The Evaluation Model of Economy and Application in the Secondary Development by Real Options Method

Yao Huang
Toutai Oilfield Co., Ltd., Daqing, 163000, China

Abstract: The secondary development is a deeper development after efficient development, more difficult to develop, higher technical risks and fluctuations in oil prices all increase uncertainty. Owing to comprehensive benefits and uncertainty, it’s essential to find a more flexibility in investment decision-making method instead of cash flow which may cause the deviations of investment decisions. Organic combining the evaluation model of capacity, risk analysis methods, Black—Scholes model, this article has established an option evaluation method of deliverability project which is fit for the secondary development, reflects comprehensive benefits and uncertainty. It has provided a more accurate method for investment decision on the secondary development evaluation under uncertainty.

Keywords: The secondary development; uncertainty; physical options; the economic evaluation; evaluation model.

1. Introduction

Secondary development is an emerging focal point aimed at enhancing the oil recovery rate in mature oilfields. It represents a significant strategic initiative and systematic engineering effort to elevate the level of oilfield development and enhance technological innovation capabilities. Planning and deployment of secondary development must adhere to principles of economic efficiency, as the economic evaluation conclusions are pivotal to the success or failure of project investment decisions. The unique aspects of secondary development, such as changes in well patterns, combinations of well networks and reservoir formations, and the integration of various displacement methods, render traditional economic evaluation methods and parameter determination approaches partially unsuitable for assessing secondary development. Additionally, the high uncertainty and limited known information associated with secondary development projects make conventional investment decision methods less flexible, potentially leading to investment decision errors. Therefore, it is imperative to establish an economic evaluation methodology that reflects the comprehensive benefits and uncertainties of secondary development projects.

2. The characteristics of economic evaluation for secondary development

2.1 The characteristics of secondary development projects

The secondary development of a joint-stock company refers to a strategic and systematic engineering initiative for mature oil (gas) fields with significant resource potential. When these fields are at a stage of low-speed, inefficient extraction under existing development conditions or are nearing abandonment, a novel conceptual approach and a "triple" technological roadmap are employed. This involves the reconstruction of a new development system aimed at substantially increasing the ultimate recovery rate of the oil (gas) fields. The primary objectives include achieving a strategic and comprehensive system engineering for safe, environmentally friendly, energy-efficient, and highly effective development [1]. The objective of secondary development is to significantly increase the recovery rate, primarily achieved through a series of practices aimed at improving oil recovery efficiency. These practices include enhancing displacement efficiency, implementing deep reservoir adjustments, and transitioning development methods. The characteristics of secondary development are as follows: First, Specific Targeting. It focuses on specific targets, namely mature oil fields with over twenty years of...
development (possibly fifteen years for heavy oil). The identified fields should have achieved a recovery level of 70% or more of the proven recoverable reserves, with an overall water cut exceeding 85%. Second, Complex Distribution of Remaining Oil. The remaining oil is distributed in a highly complex manner, making the identification of small oil layers and reserves a starting point, focal point, and challenging aspect of secondary development. Third, Comprehensive Multi-Objective Approach. This involves considering multiple objectives: 1. Comprehensive consideration of geological characteristics, remaining oil distribution, reservoir dynamics, oil recovery processes, and surface facilities for a systematic, all-encompassing, and deep-level transformation of mature oil fields. 2. Multiple objectives include increasing reserves, boosting production, energy conservation, reducing consumption, ensuring safety, and maintaining environmental protection.

2.2 The characteristics of economic evaluation of secondary development compared with conventional development method

The economic evaluation of secondary development construction projects is a crucial component of the preliminary research phase for such projects. It should be established on the foundation of reservoir engineering, drilling engineering, oil recovery engineering, and surface engineering optimization. Utilizing scientific and standardized analytical methods, the economic evaluation aims to substantiate the economic feasibility of secondary development projects in mature oil fields. This process provides a basis for informed decision-making. Analyzing the technical aspects of various specialized engineering projects in secondary development, although each engineering technology possesses distinct characteristics, the fundamental nature of the project lies in mobilizing increments from existing reserves with relatively minimal additional inputs to achieve substantial additional benefits [2]. It exhibits typical characteristics of a renovation and expansion project. Therefore, in the economic evaluation, the "incremental benefits" metric should be applied to assess the project's economic viability. As secondary development involves a profound development following efficient exploitation, it is rooted in the reconstruction of the subsurface knowledge system, restructuring of well networks, and reorganization of surface processes. Its focus is on the sustainable development of mature oil fields. Consequently, unlike typical oilfield renovation and expansion projects, its benefits should be comprehensive, necessitating evaluation from multiple levels and perspectives [3]. Multilevel and multi-perspective evaluation entails examining the project's incremental benefits within the scope of the mature oil field, assessing overall incremental benefits within the entire oil region from the perspective of the oilfield branch, and calculating comprehensive incremental benefits within the entire business scope from the viewpoint of the group company. The economic evaluation of secondary development construction projects must ensure objectivity, scientific rigor, and fairness. It involves a combination of quantitative and qualitative analyses, with a principle emphasizing quantitative analysis, and a combination of dynamic and static analyses, primarily favoring dynamic analysis. This approach is crucial for evaluating the benefits brought about by investments in secondary development over time. Due to the widespread application of new technologies, the intricate distribution of various reservoirs, the complexity of stratigraphic well networks, and increased uncertainty in oil prices, the risk associated with secondary development has intensified. This renders traditional economic evaluation methods unsuitable for assessing secondary development. Instead, evaluation methods that can reflect uncertainties related to oil prices, technology, and other factors should be employed for a more accurate assessment. Therefore, the characteristics of the economic evaluation methods for secondary development can be summarized as follows: first, it reflects multiple benefits and is suitable for the technical characteristics of "triple one best". Second, it is suitable for the characteristics of the project with little known information, great risk and high uncertainty. The third is a flexible decision-making method.

3. The capacity project option valuation model for secondary development

3.1 The introduction of physical option value.

Conventional capacity project investment decision methods involve discounting cash flows (including NPV, IRR) [4]. This approach thoroughly considers the project's ability to generate future cash flows, providing a reliable estimation of expected returns. However, in investment decisions for projects like secondary development, where petroleum serves as a resource with inherent value, possessing such a resource implies ownership of that value regardless of its current development status. If it cannot be effectively implemented in the current period, investment in development may be viable in the future, contingent on changes in external conditions such as secondary development technologies and oil prices. To address the uncertainties and timing selection issues in secondary development investment projects, a new approach is required to determine the project's contingent value. A real option is the right to choose among physical assets, giving the option holder the ability to adapt their investment behavior based on the development trends of specific entities [5]. It allows the holder to make the most appropriate decision at the most opportune time. According to the fundamental idea of real option analysis, the actual value of an investment project's real option is equal to the Net Present Value (NPV) of the project plus its flexibility value. Therefore, the real value of a project is also known as the expanded Net Present Value (NPVN), distinguishing it from the traditional NPV. The value of the opportunity is also referred to as the option value (C). The real options approach is suitable for investment
decisions with long cycles, high investment costs, and significant investment risks. Using real option pricing models, one can accurately estimate the opportunities faced during decision-making. Moreover, based on the factors influencing these opportunities, one can actively adjust, control, or enhance the value of opportunities to minimize risks and improve strategic investment decisions. The real options theory breaks free from the constraints of traditional decision analysis methods. It doesn't simply negate traditional methods like NPV [6]; instead, it extends them by responding positively to uncertainty factors and their corresponding environmental changes, providing an extension of traditional methodologies.

The determination of the real option value \( C \) can be achieved using the Black-Scholes option pricing model [7], a primary model introduced in the early 1970s by Fisher Black and Myron Scholes. The Black-Scholes model is the predominant option pricing model in the field of real options. The formula is expressed as follows:

\[
C = SN(d_1) - Ke^{-rT}N(d_2)
\]  

(1)

In which:

\[
d_1 = \frac{\ln(S/K) + rT + \sigma^2T/2}{\sigma \sqrt{T}}
\]

\[
d_2 = \frac{\ln(S/K) + rT - \sigma^2T/2}{\sigma \sqrt{T}}
\]

In the formulas:

\( C \) represents the option value of the investment project. \( S \) is the current price of the underlying asset, i.e., the present value of the expected cash flow returns from the project. \( K \) is the exercise price of the option, i.e., the expected investment cost of the project. \( T \) denotes the expiration date of the option, i.e., the duration of the investment opportunity for the project. \( r \) is the risk-free compounded interest rate. \( \sigma^2 \) is the price volatility, i.e., the variance of the annual compounded return rate. \( N(d_1) \) is the cumulative probability distribution function of the standard normal distribution. \( N(d_2) \) is the cumulative probability distribution function of the standard normal distribution.

3.2 Model of Uncertain Value for Secondary Development Projects

In the context of oil field development and construction projects, it is fundamentally suitable to utilize option valuation models to determine the uncertain value of the project. When applying option pricing models to value natural resource options, a crucial consideration is the impact of the lag in resource extraction on the option's value. Since natural resources cannot be extracted immediately, there is a time gap between the decision to extract and the actual extraction. Therefore, if there is a one-year lag in development potential, the current price of the potential should be discounted for one year, using the discount rate based on the "cash flow/asset value" ratio (dividend yield). The adjustment method for the temporal nature of extraction is to discount the current value of the potential based on the length of the lag period.

The real options model is directly derived from financial options [8], but it deals with tangible assets. Tangible assets have many characteristics distinct from financial assets, and within tangible assets, there are often multiple options that interact. Therefore, the valuation of real options is more complex than financial options, presenting numerous challenges that need to be addressed. In the context of oil field development and construction projects, conditions conducive to utilizing option valuation models for estimation include [9]:

1. The underlying asset is a development block about to be invested in for capacity construction. The block's price is determined by the development value of the block, and its fluctuations follow a continuous process.
2. The variance can be determined using a risk analysis method, hence it is known.
3. For oil field development and construction projects with development potential, they can be immediately put into development. Therefore, the option can be exercised immediately. One of the premises for the validity of option pricing models is that the option can be exercised immediately.

Generally, the value of an option is primarily influenced by five factors: the current price of the underlying asset, volatility, the option's exercise price, time to expiration, and the risk-free compounded interest rate. When combined with the application of real options and financial options, the meanings of these parameters in the context of oil field development and construction project options should be:

1. Current Price of the Underlying Asset: The present value of the expected cash flow returns from the currently undeveloped capacity construction block (\( S \)), \[ S = \sum_{i=1}^{n} CI_i (1+i_i)^{-t} \]

2. Volatility: The fluctuation in project value due to the volatility of oil prices and deviations in reserve estimates (\( \sigma^2 \)).

3. Exercise Price of the Option: The development cost of the oil field project (\( K \)), \[ K = \sum_{i=1}^{n} (L & C_i) (1+i_i)^{-t} \], where \( L & C_i \) includes investment and cost expenditures during the evaluation period.

4. Time to Expiration: The expiration date of the option during the rights period (\( T \)).

5. Risk-Free Compounded Interest Rate: The risk-free interest rate (\( r \)).

According to the above analysis of option valuation model parameters for capacity construction, the option valuation model for capacity construction can be expressed by the following formula:

Call Option:

\[
C = \sum_{i=1}^{n} [CI_i (1+i_i)^{-t}] N(d_1) - \sum_{i=1}^{n} [L & C_i (1+i_i)^{-t}] e^{-rT} N(d_2)
\]

(2)

Put Option:
In which:

\[
C = \sum_{i=1}^{n} C_i (1+i)^{\gamma - i} - \sum_{i=1}^{n} I_i & C_i (1+i)^{\gamma - i} \cdot e^{-r \cdot [N(t_i ) - 1]} \tag{3}
\]

Under uncertain conditions, the value of a project is determined by both its intrinsic value and option value. According to the option valuation model for capacity construction, the potential development value (C) at different times T can be calculated. This value, added to the net present value (NPV) of the overall project benefits, provides the value of the project considering uncertainty for the secondary development specialized technology capacity construction project. Therefore, the model representing the total value under uncertainty is expressed as:

\[
NPVN = NPV + C \tag{4}
\]

In the formulas: NPVN is the total project value after considering uncertainty, in thousands of yuan. When the Net Present Value (NPV) of the overall project benefits, NPV < 0 and NPV + C ≥ 0, the project can be deferred for development until period T. If NPVN < 0, the project is currently not acceptable.

4. Application of the Uncertain Value Model for Secondary Development Projects

4.1 Determination and Explanation of Evaluation Parameters

Evaluation of the secondary development block BBGDD, which involves the development of a low-viscosity oil reservoir through water flooding to steam flooding. During the assessment, the exchange rate is set at 6.8 RMB/USD, the crude oil volume conversion factor is 7.428 barrels/ton, and the oil price is $65 per barrel. The crude oil commercial rate is calculated at 98.37%. Tax-related evaluation parameters include income tax rate (25%), value-added tax rate (17%), resource tax (5%, with preferential rates according to documentation), city construction maintenance tax (7%), and education surcharge (3%). Cost data is forecasted based on current cost expenses and neighboring block conditions for the implementation of the secondary development.

In the option valuation parameters, the block’s present value (S) and development investment (K) are measured by the above conventional evaluation calculation. The expiration period (T) represents the time until the block is planned for development, and for this evaluation, it is set at 1 year. The risk-free interest rate is the one-year Treasury bond rate (5%). The volatility of oil prices and the volatility of reserve estimates (variance \( \sigma^2 \)) are determined through risk analysis of the block.

4.2 Evaluation Results

Steam drive technology is currently predominantly applied in heavy oil reservoirs, while steam drive development in light oil is in its initial exploration phase, with substantial technical risks. Accurately assessing its development benefits can provide a basis for informed decision-making.

Through sensitivity analysis, it is found that the economic benefits of the transition zone steam drive are significantly influenced by uncertain factors such as Enhanced Oil Recovery (EOR) and steam prices (Figure 3-1). Under current conditions, the cost of steam for the project is 180 yuan per ton. According to the scheme analysis, BBGDD can increase the recovery rate by 17.89%. The project, evaluated using conventional methods even after considering comprehensive benefits, achieves an internal rate of return (IRR) of only 3.39%. Considering the potential widespread adoption of steam drive technology, if the steam acquisition price drops to 150 yuan per ton, the internal rate of return, considering multiple benefits, is 8.95%, still below the 12% standard, with a net present value of -21.86 million yuan. However, considering uncertain factors such as future technological advancements and oil price changes, the project has an option value (potential profitability) of 36.5 million yuan. The net present value of the project then reaches 14.64 million yuan (Table 3-1).

![Figure 3-1 Benefit Variation Chart at Different Recovery Rates](image-url)

Although the internal rate of return (IRR) indicator for the BBGDD block remains below 12% even when considering comprehensive benefits, the project, with its potential development value under uncertain conditions, can be planned and arranged as a valuable potential block.
### Table 3-1 Economic Evaluation Results Table for BBGDD under Different Conditions

<table>
<thead>
<tr>
<th>project</th>
<th>Steam price (yuan/t)</th>
<th>180</th>
<th>21.62</th>
<th>24.11</th>
<th>150</th>
<th>21.62</th>
<th>24.11</th>
</tr>
</thead>
<tbody>
<tr>
<td>EOR (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional Project Benefits</td>
<td>-0.13</td>
<td>7.66</td>
<td>12</td>
<td>5.08</td>
<td>12.02</td>
<td>16.11</td>
<td></td>
</tr>
<tr>
<td>Comprehensive Benefits</td>
<td>3.39</td>
<td>12</td>
<td>16.98</td>
<td>8.95</td>
<td>16.76</td>
<td>21.51</td>
<td></td>
</tr>
<tr>
<td>Total Value Considering Options (in thousands of yuan)</td>
<td>-4485.6</td>
<td>5032.8</td>
<td>11926.2</td>
<td>1464.3</td>
<td>11734.6</td>
<td>19058.5</td>
<td></td>
</tr>
</tbody>
</table>

### 5. Conclusion

(1) In the investment decision-making of oilfield secondary development, the inherent value of petroleum resources, regardless of their current development status, is a crucial factor. Possessing such resources means possessing their inherent value. The incorporation of real options can effectively reflect the latent value of resources. The establishment of an economic evaluation model for secondary development considering real options deviates from the traditional "with-or-without" net present value approach, enabling a comprehensive assessment. This model addresses the limitations of not capturing integrated benefits and dealing with uncertainties arising from new technology choices, oil price fluctuations, and other risks. It is well-suited for investment decisions in current uncertain conditions for secondary development projects.

(2) The real options-based economic evaluation model for secondary development is suitable for investment decisions at different time periods within the current management system. It enhances the scientific, standardized, and flexible aspects of investment management, holding significant importance for evaluating the secondary development of mature oilfields.

### References