا. وأظهرت النتائج أنه وفقا للظروف الحالية فهناك نسبة عالية من المخاطر وخاصةً الانخفاض الحاد في أسعار النفط. وقد تبين أن صافي القيمة الحالية الموجبة (NPV) هو 20.84 ٪ فقط، لذا يجب أن تركز الإدارة على التحكم في النفقات، والتكاليف التشغيلية، والتحليل الأساسي للاتفاقيات ذات الصلة، والتميز في التشغيل والتصويت وحقوق الفيتو في إلغاء أو تخفيض الإنفاق الرأسمالي. كما أظهرت النتائج أن أهم عنصر يجب أن يولي المزيد من الاهتمام والتحليل هو سعر النفط. ولذلك يمكن لمتخذي القرار تأجيل تنفيذ المشروعات والقرارات المتعلقة بها في الوقت الحالي نظراً لانخفاض ربحيتها وانخفاض أسعار النفط عما كانت علية في السابق.

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1-Introduction:

Capital investment decisions cannot usually be reversed or canceled. They maximize owners' wealth, or they exposures them to a loss. Consequently, they affect the value of company and the wealth of its shareholders together at the same time. As a result, increasing the risk element (Elumilode *et al*., 2006, Dayananda *et al*., 2002).

Risks and uncertainties in oil industry are large because of several factors like limited information, decline in oil price and discovered production, increase operating expenses and complexities of the oil industry (Simpson *et al*.,2000) where an average cost of a "dry hole" is in excess of $20 million (Rao, 2010).

The term " risk analysis " was first introduced by Hillier (1963), Hertz (1964), Hillier (1965), Van Horne (1966), and Wagle (1967). These researchers have suggested using of Monte Carlo simulation to get a probability distribution for net present value (NPV) or internal rate of return (IRR), which became the best applications in a field of investment risk analysis (Borgonovo and Gatti, 2013).

The Monte Carlo simulation is a computer technique that allows decision makers to determine a range of possible outcomes, likelihood that any options occur and extreme possibilities of results to calculate risk quantitatively for taking appropriate decisions (Rao, 2010).

It is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, etc. (Roger, 2000), but this study will focus on using simulation in the finance filed.

In view of importance of oil sector for Libyan economy, which is the main source of export and the Libyan state's foreign currency revenues, accounting for more than 90% of the exports (Ali and Harvie, 2013; Mahmud and Russell, 1998). Because of this sector's need to significant capital expenditures which increases risk and uncertainty, so there requires for good planning and control practice in this important economic sector. However, through field study on Libyan oil companies that wholly owned by National Oil Corporation (NOC) was found that these companies do not use simulation method to assess risk when capital budgeting is prepared.

Based on the foregoing, the study has focused on clarifying importance of using simulation Monte Carlo which is the main tool for investment risk analysis that provides important and necessary information to decisions makers to maintain on available economic resources.

The objective of this paper is to illustrate the advantages of using this quantitative method (Monte Carlo) in Libyan oil sector. This study derives its importance from the following points: **first**, it is a first attempt to apply quantitative method (Monte Carlo) to improve capital budgeting in the Libyan oil and gas sector. **Second**, it highlights importance of application of simulation as it provides decision makers quantitative information that help for risk analysis. **Third,** Because of the drop in oil prices, effective planning and control of capital expenditure became necessary. **Fourth,** the

oil and gas sector is the most important sector that contributes to economic development in Libya, and this study is expected to contribute to more studies on this sector.

2-Literature review:

There are many earlier studies that focused on the Monte Carlo simulation as a tool for the risk analysis such as the results of Hertz's study (1979) showed importance of simulation method in risk analysis, where a traditional method which uses most predictable values of elements to determine net cash flows gave an expected IRR **25.2**% before tax, while using simulations to assess the same proposed investment gave an expected IRR **14.6%.** Therefore, using traditional method to evaluate investment projects leads to results far from results of the simulation model that uses probability distributions. As a result of decreasing IRR, required project's profitability will increase to be acceptable (Asrilhant *et al*., 2006).

Eck (1979) indicated that simulation analysis gives an opportunity to decision-maker of laboratory experimentation and then gets information that enables it to exclusion of non-valuable investment alternatives that may lead to losses without exposure to risks and costs of experimentation on actual system itself.

In 1997, Ramasesh and Jayakumar proposed simulation as optimal method to assessment cash flows, which is used in evaluation of discounted cash flows during different time periods. They developed a flexible mathematical programming model to determine a potential distribution of net flows in each period for evaluation of investment expenses.

Emhjellen *et al*., (2002) explained how to use simulation method to prove mis-using likelihood ratio 50/50 (average) for capital expenditures for evaluating investment oil projects, when probability distributions of costs are non-identical. As a result, it will be errors in evaluation which lead to wrong decisions by accepting negative the NPVs oil projects.

Finch *et al*. (2002), noted in their study the most important uses of Monte Carlo simulation in an oil industry in the UK are used for estimation of economic reserves and possible productivity for investment appraisal decisions by the administration of these companies .

Asrilhant *et al*. (2006), this is a survey study about using of analytical tools by strategic project management in the United Kingdom oil and gas sector. The survey results indicate that administration of this sector used several tools to assess the risks of exploration and development projects including sensitivity analysis, simulation models and decision-tree analysis.

Brealey *et al*., (2006) criticized the sensitive analysis that does not take into account correlation between different variables. For example: increase a sale price of oil may lead to increase the activities of the project and consequently increase operating costs. For this reason, a decision maker must calculate and find out a correlation coefficient between these future variables, which is the most difficult part in project evaluation.

They suggested another way, which is Monte Carlo simulation that is sophisticated and formal method to learn all possible selections of different variables using specialized computer software. It must be carried out several times and analyze results to determine a probability distribution of outcomes to know expected value, standard deviation, and range to determine oil project's risk level.

Verbeeten in 2006, the questionnaire was sent to 704 companies in the Netherlands. The study results pointed out that companies use many tools and procedures such as Monte Carlo simulation and decision tree at the same time to assess investment projects' risk.

In another study by Lam *et al*. (2007), questionnaires were sent to a sample of 157 companies in Hong Kong. Results showed that **58.7%** of these companies used simulation model for risk analysis.

Also, by using the Monte Carlo technique, decision makers can estimate the recoverable oil reserves in the form of a probability distribution which is used to evaluate an oil project (Rao, 2010).

3. Methodology & Data:

This study focused on the case study, which defined as a research strategy, an empirical inquiry that investigates a phenomenon within its real-life context (Yin, 2014). This approach is flexible, and it can be quantitative or qualitative (Denscombe, 1998; Robson, 1993). In this study, it is used in order to demonstrate advantages of using Monte Carlo simulation to evaluate a Libyan oil project. To achieve this, this part was divided into the following main parts:

3.1- Investment appraisal:

Making a good investment decision is important since it will add to a firm's value, especially in developing countries (Elumilade *et al*., 2006). Therefore, there is an urgent need to assess these decisions effectively by identifying future cash flows and using some evaluation criteria, such as the NPV, IRR and PB for investment appraisal. The Libyan oil project oil was evaluated according to the following stages:

3.1.1. Financial Model:

The most important data and information that are necessary for project evaluation were collected from one of the Libyan oil companies' records and the Internet resources, and they are in the following table.

Table (1) financial variables

Investment Amount (M)	*Operating Costs (M)/Y*	*Average Oil Price/b*	*Project's Life (years)*	*Discount Rate*	*Oil Corp. Tax Rate*
$122,433	***$15,927***	***$33***	***15***	***15%***	***65%***

The model is designed to clarify the link between the oil project's parameters. So, this section devoted to calculate total revenue, product quantities, operating expenses, working capital and some other economic variables as sale price of crude oil, exchange rate, depreciation rate, tax rate, inflation index and discounted rate (cost of

capital) which is 15% for the state oil companies in developing countries (Beredjick and Walde,1988) to determine expected net incomes and net cash flow over project's life. Also, the impact of inflation has been excluded by using an inflation index (US) before calculating evaluation criteria.

3.1.2. Deterministic results:

Theoretically, a good assessment method must take into account the time value of money, and it does not ignore any period of time or any cash flow. It must be easier to apply and consistent with a goal of maximizing wealth of shareholders as well. Therefore, discounted cash flow methods (DCF) are not only suitable, but also the most preferred ways that were widely used by oil and gas companies to evaluate their investments. This is confirmed by the results of some previous studies. For example: in 2008, a survey study with some specialists in this field has shown that 88% of them preferred DCF methods such as the NPV and IRR for investment appraisal (Asrilhant *et al*., 2006; Doughert and Sarkar, 1993; Moore, 2009). By evaluating previous data, results are found as following:

Table (2) Evaluation Criteria

NPV@15%	IRR	PB (Year)
-$26,168.00	**9.36%**	**9.20**

From the above, we note that this project is unacceptable according to the standards of the DCF because the NPV is less than zero, and IRR is less than the cost of capital. This reflects increasing of this project's risk in the current circumstances. This requires an effective risk analysis to determine the most important elements of the risk.

3.2. Risk Assessment:

Sensitivity analysis must be used to measure the impact of inputs' changes on the oil project's value (NPV or IRR) before making a final decision (Cassia *et al*., 2007). Some previous studies such as Boyle and Schenk (1985), Doughert and Sarkar (1993), Razak (2001), Asrilhant *et a*l. (2006), Lam *et al*. (2007) Bennouna *et al*. (2010) and Maquieira *et al*. (2012) proved that sensitivity analysis is the most important methods that are used to determine critical risk variables in the oil industry and others. Through this analysis, the most important variables that affect this project's value are illustrated in the following table:

Table (3) NPV's sensitivity

Case	Input Change	NPV@ 15%(m)	% Changing in NPV
1	Decreases oil price by 50%	-$58,732	-124.4%
2	Increases oil price by 50%	$6,396	124.4%
3	Decreases exchange rate by 50%	-$29,112	-11.25%
4	Increases exchange rate by 50%	-$25,187	4%
5	Decreases investment costs by 50%	$19,391	174%
6	Increases investment costs by 50%	-$71,728	-174%
7	Decreases produced quantity by 50%	-$58,221	-122.5%
8	Increases produced quantity by 50%	$5,884	122.5%

Based on result of this analysis, oil price, investment costs, product quantity and exchange rate are most parameters that have significant effects on the NPV. We can note that the project's value is sensitive to changes in the price of crude oil in world markets. This is in line with the some previous study results such as Mohn and Misund (2009) analyzing data of 170 companies during the period 1992-2005 by applying modern panel data estimators for oil and gas investments and production. They reached some conclusions, including that increasing in volatility and instability in oil markets has a negative influence on industry's investments.

The other one is a study entitled "Risk Factors in Oil and Gas Industry Returns: International Evidence" in 34 countries showed that the oil price is the most factors in this industry. Additionally, the negative change has more impact than positive change. Moreover, there is no similar factor that has the same effect in other industries (Ramos and Veiga, 2011).

For further analysis, some measures of the descriptive statistics were calculated from previous data (1986-2014). Also, we used some charts that describe these elements' properties as following:

Table (4) descriptive statistics' measures

	Oil Price/bb	Investment Costs/(M/Y)	Product Quantity (M/Y)	Exchange Rate
Mean	**$31.06**	**$297,346**	**141,647**	**$0.77**
Standard Deviation	**$16.30**	**$187,225**	**29,508**	**$0.54**

Figure.1. illustrates the oil price volatility

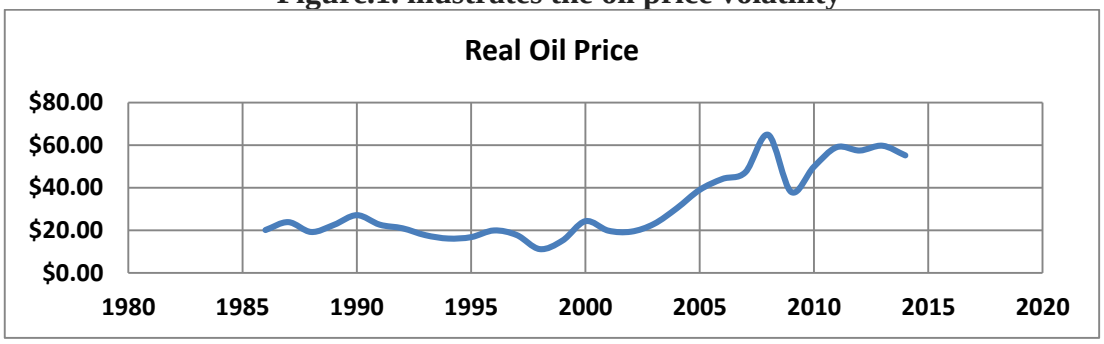


Figure.2. illustrates the investment costs

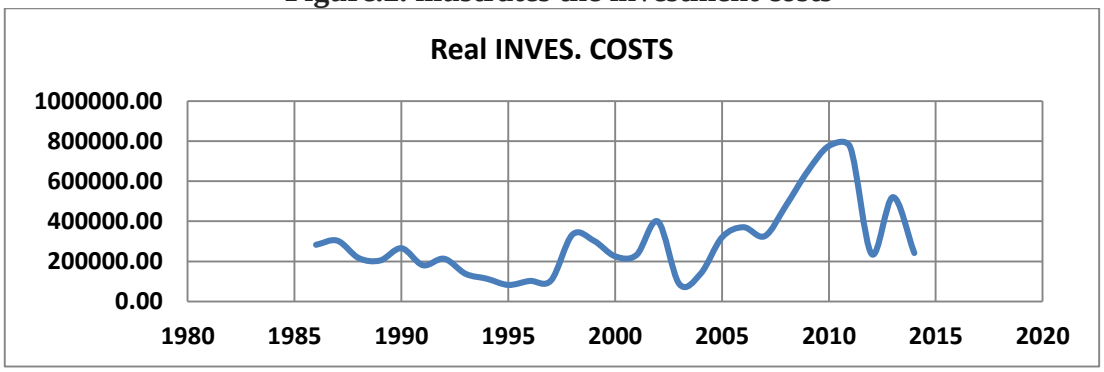


Figure.3. illustrates the product quantity

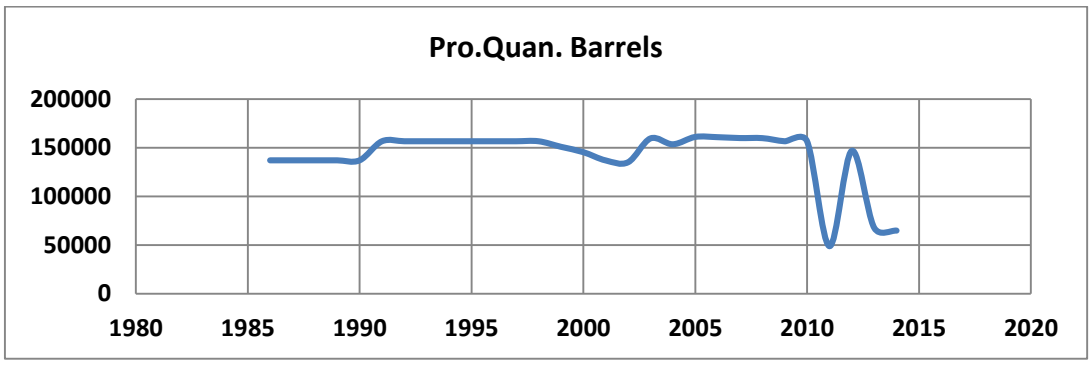
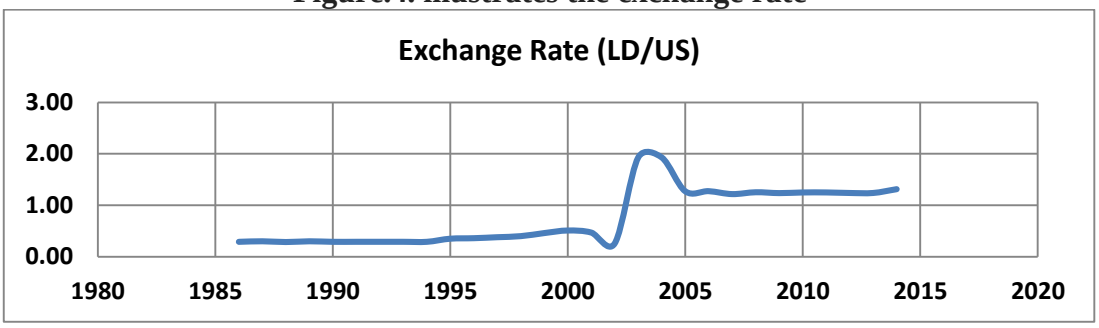


Figure.4. illustrates the exchange rate



Through the description and analysis of historical data for these important elements, it can be seen from the above table and charts the extent of variation in oil prices during the previous period where the dispersion rate was more than **50%**, which reflects instability of oil prices on global markets. In addition, we can observe dispersion in investment expenses as a result for this volatility. Moreover, we note the relative stability in the quantity of production with the exception of the period of political events in Libya in 2011. With respect to the exchange rate, we note also that it was a relatively constant because the Central Bank of Libya applied a fixed exchange rate system, so its impact was less than other risk factors on the NPV.

3.3 Risk Analysis:

The Monte Carlo simulation is defined as computer software that allows decision-makers to determine range of potential consequences, and probability distributions through run program many times. It is widely used in many applications in a field of finance and oil industry in order to risk analysis quantitatively to make rational decisions by following these steps (Finch, 2002; Guimaraes and Carvalhal, 2012):

First, specify appropriate distribution probability type (normal, triangular, uniform distribution, etc.) for each critical variable (oil price, exchange rate, investment expenses and produced quantity) by historical data analysis for each variable analysis or consult experts.

This distribution is continuous, and it is the most important distribution in probability theory because it describes many natural phenomena. Decision-makers can use it to describe uncertain variables such as inflation rate or future price of gasoline.

Triangular

This is continuous, and it describes a situation where the minimum, maximum, and most likely values to occur are known. It is useful with limited data.

Uniform

It is continuous. In this distribution, range between minimum and maximum values are known and all values in the range are equally likely to occur.

It is noted that these distributions are often used in the oil industry (Belaid *et al.*, 2009) Also, Rodriguez and Padua (2005) provide examples of probability distributions that can be used in different risk inputs which are triangular distribution for INVES.COSTS and normal distribution for historical oil prices (Guimaraes and Carvalhal, 2012). The probability distributions of key variables that used in the study can be clarified as follows:

Figure (5) Critical Variables' Probability Distributions

Assumption	Distribution	Mean	Std. Dev.	Min.	Max.	Likeliest
Oil Price	Normal	$31.07	$16.27			
Exchange Rate	Uniform			-70.19%	359.43%	
Invest. Expenses	Triangular			-73.85%	118.92%	38.55%
Prod. Quantity	Triangular			-61.70%	21.52%	16.64%

One disadvantage of the sensitivity analysis that it ignores correlation that may exist between some elements such as relationship between sales price and sales volume, and it assumes an independence of each other (Daniel *et al.*, 1972) which were taken into account when simulation is used. The following table shows the correlation coefficients between different important variables.

Table (5) Correlation Coefficient

Critical Variables	Oil Price	Exchange Rate	Invest. Costs	Prod. Quantity	Opre. Costs
Oil Price	-	**0.69**	**0.63**	**-0.47**	**-0.01**
Exchange Rate		-	**0.34**	**-0.17**	**-0.45**
Invest. Costs			-	**-0.39**	**0.13**
Prod. Quantity				-	**-0.36**

Analysis of historical data (1985 - 2014) for previous variables indicates the following:

1. There is a weak negative linear relationship between oil price and operating costs and a moderate positive (negative) linear relationship with investment cost, exchange rate and product quantity.
2. There is a weak negative linear relationship between exchange rate and product quantity and a moderate positive (negative) linear relationship with investment costs and operating costs.
3. There is a weak positive linear relationship between investment costs and operating costs and a moderate positive (negative) linear relationship with operating costs.
4. There is a moderate negative linear relationship between product quantity and operating costs.

Second, run the Monte Carlo program and analyze results:

Monte Carlo simulation has been vastly used in many applications in finance (Rodriguez and Pádua, 2005). It allows users to estimate several risk measures like standard deviation, skewness, behavior of distribution tails and probabilities of NPV values, so this study focused on illustrate advantages of using the **Crystal Ball Software** to assess an investment project in the oil sector. Through running program, the following results were found:

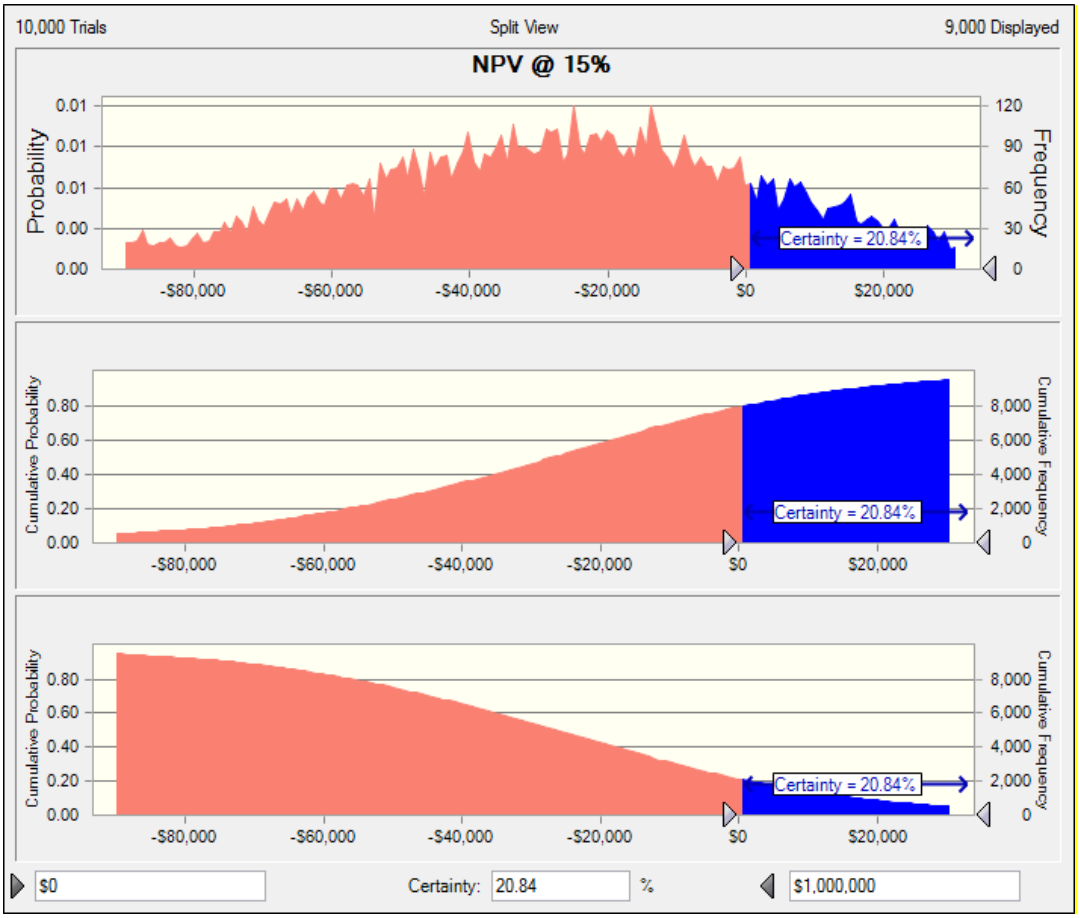


Figure (6): NPV's probability distribution & statistics.

Statistics	Value
Trials	10000
Mean	-26,913
Standard Deviation	331,821
Minimum	-9,045,943
Maximum	27,461,688

Figure (6) depicts probability distribution of the project's NPV with certainty level 20.84% that this value will be positive and average -26913$, standard deviation 331821$, minimum and maximum values are -9045943$, 27461688$ respectively, which reflects the higher risk element and the need for good planning and some quantitative risk analysis methods that provide more information to decision makers. Here, the oil company must focus on control of expenditures and operational costs. As well as, risk management should focus on fundamental analysis of relevant agreements, operating excellence, voting and veto rights, cancellation or reduction of capital expenditure, Anthony said (Anthony, 2015). Decision makers can also delay decision because of the current situation such as profitability of the project, oil price are not as high as expected.

3.4. Policy option for risk mitigating:-

To mitigate the impact of oil project's risk, Libyan Oil Company has some options such as:

3.4.1. Postpone implementation of the project:

Because the oil project's NPV is very sensitive to change in oil price, it requires more careful attention, especially with the current economic situation with a sharp decline in world oil markets. Since the equilibrium oil price for this project is **$ 46.5**, decision makers can delay this project because profitability and oil price are not as high as expected.

3.4.2. Control of expenditures and operational costs:-

In addition, reducing the project's costs is other available option to decision makers. The following table illustrates the sensitivity of the NPV and IRR's values to changing in capital costs.

Table (6) NPV & IRR Sensitivity

% Change in INVEST. Costs	NPV's value	IRR's value	% Change in NPV's value	% Change in IRR's value
-25%	-$3,388	14.09%	87.10%	50.61%
-30%	$1,168	15.33%	104.50%	63.86%
-35%	$5,723	16.67%	121.87%	78.19%
-40%	$10,279	18.28%	139.30%	95.40%

It is clear that a reduction in capital expenditures by **15%** leads to increase profitability of the project (IRR) from **14.09**% to **18.28%,** which is acceptable economic level, so management of Oil Company must focus on control project's expenditures and operational costs.

3.4.3. Improve conditions of contracts:

As well as, management must give more attention on how to control previous risk factors to reduce project's risk. Therefore, risk management should focus more on fundamental analysis of relevant agreements, operating excellence, voting and veto rights and cancellation or reduction of capital expenditure (Anthony, 2015). Thus, management will have more flexibility to plan and control this project and to reduce its effect on the company's value, preserve and invest available economic resources effectively.

4-Conclusion:

Oil price plays a key and very sensitive role in the evaluation of oil projects, so it requires careful attention to oil prices, especially with the current economic situation in sharp decline in world markets. Monte Carlo simulation of the NPV is general method, flexible in often and simple in execution. It remains one of the most successful methods of risk analysis because it is the only way that enables the integration of various dimensions of the problem based on cash flow projections and then identifies strategies to find appropriate solutions. In order to effectively reduce the risk of lower oil prices, oil companies need to determine how to reduce and save their expenses. In addition, they must review operational and financial aspects of their business and determine how to rationalize and improve their investment priorities. Moreover, management can delay investment decision if project's profitability or oil price is not high as expected.

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