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# Implementing potential risk assessment under economic and technical aspects in petroleum production stage

**Pham Ngoc Phuong Quynh[1,2], Nguyen Huynh Thong[1,2,*]**

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**ABSTRACT**

Industries grapple with formidable challenges stemming from uncertainties that not only impede economic growth but also introduce risks in technical realms, impacting operational procedures, performance, and associated services. Addressing prevalent risks in geology, economics, operations, development, and production stages becomes imperative, prompting the implementation of robust risk management and control measures. These measures are vital to ensuring production efficiency, preserving economic values, and conducting a comprehensive risk analysis that influences project outcomes, ultimately guiding investment decisions.

The research at hand aims to delve into the intricate web of factors influencing production performance and to conduct a thorough risk assessment grounded in economic values and production rates, specifically focusing on well X. Employing a holistic approach, the study seamlessly integrates qualitative and quantitative methods, utilizing sophisticated tools such as Nodal Analysis, the material balance equation (MBE), and risk assessment based on net present value (NPV) through the utilization of Crystal Ball software. The overarching goal is to provide a nuanced and comprehensive understanding of the multifaceted dynamics influencing the production of well X.

In summation, the analysis conducted in this study serves as a valuable foundation for informed decision-making processes. By identifying and thoroughly assessing factors that impact production and the economic aspects of well X, the research seeks to mitigate risks during the production stage and guide investment decisions. The amalgamation of qualitative and quantitative methodologies employed in this study not only enriches the depth of understanding but also contributes to a more sophisticated approach to decision-making in the intricate domains of production and investment. Ultimately, the recommendations derived from this study are poised to enhance the resilience of well X in the face of uncertainties, bolstering both its production performance and economic viability.

**Key words:** Nodal Analysis, Net Present Value, economic evaluations

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## INTRODUCTION

The petroleum industry is a key economic sector, ensuring national energy security, ensuring the economic growth of the country quickly and sustainably, as well as protecting national security and sovereignty at sea. Risks in oil and gas differ from other industries due to their specialized characteristics as well as the technical parameters, which are the foundation, supporting the decision-making process [1–3].

Therefore, learning about oil and gas and issues related to this field also contributed to the process of developing oil and gas projects. There are several stages of an oil and gas process: Exploration, Appraisal, Development, Production, and Abandonment, which describe a long-life cycle of a petroleum project [4–6]. Besides, there are many deciding elements in the choice to construct an oil and gas project, making the use of statistical risk assessment difficult. As a result, issues of technical and economic values also have an impact on the investment decision of the project during the production phase due to the high risks associated with oil and gas [5,7].

## METHODOLOGY

For each stage of petroleum industry, there are variety of methods to define and evaluate risks such as deterministic, probabilistic and intergrated approach. In this research, with various factors affecting to the production such as techinical error, cost overruns, uncertainties in relation to critical variables (infrastructure, production schedule, quality of oil, operational costs, reservoir characteristics,...) and uncertainties in decision-making, therefore, an integrated model was defined so as to analyze technical and economic aspect of an oil well in petroleum production stage [8,9].

A general workflow that proposed by this research is presented in (Figure 1) and is briefly described as below:

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First, the production model is performed to calculate the flowrate of well due to pressure base on Beggs and Brill correlation and define the operation flowrate of the Inflow Performance (IPR) and Outflow Performance (OPR) of production well 1X.

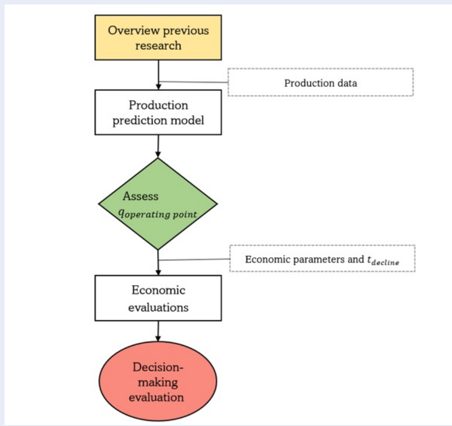


**Figure 1**: Workflow for the model's calculation

• Then, the Economic evaluation is conducted by using Material Balance Equation (MBE) to calculate the production rate decline, decline rate and abandonment production. Based on some assumptions, this provides economic parameters and assists the Risk analysis model.

• After that, the Risk analysis model is performed to analyze the effects of Net Present Value (NPV) by using Probabilistic risk assessment approach (PRA).

This workflow is described in detail for each step in each approach in the next section.

## Multiphase flow modeling

The multiphase modeling in this section determines the relationship of outflow and inflow performance, flow regime and pressure distribution of the fluid along the wellbore.

This research utilizes Vogel's method for the Inflow performance calculation for multiphase flow's calculation [10–12].

The indicated a empirical equation applied for two phase flow, which is described as:

$$\frac{q_0}{q_{max}} = 1 - 0.2\left(\frac{p_{wf}}{p_b}\right) - 0.8\left(\frac{p_{wf}}{p_b}\right)^2$$

Where $q_{max}$ is the maximum flow rate, $q_0$ is the initial flowrate, p_bis the pressure at the bubble point, and $q_{wf}$ is the pressure at the well flow.

For the pressure drop, the correlation is one of the few correlations capable of handling all flow directions encountered in oil and gas operations, namely uphill, downhill, horizontal, inclined and vertical flow for two phase fluid [12,13]. Total pressure gradient is described following steps below:

Step 1: Calculate the mixture flow rate

$$q_{mixture} = \left(B_0 q_{0,sc} B_{w,sc} q_{w,sc}\right) + \left(B_g \frac{q_{g,sc} - q_{o,sc} R_s}{5800.6408}\right)$$

Step 2: Calculate the mixture specific gravity

$$\gamma_{mixture} = \frac{(\rho_L H_L) + (\rho_G (1 - H_L))}{62.28}$$

Step 3: Calculate the no-slip mixture specific gravity

$$\gamma_{mixture} = \frac{(\rho_L \lambda) + (\rho_G (1 - \lambda))}{62.428}$$

Step 4: Calculate the mixture density

$$\rho_{mixture} = (\rho_L H_L) + \rho_G (1 - H_L)$$

Step 5: Calculate the mixture viscosity

$$\mu_{mixture} = (\mu_L H_L) + \mu_G (1 - H_L)$$

Step 6: Calculate the Reynold's number using no slip mixture density and viscosity

$$Re = 124 \times \frac{\rho_{mixture} |V_m| d_{ti}}{\mu_{mixture}}$$

Step 7: Calculate the no-slip friction factor

If $R_e \leq 2300$, $\frac{64}{R_e}$

$$f_{ns} = \frac{4\left(\frac{1}{-4\log_{10}\frac{\in}{d_{ti}}}\right)}{3.7065} - \left(\frac{5.0452}{R_e} \times \frac{\log_{10}\frac{\in}{d_{ti}1.1098}}{2.8257}\right) + \left(\left(\frac{7.149}{R_e}\right)^{0.8981}\right)^2$$

The ratio of friction factor is calculated using Colebrook-White equation:

$$e^S = \frac{f}{f_{ns}}$$

The value of S is governed by following conditions:

$$S = \ln(2.2y - 1.2)$$

If $1 < y < 1.2$, $\ln(2.2y - 1.2)$

And this "s" value is defined as:

$$\frac{\ln(y)}{(-0.00523 + 3.182\ln(y) - 0.8725\ln(y)^2 + 0.01853\ln(y)^4)}$$

Where:

$$y = \frac{\lambda}{H_L(\theta)^2}$$

Step 8: Calculate the pressure change due to the hydrostatic head of the vertical component of the pipe.

$$\left(\frac{dp}{dz}\right)_{elevation} = 0.433 \times \gamma_{mixture} \times \sin\theta$$

Step 9: Calculate the pressure loss due to friction

$$\left(\frac{dp}{dz}\right)_{friction} = 0.000011471 \times \frac{f_n \dfrac{f}{f_n} \gamma_{no\ slip\ mixture} q_{mixture}^2}{d_{ti}^5}$$

Finally, calculate the total pressure gradient from the pressure change due to the hydrostatic head of the vertical component of the pipe and pressure loss due to friction.

$$\left(\frac{dp}{dz}\right) = \left(\frac{dp}{dz}\right)_e = \left(\frac{dp}{dz}\right)_f$$

## Economic evaluations

For petroleum economic evaluation, the worth of petroleum qualities, quantities of petroleum commodities, and corresponding economic life are determined using Net Present Value and related computations. Quantities of producible oil and gas up to the economic life reserve are quantified. Almost all economic appraisals of petroleum properties are purely based on decline curve analyses, with no consideration given to material balance parameters and their implications on reservoir pressures and decreasing rates, as well as their effects on value [14].

Material Balance Equation is utilized to support the important pressure-time relationship in addition to the underground extraction and reservoir depletion (Figure 2). Therefore, the forecast of good production would be related with well deliverability [15].

This section utilizes material balance equation's calculation to calculate the cumulative oil production, abandonment time and define oil and gas production forecast, where the $N_p^1$ and $G_p^1$ is the cumulative oil and gas production at the beginning of the interval and $\triangle N_p^1$ and $\triangle G_p^1$ is the is the incremental cumulative oil and gas production.

$$\triangle N_p^1 = \frac{1 - \bar{\phi}_n N_p^1 - \bar{\phi}_g G_p^1}{\bar{\phi}_n + \bar{R}\bar{\phi}_g}$$

and

$$\triangle G_p^1 = \triangle N_p^1 \bar{R}$$

From these tasks, the Production decline profile can be obtained to support the economic calculations such as Net present value, which is a financial statistic that attempts to represent the total worth of the investment opportunity.

The research can generate the economic calculation to obtain the NPV value using the fomular below:

$$NPV = \sum_{N}^{n=1} \frac{C_n}{(1+n)^n}$$

Then, the Net present value (NPV) can also be determined by calculating the difference between the Present Value (PV) after a time period of investment and the initial amount invested, where the Present Value "PV" after time "t" given a rate of return "r" can be calculated.

## Risk analysis modeling

The risk analysis model in this research applied Crystal Ball software to analyze the Net Present Value using the Probabilistic approach (Figure 3).

Sensitivity analysis (SA) is an important component for determining which model variables will have the greatest impact on the outcome. The impact of a reservoir property is defined in the SA as the difference (absolute value) between the NPV evaluated at the minimum and maximum value of the property (NPV).

Besides, sensitivity analysis (SA) is a vital assessment component for determining which variables will have the greatest impact on the outcomes. The impact of a reservoir property is defined in the SA as the difference (absolute value) between the NPV evaluated at the minimum and maximum value of the property (NPV).

# RESULTS

Input data of this research is collected from book and references in petroleum engineering, a production oil well with multiphase flow including oil, gas and water. Some of the main assumptions are used in this work and described in this workflow:

- The well is vertical.
- Fluid flow in the tubing is pseudo-steady state and one dimension from bottom-hole to wellhead.
- The temperature of fluid distributes linearly with depth from bottom-hole to wellhead.
- The cost is hypothesized to perform the economic calculation

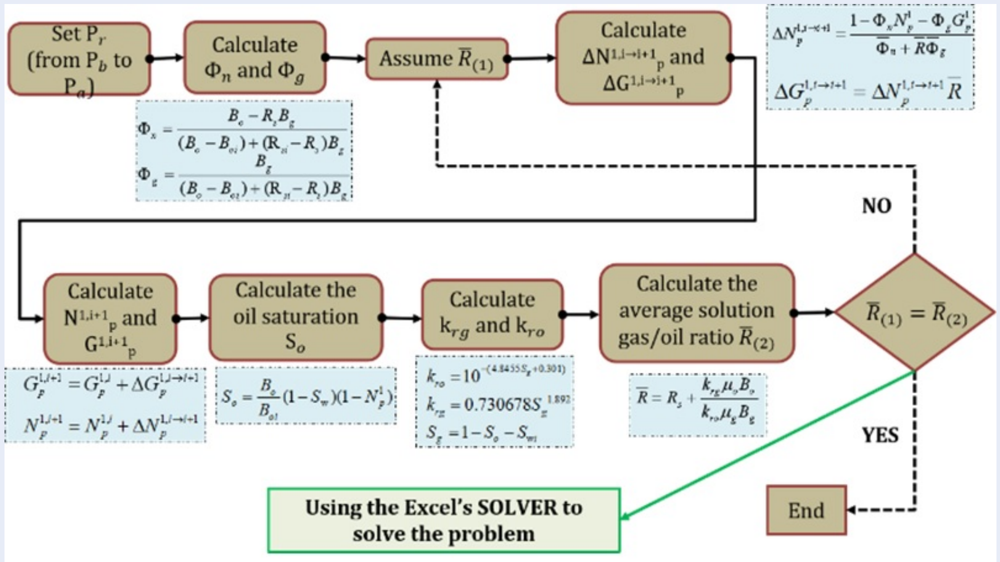


**Figure 2**: Workflow for MBE calculation

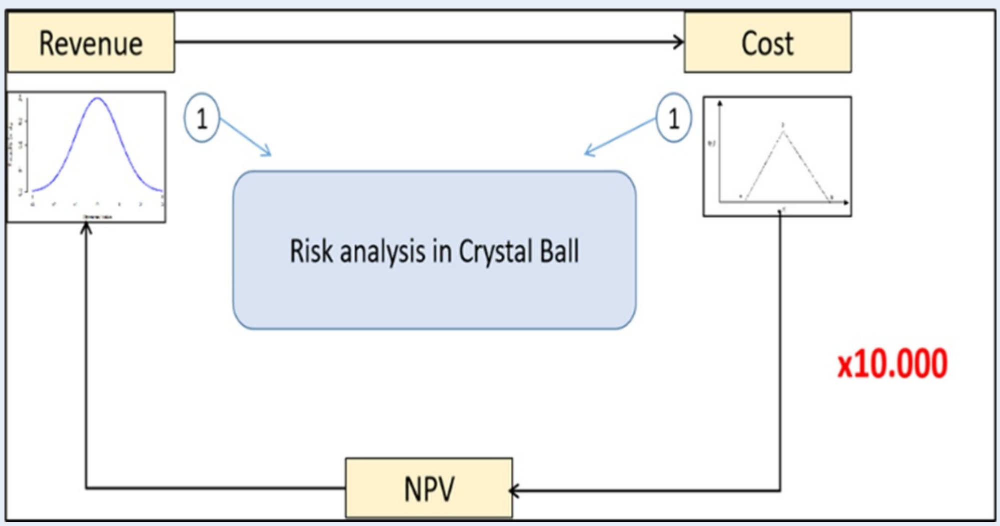


**Figure 3**: Calculation procedure in Crystall Ball.

## Production rate calculation results and sensitivity analysis

The Nodal Analysis, from combining the IPR and OPR curves reveals the operating point at which a well can produce at a given pressure and rate (Figure 4). The result for the operating production rate is to obtain at the $q_{operating}$ = 965,7759675 stb/day when pressure is at 3419,497098 psia due to the relationship between IPR and OPR, shown in the figure below.

With variation of reservoir pressure, the well performance is described in the (Figure 5). Sensitivity anlysis in (Figure 6), it demonstrates the influence of wellhead pressure has a great impact on the performance of the production rates.

Besides, Systems Nodal Analysis can be used to investigate the effects of a wide range of circumstances on oil and gas well performance.

Well head pressures are varied from 450 psia to 2000 psia, which means from the operating point until the point where the OPR and IPR lines no longer intersect.

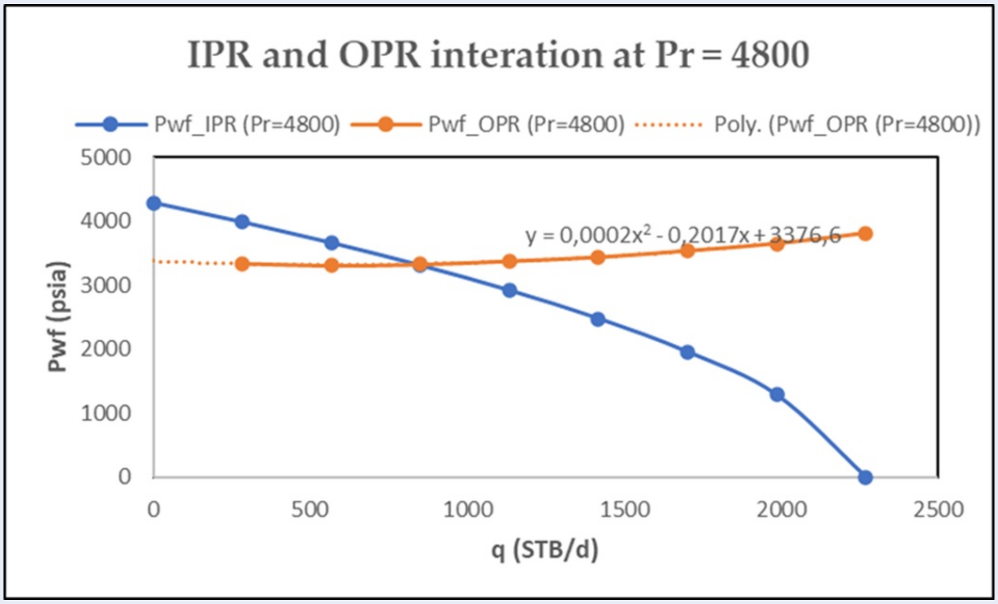


**Figure 4**: IPR And OPR curve at the reservoir pressure

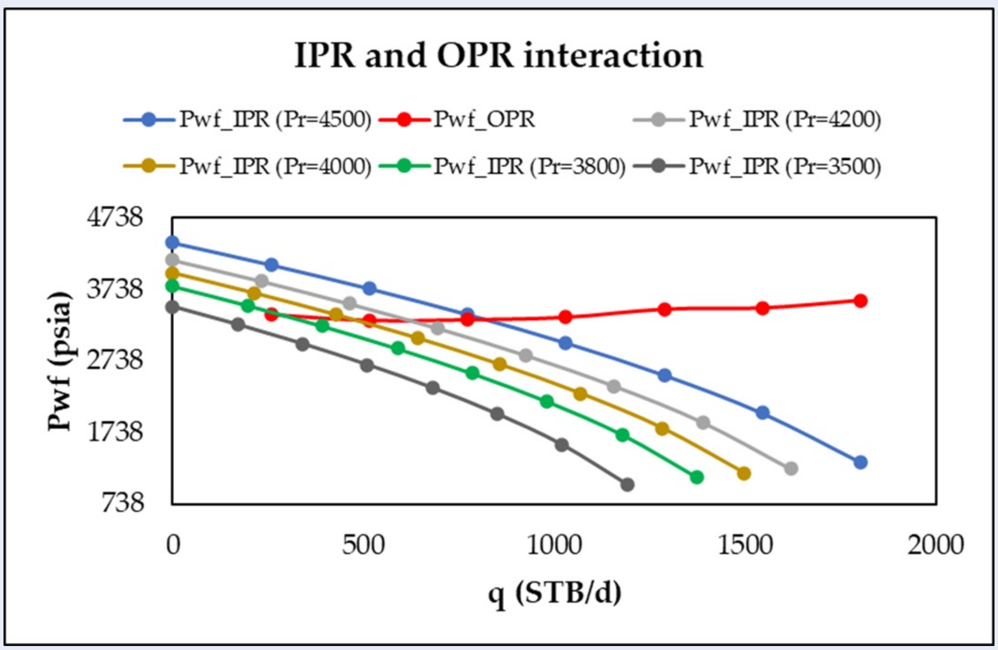


**Figure 5**: Operating q point with variation of reservoir pressure based on IPR and OPR in Excel.

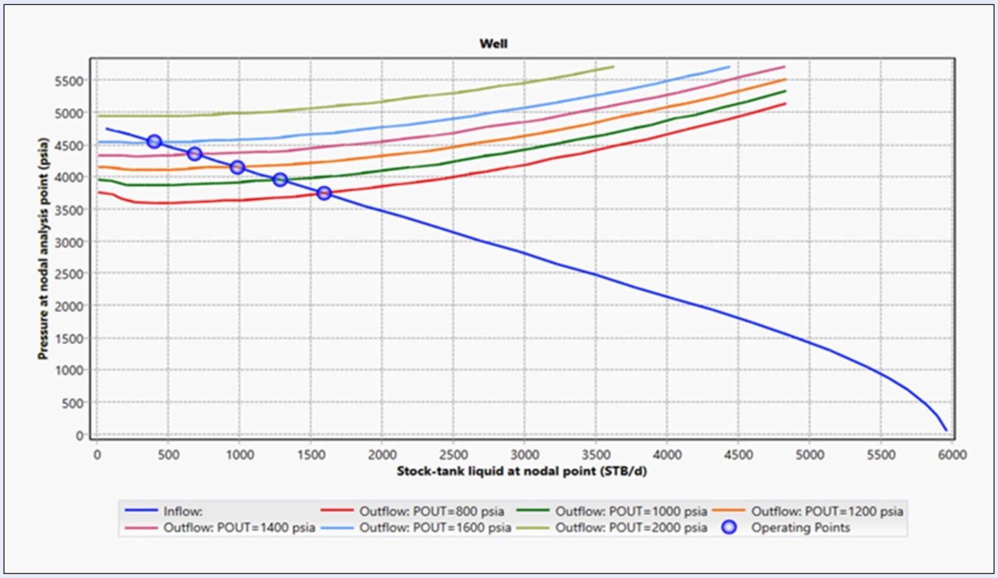


**Figure 6**: Variation of well head pressure in IPR and OPR plot

The Nodal analysis evaluates the behavior and effect of the components that make up the production system, perforation density and size, formation fluid characteristics, and fluid production rates. Besides, the water cut ranged from 15% up to 80% so as to observe the effect of this parameter on the IPR.

From the result from the software, it can be seen that the 80% of water cut received significant impact to the well performance (Figure 7).

## Economic evaluation and risk analysis model

From the Production decline profile, it can be observed the well production problems as well as the well preformance and life of a project based on production data. The outcome of production rates gradually decreased year by year with production from 736.139 to 137.735 stb/day during 8 years (Figure 8).

Figure 9 showed that the flow value continuously declines in both days and years with total CAPEX and OPEX expenditures totaling $16.770.276,818 at an oil price of 70$/barrel and annual operating costs of approximately $545,000.

The results from the above diagram indicated the net present value is $37.990.032,443 from production decline profile with respect to the time and economic assumptions (Figure 10).

For risk analysis in Crystal Ball, **t**he concept is the revenue focusing on normally distributed with error +10% or -10% and cost according to triangle distribution with min, likely and max cases to calculate NPV value based on analysis in Crystal Ball (Figure 11).

The simulation followed the normal distribution to compute the predicted NPV value based on the specified input distribution. The graph shows that the NPV value based on probability ranges from $25.000.000 to $55.000.000 relying on normal distribution.

When the model set the revenue limit, the likelihood of achieving an NPV value of $39.990.032,443 reaches up to 57.85%. Around 48.89% of this model failing to achieve this value, the negative NPV values might be between $25.000.000,000 to $40.000.000,000 according to the NPV's graph following the normal distribution (Figure 12).

Besides, when the model sets the revenue limit with the certainty at 80%, the NPV value can be achieved from between over $31.541.593,720 to $46.526.542,491 (Figure 13).

In this sensitivity analysis section, based on the diagram, the impact of revenue on NPV is 87.1% while the cost only takes up about 12.9%. Besides, with the support of sensitivity analysis, the influences of relevant parameters are presented due to the simulation analysis.

# DISCUSSION

Establishing an effective methodology proves to be a formidable challenge when addressing the input characteristics directly associated with a virtual model utilizing MBE and NPV. Consequently, the resulting output aims to illustrate the relationship between IPR

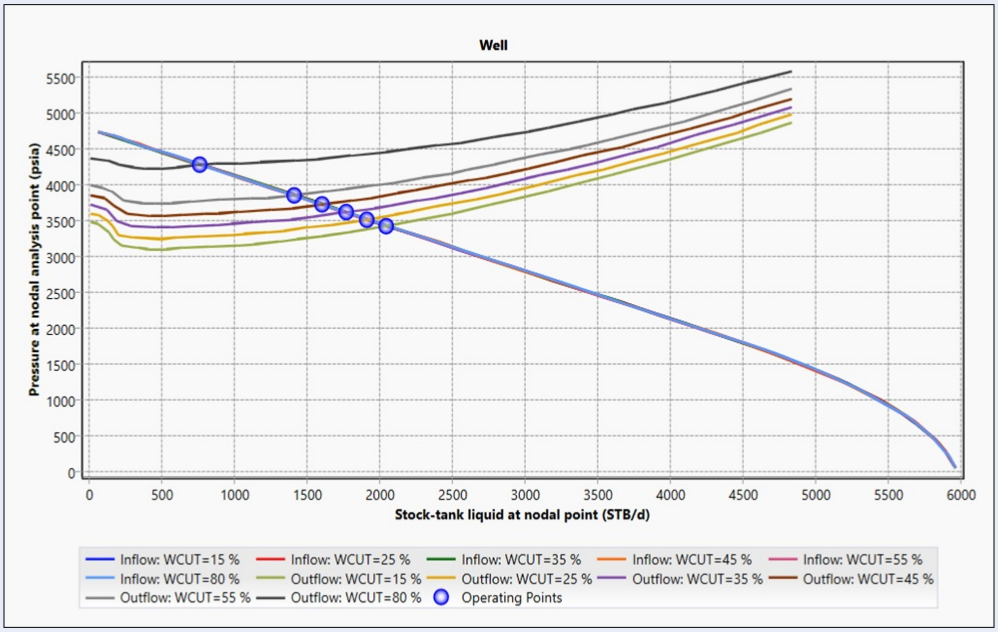


**Figure 7**: Variation of water cut in IPR and OPR plot

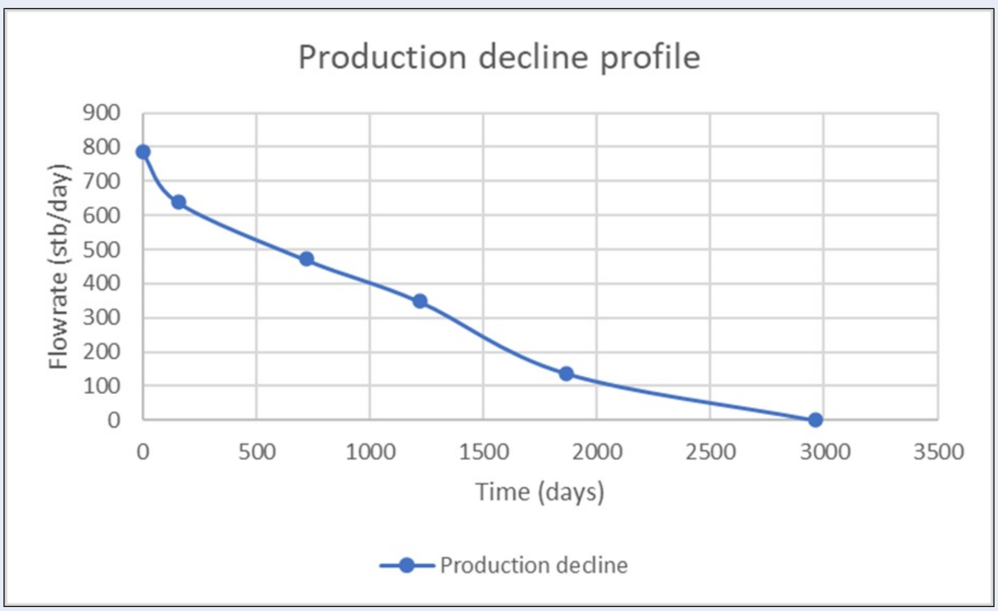


**Figure 8**: Production decline profile vs. flowrate

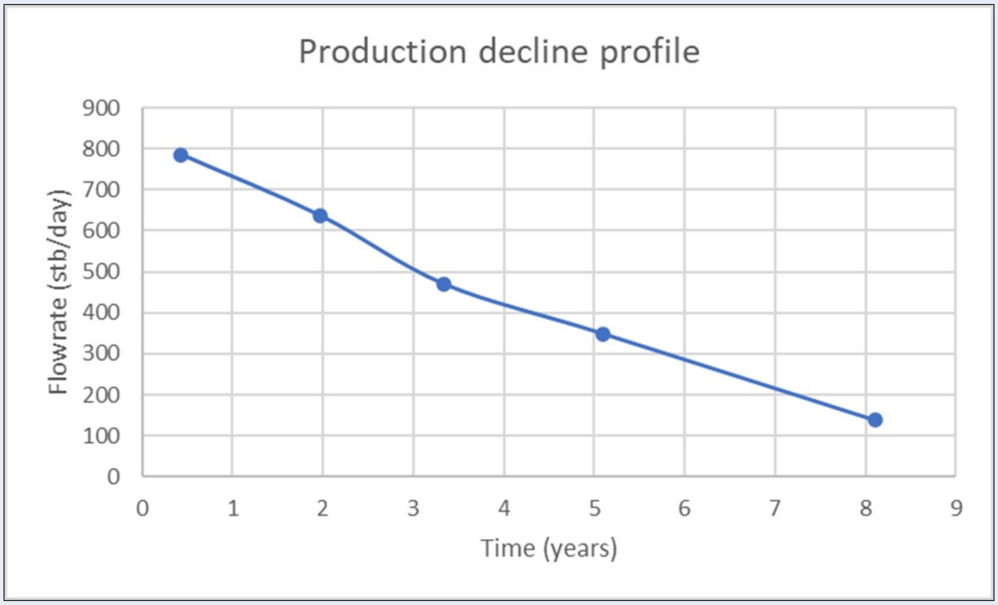


**Figure 9**: Production decline profile of Oil Well X due to years

| Year | Flowrate | Revenue ($/day) | Revenue ($/year) | Cost of oil ($/year) | Tax |
|---|---|---|---|---|---|
| 0,4 | 786,1 | $55.029,7 | $20.085.848,2 | $3.347.641,4 | $2.008.584,8 |
| 2,0 | 638,0 | $44.663,1 | $16.302.026,4 | $2.717.004,4 | $1.630.202,6 |
| 3,3 | 470,9 | $32.965,2 | $12.032.288,9 | $2.005.381,5 | $1.203.228,9 |
| 5,1 | 348,6 | $24.398,6 | $8.905.496,1 | $1.484.249,3 | $890.549,6 |
| 8,1 | 137,7 | $9.641,4 | $3.519.128,6 | $586.521,4 | $351.912,9 |

**Figure 10**: Result for economic evaluation due the the production decline analysis

and OPR through a plotted graph. However, the representation faces additional limitations attributed to imperfections in the imperial diagram. These constraints pose obstacles in achieving a more nuanced and accurate portrayal of the relationship between IPR and OPR. The imperfections within the imperial diagram contribute to the challenges of comprehensively capturing the dynamics involved in the interplay between input characteristics and their corresponding output results. Mitigating these limitations becomes imperative for refining the reliability and precision of the virtual model, ensuring a more thorough depiction of the complex relationships within the IPR and OPR framework. Morever, economic evaluation and risk analysis model with NPV at P50 and P80 of Crystal Ball's analysis are just simulation analysis, so that still more limitation.

## CONCLUSIONS

In summary, the research has achieved objectives as an integrated model for predicting production rate, economic evaluations, and risk analysis model in the production stage. The model can be applied to production wells, with black-oil models with empirical correlations.

This procedure can be used to the preliminary period of the project or production stage to support the decision-making process and define the production forecast.

The risk analysis model using the Crystal Ball software and a visualized model has been introduced to evaluate the risk for the decision-making process.

Besides, the sensitivity analysis evaluated the effects of pressure, and water cut after defining the operating

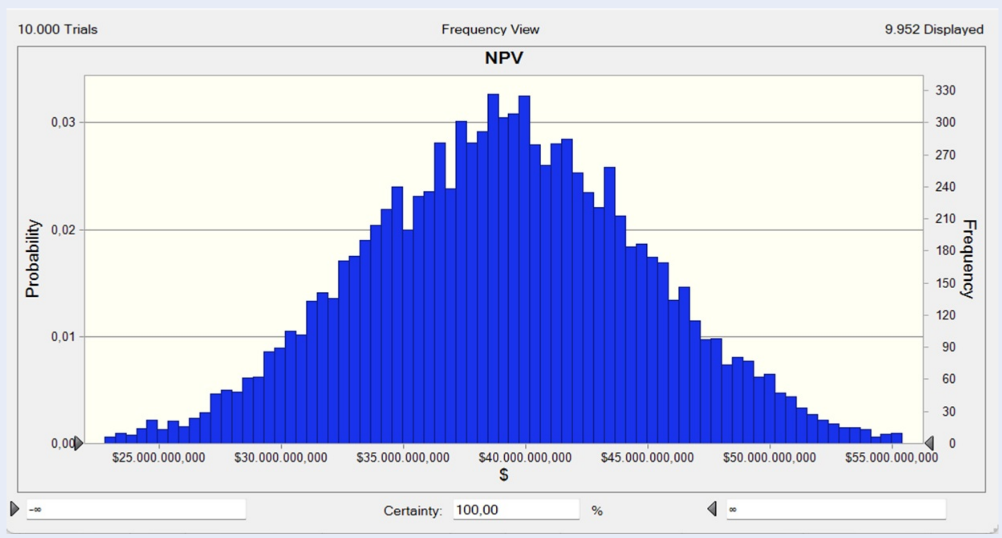


**Figure 11**: NPV analysis with 10000 iterations

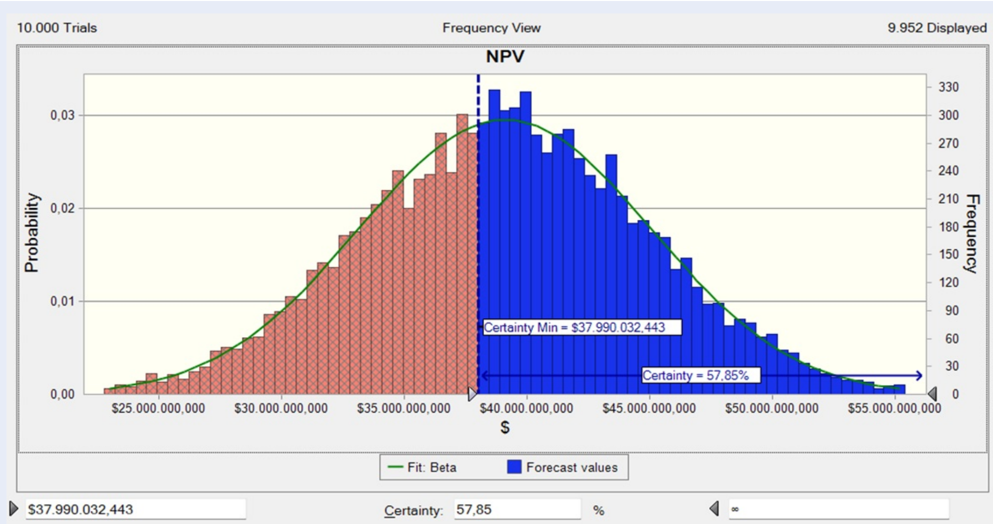


**Figure 12**: NPV at P50 of Crystal Ball's analysis

point due to the relationship of IPR and OPR from Nodal Analysis along the wellbore. The economic evaluations also determine the NPV value and the risk analysis, which assist in the decision-making process of the project.

## ACKNOWLEDGEMENTS

We acknowledge the support of time and facilities from Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

## ABBREVIATIONS

$q_o$ is oil production rate, stb/day.
$q_{max}$ is the maximum flow rate, stb/day.
$p_{wf}$ is the pressure at the well flow, psia.
$p_b$ is the pressure at the bubble point, psia.
$q_{mixture}$ is the mixture flowrate.
$B_o$ is the oil formation volume factor, rb/stb.
$B_g$ is the gas formation volume factor, rb/bbl.
S is the skin factor.
$\gamma_{mixture}$ is the mixture specific gravity.
$\rho_{mixture}$ is the mixture density.
$\rho_L$ is the density of liquid.

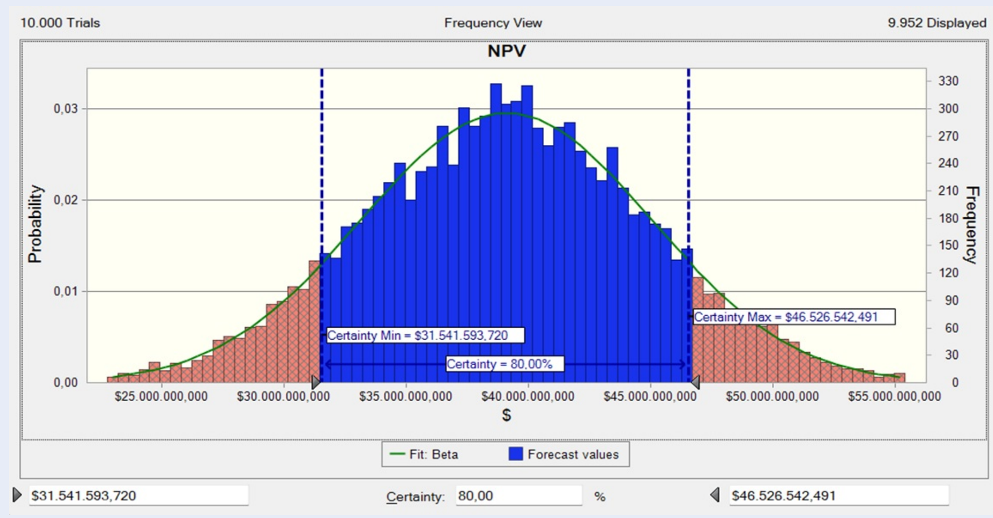


**Figure 13**: NPV at P80 of Crystal Ball's analysis

$\rho_G$ is the density of gas (lbm/[ft]^3).

d$_{ti}$ is the inner tubing diameter, in.

$\lambda$ is the the input liquid content.

V$_m$ is volume of mixture associated with 1 stb of oil, [ft]^3.

$\mu_{mixture}$ is the mixture viscosity (cp).

Re is the Reynold's number.

H$_L$ $(\theta)$ is the liquid hold-up.

f is the friction factor, dimensionless

f$_{ns}$ is no-slip friction factor.

$\frac{f}{f_{ns}}$ is the ratio friction factor.

$\psi$ is the the liquid holdup inclination correction factor.

$\left(\frac{dp}{dz}\right)_{elevation}$ is the pressure change due to the hydrostatic head of the vertical component of the pipe.

$\left(\frac{dp}{dz}\right)_{elevation}$ is the pressure loss due to friction.

$N_p^1$ and $G_p^1$ is the cumulative oil and gas production at the beginning of the interval.

$\triangle N_p^1$ and $\triangle G_p^1$ is the is the incremental cumulative oil and gas production.

PRA is Probabilistic risk assessment approach.

IPR is Inflow Performance Relationship.

OPR is Outflow Performance Relationship.

NPV is the Net Presen Value.

SA is the Sensitivity Analysis.

MBE is the Matereial Balance Equation.

## COMPETING INTERESTS

We declares no any conflicts of interest to all.

## CREDIT AUTHOR STATEMENT

**Thong N.H.and Quynh P.N.P.** Conceptualization; Methodolody; Data; Analysis; Writingg – Review & Editing. **Thong.N.H.** Supervision. Both **Thong N.H. and Quynh P.N.P.** contributed equally and have the right to list their name first for this article.

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*Bài nghiên cứu*

# Ứng dụng đánh giá rủi ro dưới khía cạnh kinh tế và kỹ thuật trong giai đoạn khai thác dầu khí

**Phạm Ngọc Phương Quỳnh[1,2], Nguyễn Huỳnh Thông[1,2,*]**



**TÓM TẮT**
Các ngành công nghiệp đối mặt với những thách thức đáng kể xuất phát từ sự không chắc chắn không chỉ làm chậm quá trình tăng trưởng kinh tế mà còn đưa ra những rủi ro trong lĩnh vực kỹ thuật, ảnh hưởng đến quy trình vận hành, hiệu suất và các dịch vụ liên quan. Việc đối mặt với rủi ro phổ biến ở các giai đoạn địa chất, kinh tế, vận hành, phát triển và sản xuất trở nên cấp bách, thúc đẩy việc triển khai các biện pháp quản lý và kiểm soát rủi ro mạnh mẽ. Những biện pháp này là quan trọng để đảm bảo hiệu suất sản xuất, bảo toàn giá trị kinh tế và thực hiện một phân tích rủi ro toàn diện ảnh hưởng đến kết quả dự án, từ đó hướng dẫn quyết định đầu tư.
Nghiên cứu này nhằm làm rõ mạng lưới phức tạp của các yếu tố ảnh hưởng đến hiệu suất sản xuất và thực hiện đánh giá rủi ro kỹ lưỡng dựa trên giá trị kinh tế và tỷ lệ sản xuất, tập trung cụ thể vào giếng X. Sử dụng một phương pháp tiếp cận toàn diện, nghiên cứu tích hợp cả phương pháp định tính và định lượng, sử dụng các công cụ như Phân tích Nodal, phương trình cân bằng vật liệu (MBE), và đánh giá rủi ro dựa trên giá trị hiện tại ròng (NPV) thông qua việc sử dụng công cụ Crystal Ball. Mục tiêu tổng thể là cung cấp các kiến thức để nhận diện đa chiều ảnh hưởng đến sản xuất giếng X.
Tóm lại, phân tích được thực hiện trong nghiên cứu này đóng vai trò như một nền tảng cơ sở cho việc đưa ra quyết định. Bằng cách xác định và đánh giá kỹ lưỡng các yếu tố ảnh hưởng đến sản xuất và khía cạnh kinh tế của giếng X, nghiên cứu nhằm giảm thiểu rủi ro trong giai đoạn sản xuất và hướng dẫn quyết định đầu tư. Sự kết hợp của phương pháp định tính và định lượng được áp dụng trong nghiên cứu này không chỉ làm phong phú sâu sắc kiến thức mà còn đóng góp vào một phương pháp đưa ra quyết định chắc chắn hơn trong các lĩnh vực phức tạp của sản xuất và đầu tư. Cuối cùng, các khuyến nghị xuất phát từ nghiên cứu này được kỳ vọng sẽ tăng cường sự linh hoạt của giếng X trước sự không chắc chắn, nâng cao cả hiệu suất sản xuất và khả năng kinh tế của nó.
**Từ khoá:** Phân tích Nodal, giá trị hiện tại ròng (NPV), đánh giá kinh tế

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