BACHELOR THESIS

APPLICATION OF REAL OPTIONS ANALYSIS IN COAL MINING PROJECT VALUATION: A STUDY CASE OF PT XYZ

Compiled and submitted by:

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MINING ENGINEERING BACHELOR STUDY PROGRAM
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LEGALIZATION

APPLICATION OF REAL OPTIONS ANALYSIS IN COAL MINING PROJECT VALUATION: A STUDY CASE OF PT XYZ

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LEMBAR PENGESAHAN

APLIKASI ANALISIS REAL OPTIONS PADA VALUASI PROYEK PENAMBANGAN BATUBARA: SEBUAH STUDI KASUS PT XYZ

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Is my own writing work and is not a takeover of other people's writings and that the thesis that I wrote is truly the result of my own work.

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If in the future it is proven or can be proven that part or all of the contents of this thesis are the work of other people, then I am willing to accept sanctions for these actions.

Gowa, November 3rd 2023

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ABSTRACT

ANDHIKA BAHARUDDIN. *Application of Real Options Analysis in Coal Mining Project Valuation: A Study Case of PT XYZ* (supervised by Rini Novrianti Sutardjo Tui and Rizki Amalia)

PT XYZ is a mining company engaged in coal mining. At present, the company is using discounted cash flow (DCF) approach for the upcoming pit LMN project valuation. Therefore it uses a single expected value of future cashflow that presents some crucial limitations when dealing with uncertainty associated to volatility thus it lacks of recognition of managerial flexibility. In seeking solutions to optimize the value of the company's strategic investment decisions and management of flexibility, an appropriate approach needs to be taken.

The aim of this research is to conducting real option valuation (ROV) to obtain the expanded NPV (ENPV) through NPV calculation of the option to abandon in pit LMN project of PT XYZ. The model of DCF valuation used in this research is the Free Cash Flow to Firm (FCFF). The sensitivity analysis technique used is one of the one-at-a-time (OAT) method, the one-way method. The real option analysis model used in this research is binomial lattice model as most common technique implemented that works well for complex options.

DCF valuation on Pit LMN project of PT XYZ resulting in NPV of US $105,126,304.47. RO valuation with option to abandon is conducted using the NPV of DCF valuation as underlying asset, with 30.60% volatility, 3.42% risk-free rate, 5 years of maturity, 0% dividend, 60 lattice steps, and using American option, the resulting expanded NPV is US $105,126,313.05. The difference between NPV of DCF valuation and expanded NPV of RO valuation is US $8.58 which is due to the abandonment option. It is wise for PT XYZ to continue with the development. Otherwise, if circumstances force the value of the development effort down to US $6,031,721.79, then it is more optimal to abandon the project.

Keywords: Coal, DCF, Volatility, ROV, ENPV

ABSTRAK

ANDHIKA BAHARUDDIN. *Aplikasi Analisis Real Options pada Valuasi Proyek Penambangan Batubara: Sebuah Studi Kasus PT XYZ* (*dibimbing oleh* Rini Novrianti Sutardjo Tui and Rizki Amalia)

PT XYZ adalah perusahaan pertambangan yang terlibat dalam penambangan batubara. Saat ini, perusahaan menggunakan pendekatan arus kas diskon (DCF) *untuk valuasi proyek* pit LMN *yang akan datang. Oleh karena itu, pendekatan ini hanya menghasilkan satu nilai valuasi dari arus kas di masa depan yang menghadirkan beberapa batasan ketika berurusan dengan ketidakpatian yang terkait dengan volatilitas sehingga nilai yang didapatkan terhadap fleksibilitas manajerial akan berkurang. Dalam mencari solusi untuk mengoptimalkan nilai keputusan investasi strategis perusahaan dan manajemen fleksibilitas, valuasi yang tepat harus dilakukan.*

Tujuan penelitian ini adalah untuk melakukan real option valuation (ROV) *untuk mendapatkan* expanded NPV (ENPV) *melalui perhitungan* NPV *dari* option to abandon *dalam proyek* pit LMN PT XYZ. *Model valuasi DCF yang digunakan dalam penelitian ini adalah* Free Cash Flow to Firm (FCFF). *Teknik analisis sensitivitas yang digunakan adalah salah satu metode* one-at-a-time (OAT), *metode satu arah. Model* real option *yang digunakan dalam penelitian ini adalah model binomial sebagai teknik yang paling umum diterapkan yang bekerja dengan baik untuk opsi kompleks.*

Valuasi DCF *pada proyek* Pit LMN PT XYZ *menghasilkan* NPV *sebesar* US $105.126.304,47. *Valuasi* RO *dengan* option to abandon *dilakukan menggunakan* NPV *dari valuasi* DCF *sebagai aset dasar, dengan volatilitas* 30,60%, risk-free rate 3,42%, 5 *tahun kelangsungan hidup*, 0% *dividen*, *dan* 60 *langkah* lattice, *dan menggunakan* American option, *nilai* expanded NPV *yang didapatkan adalah* US $105.126.313,05. *Perbedaan nilai* NPV *dari valuasi* DCF *dan* expanded NPV *dari valuasi* RO *adalah* US $8,58 *yang diakibatkan penggunaan* option to abandon. PT XYZ *bijaknya tetap melanjutkan pengembangan proyek sesuai yang direncanakan. Sebaliknya, jika keadaan memburuk dan nilai proyek turun hingga* US $6.031.721,79, *maka akan lebih optimal untuk meninggalkan proyek.*

Kata Kunci: Batubara, DCF, *Volatilitas*, ROV, ENPV

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LIST OF ABBREVIATIONS AND SYMBOL MEANING

Abbreviation/Symbol	Meaning and Description
$	Dollar
σ	Volatility
β	Beta
∆PP&E	Change in properties, plants, and equipments
A	
Adb	Air-dried base
AFT	Ash fusion temperature
Ar	As received
B	
Bcm	Bank cubic meter
C	
Capex	Capital expenditure
CAPM	Capital asset pricing model
CPP	Coal Processing Plant
CV	Caloric value
D	
D	Debt composition
d	Down factor
DCF	Discounted Cash Flow
DDM	Dividend Discounted Model
Deg	Degree
E	
E	Equity composition

Abbreviation/Symbol	Meaning and Description
EBITDA	Earning before taxes, interests, depreciation, and amortisation
EBT	Earning before tax
ENPV	Expanded net present value
ERP	Equity risk premium
F	
FAD	Fund allocated distribution
FC	Fixed carbon
FCFE	Free cash flow to equity
FCFF	Free cash flow to firm
FR	Fuel ratio
G	
Gar	Gross as received
H	
Ha	Hectare
HBA	Harga Batubara Acuan
I	
i	Interest rate
ICI	Indonesia Coal Index
IDI $10I_{geom}$	10-Years Indonesia Inflation rate
$IDI10Y_{geom}$	10-Years Indonesia Bond geometric mean
IDR	Indonesian rupiah
IDT	Initial deformation temperature
IM	Inherent moisture
IRR	Internal rate of return

Abbreviation/Symbol	Meaning and Description
K	
K	Exercise price
Kcal	Kilo calorie
Kd	Cost of debt
Ke	Cost of equity
KL	Kilo liter
Km	Kilo meter
L	
LN	Lognormal
LOM	Life of mine
LP	Linear programming
Ls	Logistic specialist
M	
m	Meter
m^2	Meter cubic
MIP	Mixed integer programming
MS	Microsoft
N	
n	Number
NPV	Net present value
O	
OAT	One at time
Opex	Operational expenditure
P	
PBP	Payback period
Pcs	Pieces

Abbreviation/Symbol	Meaning and Description
PV	Present value
Q	
Qty	Quantity
R	
Rc	Country risk premium
RED	Reduced atmosphere
Rf	Risk-free rate
Rm	Market return
rm_{geom}	Market rate of return geomean
RO	Real option
ROA	Real option analysis
ROV	Real option valuation
S	
S	Value of underlying asset
SLS	Super lattice solver
T	
T	Time to expiration of option
t	Corporate tax rate; Number of months
TS	Total sulphur
U	
u	Up factor
US	United States
USD	United states dollar
V	
VM	Volatile matter

Abbreviation/Symbol	Meaning and Description
W	
WACC	Weighted Average Cost of Capital
WMP	Water management point

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Andhika Baharuddin

CHAPTER 1
INTRODUCTION

1.1 Background

Indonesia is one of the countries with very abundant natural wealth, various natural resources are scattered in various regions in Indonesia and one of the natural resource commodities that has the potential to improves people's welfare in Indonesia is mining commodity. Indonesia is one of the biggest producer and exporter of coal in the world. It is recorded that the country's coal export contributes to the gross domestic product of Indonesia for about 5% and 12% of all export income. (LPEM UI, 2022; Nale, 2012)

Mining investment are particularly irreversible and involve many uncertain factors throughout the life of the project, therefore these variables and the correct timing of the investment must be clearly understood. When investment are irreversible and the economic environment is volatile, the value of the abilities to maintaining managerial flexibility is high. The ability to delay is a powerful component of the strategy of mining investment. The irreversibility of investment creates exposure to losses in the highly volatile commodity market. (Foo, et al., 2018; Miranda & Brandão, 2013).

The most important aspect in a mining project, especially for coal, is economic valuation, but many variables greatly influence it, such as coal price volatility. It makes planning a valuation calculation crucial in describing conditions that may occur in the future, including considering the risks. The valuation calculation widely used today is the NPV with the DCF method, which will describe the value of a project in the present time. However, the DCF method is considered to have a limitation in determining the actual project value, mainly because of the use of a single risk factor known as the discount rate and imposed on the overall cash flow. As a result of applying the same discount rate to all projects, more risky ones may be overvalued compared to less risky ones (Guj, 2006).

The traditional approach to project valuation is based on the calculation of the net present value of a project over its entire life cycle. Investment costs and production phase free cash flow are accounted using a discount factor that best represents the risk associated with the project. One or multiple net present values can be obtain by using different methods and varying input variables. If the net revenues during the production phase are higher than the investment cost, the project is considered worthy of investment (Anderloni, 2011).

Mining commodity prices always show greater volatility than those of any other primary products. As a result of these uncertainties, finding the critical price at which it is optimal to invest in a project is crucial. The most suitable tool for handling uncertainty and for justifying an investment in system flexibility, particularly a mining operation is The Real Option (RO) tool. The RO theory postulates that uncertainty has value and only those that embrace it can minimise losses or maximise opportunities that come with associated volatility. The real options approach attempts to value project by considering the value of being able to decide among several strategic options (Zhang, 2006).

PT XYZ is a mining company engaged in coal mining. At present, the company is using discounted cash flow (DCF) approach for the upcoming pit LMN project valuation. Therefore it uses a single expected value of future cashflow that presents some crucial limitations when dealing with uncertainty associated to volatility thus it lacks of recognition of managerial flexibility. In seeking solutions to optimize the value of the company's strategic investment decisions and management of flexibility, an appropriate approach needs to be taken.

1.2 Problem Statement

Real option (RO) analysis is able to incorporate the value of management decision making and flexibility to act according to changes or revise past decisions with time, based on new information. Therefore, it provides a transparent guideline for analysing the timing of strategic and operational decisions as it deals with the different sources of uncertainty individually, accounting for all possible scenarios of future outcomes thus this approach can provide better managerial flexibility and strategic investment decisions by finding the expanded NPV through ROV. Based on the background, the problem statement of this research is "what is the expanded NPV obtained through the Real Option valuation with option to abandon of the pit LMN project?".

1.3 Aim of Research

The aim of this research is to conducting real option valuation (ROV) to obtain the expanded NPV (ENPV) through NPV calculation of the option to abandon in pit LMN project of PT XYZ.

1.4 Use of Research

This research has the following uses:

1. For the student

   By doing this research, student can directly apply the real option theory in mining project valuation therefore it will increase their knowledge and understanding of real option on decision making in mining financial valuation.
2. For the company

   The result of this research can be applied to provides and generates the value of the investment projects for better managerial flexibility.

1.5 Scope of Research

The scope of this research is limited to a single mining project valuation pit LMN which secondary data acquired from PT XYZ's feasibility study in 2020 and historical market data within 2012-2021 period, these data are used for the sake of supporting data processing and analysing. There is no shares valuation of the company in this research, thus, the Cost of Equity will be calculated using the Capital Asset Pricing Model (CAPM) instead of Capitalization Model and the dividend rate will set to 0%.

CHAPTER 2
LITERATURE REVIEW

2.1 Uncertainty Categories in The Mining Industry

The mining industry is one of the riskiest sectors when compared to other industries. A skilled team, courage and an optimistic view are required to attract financial investor support for mining projects. Most natural resource investments are irreversible, implying that if a firm has made a commitment to finance a mine, then it will be difficult to wind back that investment (Martinez & McKibben, 2010).

Investors and managers normally face a dilemma regarding whether to continue with the mining investment when the commodity market is worse than expected, or simply forgo the capital already invested and discard the project. Considering the amount of capital investment required to develop a mine, the above choices are nor easy for managers to make. It takes a number of years from the commencement of an investment to the actual production of saleable ore product. This can range from between three to seven years, providing an opportunity to gather more information and make informed decisions. Most people involved believe that the best way of doing this is to use the real option (RO) approach. This describes the possibilities a firm has, allowing the world to be opened up as a map of opportunities. The methodology is used to justify an increase in system flexibility under uncertainty. (Groeneveld, et al., 2010; Topal, et al., 2009; Edelmann & Koivuniemi, 2004)

The special characteristics of any mining project are the high level of uncertainty in ore grade estimation and the volatile fluctuations in commodity prices. Moreover, there are myriad risks and uncertainties associated with individual operations. Some of these uncertainties stem from the industry itself and the operating environment as well as the geopolitical factors of the host country. The main uncertainties of any mining project can be categorized as either exogenous, endogenous, or a combination of both. Those uncertainties that fit into the both categories are shown in Table 1 (Groeneveld & Topal, 2011; Kazakidis & Scoble, 2003).

Table 1 Uncertainty categories in the mining industry

External (Exogenous)	Internal (Endogenous)
• Market prices • Industrial relations • Legislation/regulations • Political risks • Government policies	Operating • Grade distribution • Ground-related conditions • Equipment • Infrastructure • Recovery method Other • Workforce • Management/operating team

Source: (Kazakidis & Scoble, 2003)

Table 1 above shown the uncertainty categories in the mining industry. The external (exogenous) categories are: market prices, industrial relations, legislation/regulations, political risks, and government policies while the internal (endogenous) are: grade distribution, ground-related conditions, equipment, infrastructure, recovery method, workforce, and management/operating team.

Despite an ever-increasing level of uncertainty, most corporations make their financial decisions based on discount cash flow (DCF) methods, such as net present value (NPV) and internal rate of return (IRR) which are static. Any future value must be counted down to the present to be comparable to any current price. Production planning and design would be easy if variables like price or ore grades followed a known value. Methodologies such as linear programming (LP), mixed integer programming (MIP) and the heuristic method commonly used in engineering design (and especially in the mining industry) can also be used to model flexibility and maximize a project's NPV, based on the assumptions of the DCF analysis (Akbari, et al., 2009; Adelman & Watkins, 1995).

2.2 Discounted Cash Flow (DCF) Valuation

The most used project appraisal method in industrial practice is the DCF analysis. The Discounted Cash Flow (DCF) is a valuation method of an assets by assuming its present value's cash flows that can be generated by the asset, discounted at a specific ratio which represents the risk of cash flows. In DCF valuation, the value of an asset is the present value of the expected cash flows on assets, discounted at a rate that reflects the risk of these cash flows. The DCF method is divided into three models, i.e., Dividend Discounted Model (DDM), Free Cash Flow to Equity (FCFE), and Free Cash Flow to Firm (FCFF) (Damodaran, 2006; Graham & Harvey, 2001).

DCF valuation attempts to figure out the value of an investment today, based on projections of how much money it will generate in the future by apply discount rate. The discount rate will be a function of the riskiness of the estimated cash flows, with higher rates for riskier assets and lower rates for safer projects. The discounted cash flow is the foundation on which all other valuation approaches are built on and that when holding other things equal such as: higher cash flows, higher growth and lower risk should result in a higher value of the company (Damodaran, 2012).

The research of academic literature disclosed that DCF analysis is relatively easy to implement, widely taught, widely accepted and has many advantages over alternative investment evaluation methodologies in that is (Locatelli, et al., 2016; Regan, et al., 2015; Mun, 2005; Thomas, 2001):

1. Is a definite, consistent decision making criterion for all investment projects.
2. Grants the same results, despite of risk preference of investors.
3. Is less vulnerable to accounting formalities.
4. Factors in both risk and the time value of money.

Under uncertainty strategic investment projects violate a large part of discounted cash flow (DCF) assumptions, causing discounted cash flow analysis to be of limited value or misleading. The issue of the main limitations associated with discounted cash flow analysis has already been addressed in finance research and is summarized as follows (Pless, et al., 2016; Schachter & Mancarella, 2016; Yeo & Qiu, 2003; Adler, 2000; Dessureault & Scoble, 2000; Park & Herath, 2000):

1. It focuses on tactical investment decision making rather than long-term strategic goals and places short-term goals before long-term profitability.
2. It is difficult to decide upon the correct discount rate. The higher the uncertainty implicated by the project, the higher the discount rate, reflecting

a higher risk premium, is used, and the benefits associated with later years' cash flows are greatly diminished.

3. It disregards the qualitative benefits that frequently characterize strategic investment projects and the criticality of some investments to the survival of a company.
4. It ignores future opportunities and views investment decisions as now or never type decisions. Thereby, the flexibility to modify decisions as new information appears is defied. DCF methodology assumes that regardless the high uncertainty a strategic project will be launched now and continuously operated until the end of its expected life.

In reality, there are several issues that an analyst should be aware of prior to using DCF analysis as shown in Table 2 below (Mun, 2002):

Table 2 DCF Assumptions versus Realities

DCF Assumptions	Realities
Decisions are made now and cash flow streams are fixed for the future	Uncertainty and variability in future outcomes. Not all decisions are made today, as some may be deferred to the future, when uncertainty becomes resolved
Projects are interchangeable with whole firms	With the inclusion of network effects, diversification, interdependencies, and synergy, firms are portfolios of projects and their resulting cash flows. Sometimes projects cannot be evaluated as stand-alone cash flows
Once launched, all projects are passively managed	Project are usually actively managed through project life cycle
Future free cash flow streams are all highly predictable and deterministic	It may be difficult to estimate future cash flows as they are usually stochastic and risky in nature

DCF Assumptions	Realities
Project discount rate used is the opportunity cost of capital, which is proportional to non-diversifiable risk	There are multiple sources of business risks with different characteristics, and some are diversifiable across projects or time
All risk are completely accounted for by the discount rate	Firm and project risk can change during the course of a project
All factors that could affect the outcome of the project and value to the investors are reflected in the DCF model through the NPV or IRR	Because of project complexity it may be difficult or impossible to quantify all factors in terms of incremental cash flows. Distributed, unplanned outcomes can be significant and strategically important
Unknown, intangible, or immeasurable factors are valued at zero	Many of the important benefits are intangible assets or qualitative strategic positions.

Source: (Mun, 2002)

As shown in Table 2, DCF analysis assume that the decisions are made now and cash flow streams are fixed for the future but in reality, there are uncertainty and variability in future outcomes. DCF assume once projects launched, they are passively managed but in reality, they are usually actively managed through project life cycle. DCF also assumes that the future free cash flow streams are all highly predictable and deterministic, project discount rate used is the opportunity cost of capital, all risk are completely accounted for by the discount rate, and all factors that could affect the outcome of the project and value of the investors are reflected in the DCF model through the NPV or IRR but in reality, project are usually actively managed through project life cycle, it may difficult to estimate future cash flow as they are usually stochastic and risky in nature, there are multiple sources of business risks, firm and project risk can change during the course of a project, and because of project complexity it may difficult or impossible to quantify all factor in terms of incremental cash flows.

2.2.1 Free cash flow to firm

Free cash flow to firm is also called unlevered free cash flow. In corporate practice, the FCFF technique is most commonly used. FCFF includes in addition to equity, bondholders, and preferred stockholder, it allows the analysis to be performed from the point of view of all parties financing. The high FCFF indicates that the company has money left behind for its operations and performance, and at this point suggests good economic health for the company (Corporate Finance Institute, 2023; Miecarz & Mlinarič, 2014; Damodaran, 2012).

The applicability of DCF models where the FCFF approach is included, depends on the infomational requirements of expected future cashflows and discount rates. This approach is easiest to used for firms with currently positive cashflows and with some degree of reliability of estimating future cashflows. It is also requiring a proxy for risk that can be used as discount rate for the company. If these information requirements are not fulfilled, the difficulties of making an objective valuation will increase (Damodaran, 2012).

2.2.2 Weighted Average Cost of Capital

Weighted average cost of capital (WACC) represents its blended cost of capital across all sources, including common shares and debt. The cost of each type of capital is weighted by its percentage of total capital and then are all added together as shown in Figure 1 below. WACC is used in financial modeling as the discount rate to calculate the net present value of a business. More specifically, WACC is the dicount rate used when valuing a business or project using the unlevered free cash flow approach (Corporate Finance Institute, 2023).

The cost of WACC is to determine the cost of each part of the company's capital structure based on the proportion of equity, debt, and preferred stock it has. The company usually pays a fixed rate of interest on its debt and usually a fixed dividend on its preferred stock. Even though a firm does not pay a fixed rate of return on common equity, it does often pay cash dividends (Corporate Finance Institute, 2023).

The components of WACC can be seen in Figure 1 below.

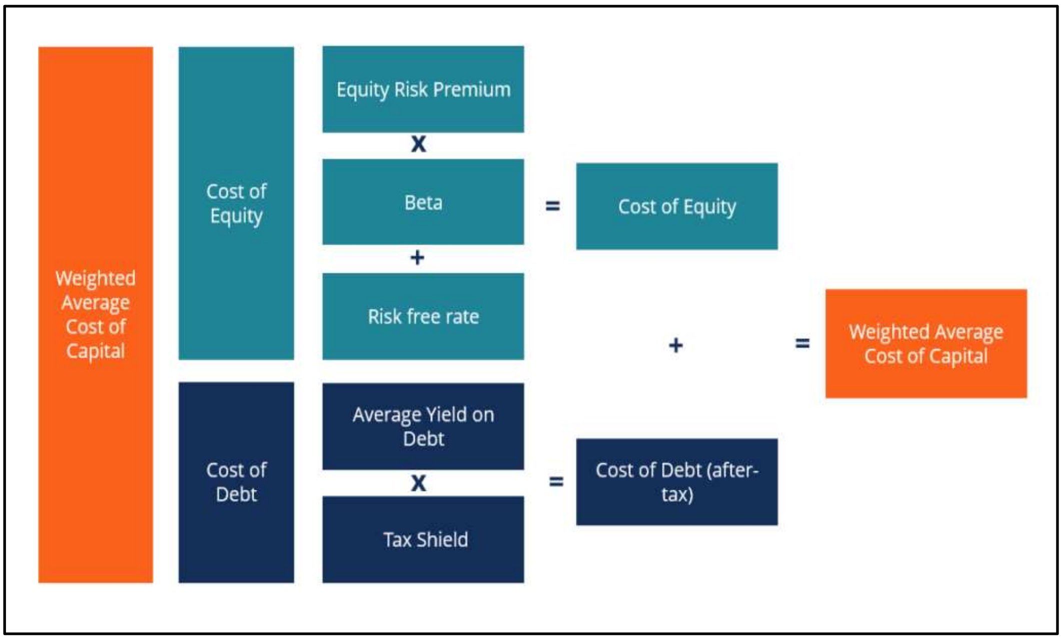

Figure 1 WACC's components (Corporate Finance Institute, 2023)

From Figure 1 above, we can find that the weighted average cost of capital is the sum of cost of equity and cost of debt.

The weighted average cost of capital is an integral part of a DCF valuation model, thus, its an important concept to understand for finance professional, especially for investment banking, equity research, and corporate development roles (Corporate Finance Institute, 2023).

The components of WACC are as follows (Corporate Finance Institute, 2023):

a. Cost of Equity

The cost of equity is calculated using the Capital Asset Pricing Model (CAPM) which equates rates of return to volatility. The cost of equity is an implied cost or an opportunity cost of capital. It is the rate of return an investor requires in order to compensate for the risk of investing in the stock. Beta is a measure of a stock's volatility of return relativc to the overall stock market.

1) Risk-free rate

The risk-free rate is the return that can be earned by investing in a risk-free security, e.g., U.S Treasury Bonds. Typically, the yield of the 10-years U.S. Treasury is used for the risk-free rate.

2) Equity risk premium (ERP)

The equity risk premium is defined as the extra yield that can be earned over the risk-free rate by investing in the stock market. One simple way to estimate ERP is to subtract the risk-free return from the market return.

3) Beta (β)

Beta refers to the volatility or riskiness of a stock relative to all other stocks in the market. The simplest way to calculate the beta is by using the company's historical beta using regression analysis.

Figure 2 Beta's regression analysis (Corporate Finance Institute, 2023)

Figure 2 above shown the resulting regression analysis of the Beta, the slope of the line is the beta.

b. Cost of Debt

Cost of debt is the yield to maturity on the firm's debt.

c. Cost of Preferred Stock

Cost of preferred stock is the dividend yield on the company's preferred stock.

Despite its prevalence in corporate finance, WACC does have several limitations as follows (Corporate Finance Institute, 2023):

a. Difficult to measure in practice

Some of the input to WACC are difficult to measure in practice and require analyst judgment.

b. Difficult to apply to a specific project

   WACC is usually calculated at the corporate level, using the corporation's cost of equity and target capital structure. It requires a margin of error to its corporate-level WACC to account for the potentially higher risk of the individual investments because its considering or may not have the same risk-and-return characteristics of the parent company.

c. Use of historical data

   WACC's inputs are based on historical data, therefore WACC implicitly assumes the past will continue in to the future, which is obviously not always the case.

d. Private companies

   Although its possible to calculate WACC for private companies, it is more difficult especially around cost of equity.

2.3 Real Option Valuation

The concept of real options was introduced by Stewart Clay Myers who was the first to recognize the potential value of applying the financial options theory to real investment projects and presented a formal real options model. The real option allows the investor to lock losses at a certain cost in advance when facing future uncertainties while retaining the chance to gain future rewards at the same time. In contrast to investment decision analysis based on the traditional discounted free cash flow method of asset valuation, which bounds the investor to a fixed setting, the real options provide future flexibility in investment decisions. Application of real option in investment decision analysis permits the decision-maker to effectively deal with the uncertainties associated with the investment. Moreover, in any investment decisions in real assets such as investment in natural resource exploration, acquisitions of enterprises, or investment in technology development, real options give the investor the options to "defer, abandon, shutdown and restart, expand, contract, and switch" (Trigeorgis, 1999; Myers, 1977).

The real options approach incorporates a learning model, such that management makes better and more informed strategic decisions when some levels of uncertainty are resolved through passage of time. The discounted cash flow analysis assumes a static investment decision and assumes that strategic decisions are made initially with no recourse to choose other pathways or options in the future (Pandza, et al., 2003).

Real option are crucial in (Mun, 2002):

1. Identifying different corporate investment decision pathways or projects that management can navigate given the highly uncertain business condition.
2. Valuing each strategic decision pathway and what it represents in terms of financial viability and feasibility.
3. Prioritizing these pathways or projects based on series of qualitative and quantitative metrics.
4. Optimizing the value of your strategic investment decisions by evaluating different decision paths under certain conditions or using a different sequence of pathways to lead to the optimal strategy.
5. Timing the effective execution of your investment and finding the optimal trigger values and cost or revenue drivers.
6. Managing existing or developing new optionalities and strategic decision pathways for future opportunities.

Analysts should be aware of several constraints before starting the analyse of real option, the following five requirements must be met before it is conducted (Mun, 2002):

1. There must be a financial model.
2. There must be uncertainty.
3. Uncertainty must effect decisions made by a company during the realization of a ventures as well as it must affect the results of the financial model.
4. The manager must have the possibility of flexible decision making or the possibility of implementing changes during the active realization of the project.
5. The decision-maker must be predicting and credible enough to realize an option at the optimal moment.

2.3.1 Value drivers

Option could be further distinguished as either European or American. European options can be exercised only on their expiration date and American options can be exercised at any time up to the expiration date. As American options grant the option holder more rights, they are at least worth the same as their European counterparts (Copeland & Antikarov, 2001).

Regardless of the structure of the option or the quantification method, the value of a Real-Option depends on the variables listed below:

1. Value of the underlying asset (*S*)

   This represents the value of the underlying asset or the present value of the cash flows from the project (excluding the capital investment to be made and the present value of the upfront fees and development costs over the next two years). There are basically two methods to estimate this value such as the financial markets and the market asset disclaimer (MAD) (Aarle, 2013; Black & Scholes, 1973).

2. Exercise price (*K*)

   This represents the capital investment to be made approximately years. The exercise price in real options is the advance capital outlays by the investor to obtain the right to begin work on a project or the right to enter an industry. The concept of the preinvestment value of real option projects is considered similar to the concept of the strike price of financial options but does not account for the sunk cost contained in real options. (Li, et al., 2021; Black & Scholes, 1973).

3. Time to expiration of option (*T*)

   This represent the time option being exercisable, varied over two, three and four years or the amount of time between the moment the opportunity arises and the latest moment this opportunity will be accessible. For Real-Options the time to expiration could be either easy to establish or rather vague. It is easy to establish if the company holds a licence to investment with a clear expiration date, or has an ultimatum for investment. However, in some cases the time to expiration can theoretically be infinite, for example for the option to defer an investment. In reality, the time to expiration is often dependent on the competition, changes in technology and macroeconomic factors and is therefore not explicitly fixed. A longer time to expiration will also lead to an increase in the value of a RO, as it will allow us to learn more about the uncertainty (Aarle, 2013; Black & Scholes, 1973).

4. Volatility of project value (σ)

   This represents a sample of annual standard deviation of return for stocks obtained from an investment bank. The volatility indicates the sensitivity to price fluctuations of the underlying asset, the uncertainty about the future value of the project's cash flows. In case of a Real-Option, managerial flexibility leads to uncertainty in the price of the underlying asset, which will increase its volatility. An increase in the volatility will also increase the option's value. Volatility is measured as the standard deviation of the rate of return of the underlying asset. It is common to express the volatility as an annual figure, e.g. when the volatility is 25%, it is usually mean that the volatility is 25% per annum (Aarle, 2013; Black & Scholes, 1973).

5. Risk free rate of interest (r)

   The risk free rate of interest is the theoretical rate of return of an investment with zero risk. For Real-Options, when making use of risk-neutral probabilities, the risk free rate of interest can be derived in the same way as for financial options. However, for Real-Options with an unfixed time to expiration, the risk free rate of interest is stochastic (Hull, 2008).

6. Dividend

   Dividend is a return to the shareholders for providing capital to the company. In Real-Options literature, a dividend is a cash outflow from the real asset, in other words it decreases the value of the asset. For RO, this could be useful to take into account cash flow losses due to for example competition. However, such leakage in value is difficult to model, as the amount and timing are dependent on exogenous influences (Aarle, 2013).

2.3.2 Appraisal method of real option

Mathematical models originally developed to evaluate financial options are usually implemented for the RO appraisal. However, RO face more uncertainties than financial options and there are more complicated interactions between options. Many methods have been proposed for assessing RO, but the majority of them are extensions of well-known algorithms used for financial options. RO models can be divided into analytical (based of exact equations such as the Black-Scholes model) and the numerical (based on approximation provided by computational simulations) (Gamba & Tesser, 2009; Gamba, 2003; Alvarez & Stenbacka, 2001).

Analytical methods are the best approach when applicable, as they are extremely fast to compute and generate exact solutions. Analytical methods have been developed primarily for the financial world, consequently many of these methods are not suitable for the energy and utility sector as they depend of very strict assumptions. For example, unlike classical algorithms for the pricing of financial options, RO do not have a predetermined exercise date, the risk is not constant over time, returns for most real assets are not normally distributed. In summary, these methods are applicable only to a few special cases (Gamba & Sick, 2010; Mun, 2005; Moreno & Navas, 2003).

Numerical methods must be used when there is no analytical solution. Numerical methods approximate stochastic processes and divide the time horizon into a set of time-steps in which the option can be exercised. The most common numerical methods in the literature are: finite difference schemes to resolve partial differential equations, binomial (or multinomial) trees and lattices, and Monte Carlo simulations (Cortazar, 2000):

1. The finite difference schemes method

   The finite difference method discretises the state variable. In practice, this method is hardly applicable because options interact with each other and due to the phenomenon called "curse of dimensionality" (Shahnazari, et al., 2017; Bellman, 1972).

2. Binomial (or multinomial) trees and lattices method

   Binomial (or multinomial) trees and lattices are methods based on the assumption that the stochastic variables can assume only a finite number of values (two in binomial case, three in the trinomial case, etc) at each time step. For instance in binomial trees, the value of the state variable could move up or down by a specific factor with a certain probability. This method is relatively easy to implement with only one variable/risk, e.g. the electricity price, but hardly applicable for more than one state variable as the number of nodes grows exponentially with the number of state variables (Wang, et al., 2014; Stentoft, 2004; Cox, et al., 1979).

Binomial model looks like a decision tree in which the possible values of the basic property change depending on time of option's maturity. This model tracks the movement of asset prices as a binomial process in which assets can move in two possible directions, i.e. may fall or increase. The changes in the property value are marked with *u* and *d* factors, where *u*>1 and *d*<1 (Cox, et al., 1979).

Initial point S_0 in the binomial model shows the current value of the underlying asset. Probability of changing asset value in the future indicates the p. Conversely, the probability of value can move in two directions, up to (S_0u) or down to (S_0d). The next step results in three possible assets values such as (S_0u_2, S_0d, S_0d_2), the third time step in four (S_0u^3, S_0u_2, S_0ud_2, S_0d_2) etc. The last step in the binomial model indicates the range of possible assets values at the end of the option life (Kodukula & Papudesu, 2006).

The basic inputs are the present value of the underlying asset (*S*), present value of implementation cost of the option (*X*), volatility of the natural logarithm of the underlying free cash flow returns in percent (σ), time to expiration in years (*T*), risk-free rate or the rate of return on a riskless asset (*rf*), and continuous dividend outflows in percent (*b*). In addition, the binomial lattice approach requires two additional sets of calculations, the up and down factors (*u* and *d*) that can be expressed in Equation 1, Equation 2, and Equation 3, as well as a risk-neutral probability measure (*p*) that can be expressed in Equation 4 below (Mun, 2002):

a. Up factor (u)

$$u = e^{\sigma\sqrt{\delta t}} \quad (1)$$

Where:

u	= Up factors
σ	= Volatility (%)
δt	= The time-steps or time scale between steps

b. Down factor (d)

$$d = e^{-\sigma\sqrt{\delta t}} \quad (2)$$

Where:

d = Down factors

σ = Volatility (%)

δt = The time-steps or time scale between steps

The equation can be rewritten as:

$$d = \frac{1}{u} \quad (3)$$

Where:

d = Down factors

u = Up factors

From Equation 1 to Equation 3 above, up factor is simply the exponential function of the cash flow volatility multiplied by the square root of time-steps or stepping time (δt). Time-steps or stepping time is simply the time scale between steps. That is, if an option has a one-year maturity and the binomial lattice that is constructed has 10 steps, each time-step has a stepping time of 0.1 years. The volatility measure is an annualized value; multiplying it by the square root of time-steps breaks it down into the time-step's equivalent volatility. The down factor is simply the reciprocal of the up factor. In addition, the higher the volatility measure, the higher the up and down factors.

c. Probability measure (p)

$$p = \frac{e^{(R_f)(\delta_t)} - d}{u - d} \quad (4)$$

Where:

p = Risk-neutral probability measure (%)

R_f = Risk-free rate (%)

u = Up factors (%)

d = Down factors (%)

δt = The time-steps or time scale between steps

From Equation 4 above, through every time period there is a probability p that asset value will grow for percentage *p*, respectively the probability (1-P) that the assets will fall for percentage *d*.

Using the solved binomial lattice equations, make the lattice evolution of the underlying. The values are created in a forward multiplication of up and down factors, from left to right. The example of the lattice evolution of the underlying can be seen in Figure 3 below.

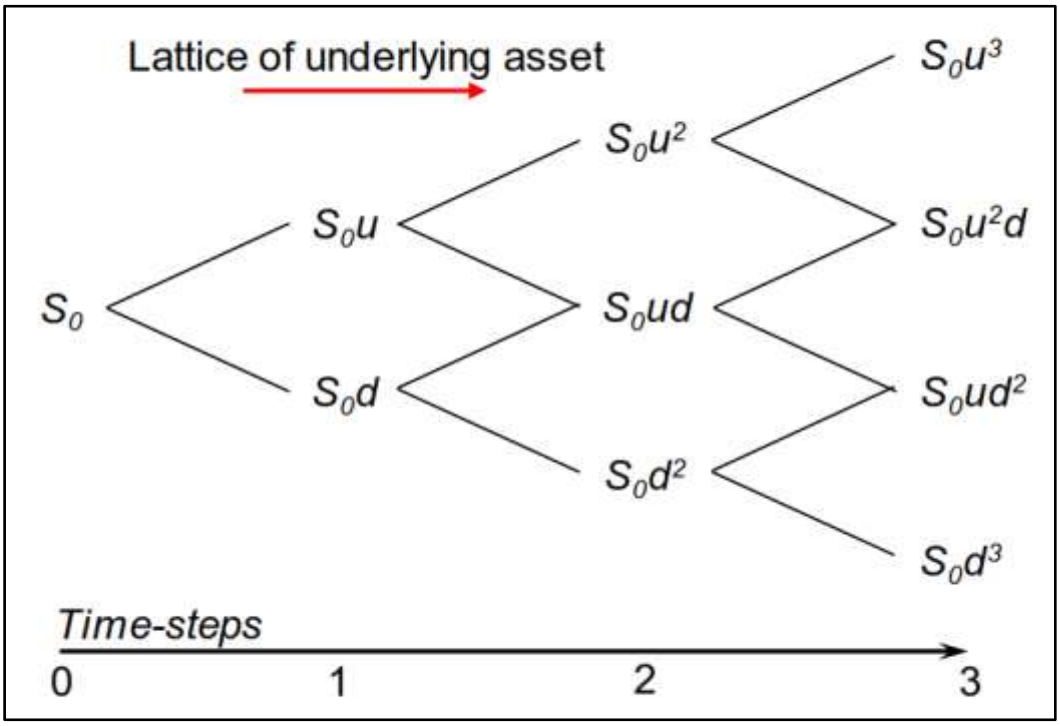

Figure 3 Lattice evolution of the underlying asset (Mun, 2002)

Figure 3 above illustrates the first lattice in the binomial approach. This lattice is created based on the evolution of the underlying asset's present value of future cash flow using the solved binomial lattice equations. The underlying asset value in S_0 is multiplied with the up and down factor to obtain the S_0u and S_0d respectily with probability of *p* and so on until the terminal node in the farthest right.

Creating the second lattice, that is the option valuation lattice by doing backward induction on the terminal nodes and intermediate nodes to obtain an option value at the farthest left node of the lattice. The illustration can be seen in Figure 4 below.

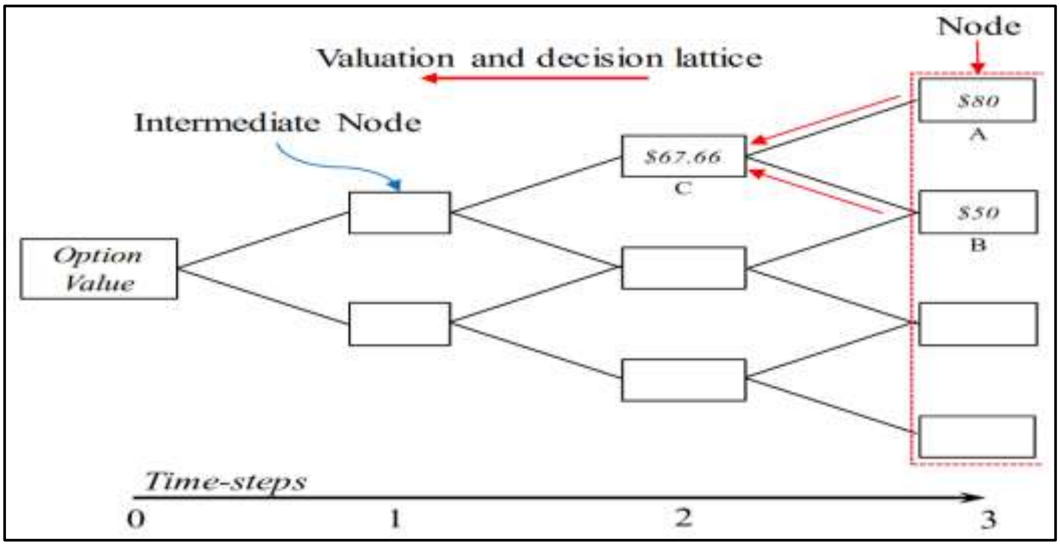

Figure 4 Option valuation lattice (Mun, 2002)

The calculation in Figure 10 proceeds in a backward manner, starting from the terminal nodes. That is the nodes at the end of the lattice are valued first, going from right to left.

The value placed in terminal node is the maximum of zero and the between value *S* and exercice price *X* can be seen in Equation 5 below.

$$Terminal\ value = Max\ (S - X, 0) \tag{5}$$

Where:

S = Present value of the underlying asset

X = Exercise price

Then calculation of intermediate nodes using risk-free probability can be done through Equation 6 below:

$$Intermediate = \big((p)up + (1 - p)down\big)e^{(-R_f)(\delta T)} \tag{6}$$

Where:

p = Risk neutral probability measure (%)

R_f = Risk-free rate (%)

δt = The time-steps or time scale between steps

3. The Monte Carlo simulation is usually implemented as “least-squares Monte Carlo” with the advantages of being able to cope with the complexity that remains fast and efficient. The input of this method are deterministic and the result of the method is expanded NPV of the investment, which incorporate the value of the options (Zhu & Fan, 2013; Longstaff & Schwartz, 2001).

2.3.3 Type of active decision of real option

The flexibility available to management will relate to project size, project timing, and the operating of the project once establish, as follows (Kremljak & Hocevar, 2013; Orsag, 2006; Copeland, et al., 1994):

1. Options relating to project size:

a. Option to expand

Option to expand allows expansion of production if market conditions become favourable. The project is built with capacity in excess of the expected level of output so that it can produce at higher rate if needed. A project with the option to expand will cost more to establish but is worth more than the same without the possibility of expansion.

This option is equivalent to a call option, which provides limited loss in unfavourable circumstances and significant profit prospects in favourable. The option to expand can be used as European option, that the project can be expanded only at a certain date in the future and it can also used as American option, which allowed expanding project at any time during the project's life. The option to expand a project is main used in natural resource industries. Fashion apparel, consumer goods, and commercial real estate.

The illustration of decision tree with expand options can be seen in Figure 5 below.

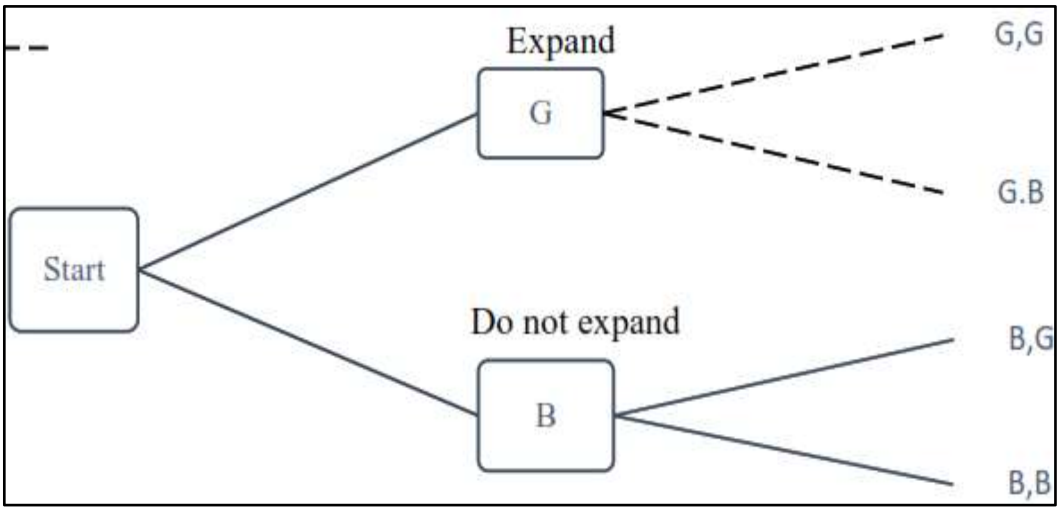

Figure 5 Illustration of decision tree with expand options
(Copeland, et al., 1994)

From Figure 5 above, we can find that the expansion option gives management the right to make additional follow-on investment when the project condition turn out good.

b. Option to contract

In option to contract, the project is engineered such that output can be contracted in future should conditions turn out to be unfavourable that manager may reduce the scale of operations. This is the equivalent to a put option. This option is used to reduce the loss in investment.

Similar to the option to expand, option to contract is also used in natural resource industries such as mine operations, facilities planning and construction in cyclical industries, fashion apparel, consumer goods, and commercial real estate.

The illustration of decision tree with contract options can be seen in Figure 6 below.

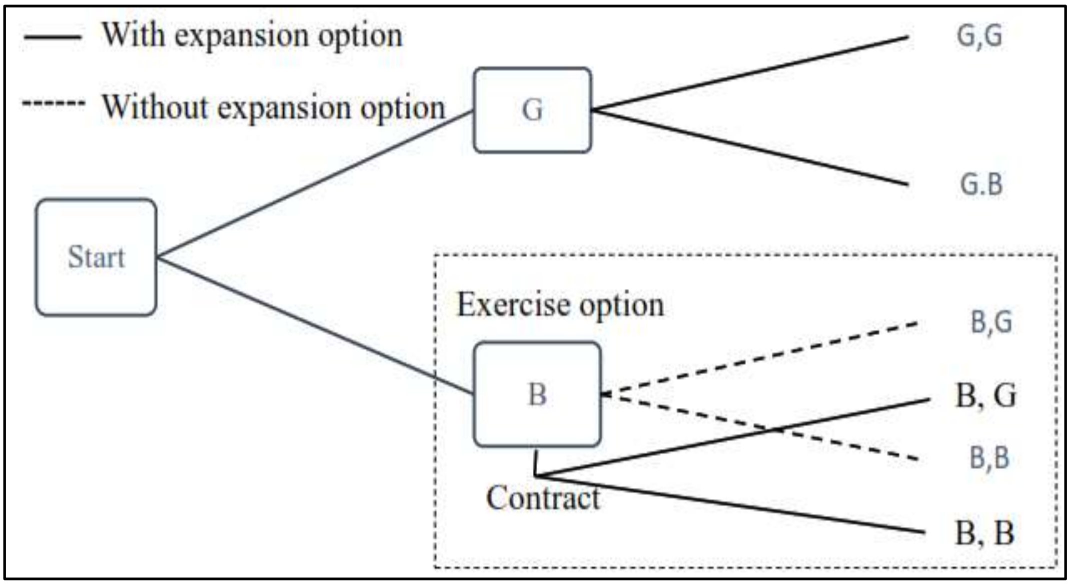

Figure 6 Illustration of decision tree with contract options
(Copeland, et al., 1994)

As shown in Figure 6 above, we can find that the option to contract is similar to option to expand. If the contracted project value by paying the additional cost is higher than the gross project value with the basic scale of project, manager can contract the project and receive a part of investment cost.

c. Option to expand or contract

The project is designed such that its operation can be dynamically turned on and off. Management may shut down part or all of the operation when condition are unfavourable (a put option), and may restart operations when condition improve (a call option). This options is also known as a switching option.

2. Options relating to project life and timing:

a. Initiating or deferment option

Management has flexibility as to when to start a project. Defer option is similar to a European call option, which requires waiting until the value of the underlying asset exceeds the strike price before exercising.

The illustration of decision tree with defer options can be seen in Figure 7 below.

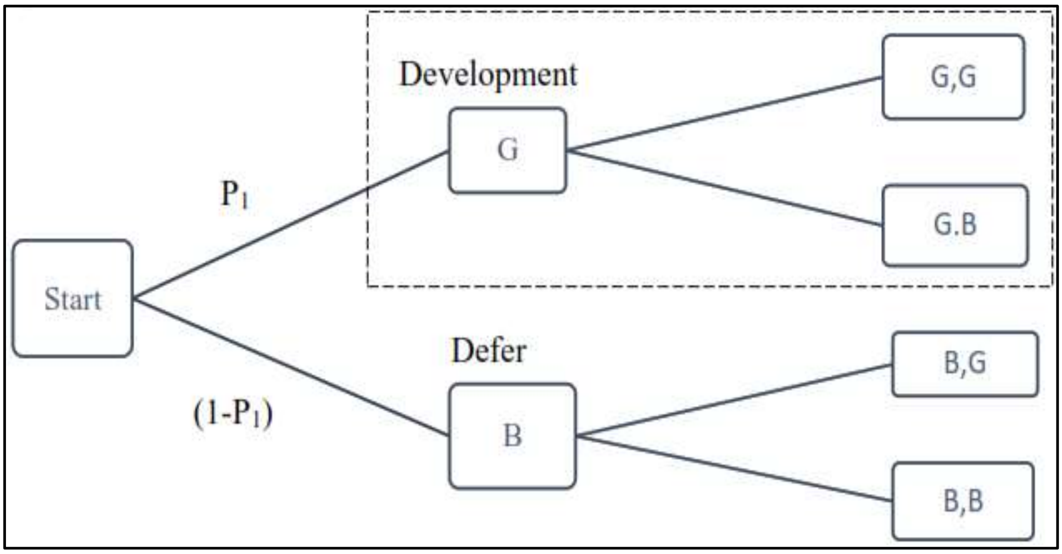

Figure 7 Illustration of decision tree with deferment options
(Copeland, et al., 1994)

Figure 7 above illustrates the option to defer a project. Here, *B* means bad condition and *G* represents good condition which is then choosed because the manager has the right, not an obligation to defer the project.

b. Option to abandon

Management may have the option to cease a project during its life and possibly to realise its salvage value. Here, when the present value of the remaining cash flows falls below the liquidation valued, the asset may be sold and this act is effectively the exercising of a put option.

An option to abandon a project looks like a put option, if the investment decision has produced results lower than expected, manager may decide to abandon the whole project and sell at a liquidation value. Therefore, manager has a put option on the gross value of the project when exercise price equals to salvage value.

Illustration of decision tree with abandon options can be seen in Figure 8 below.

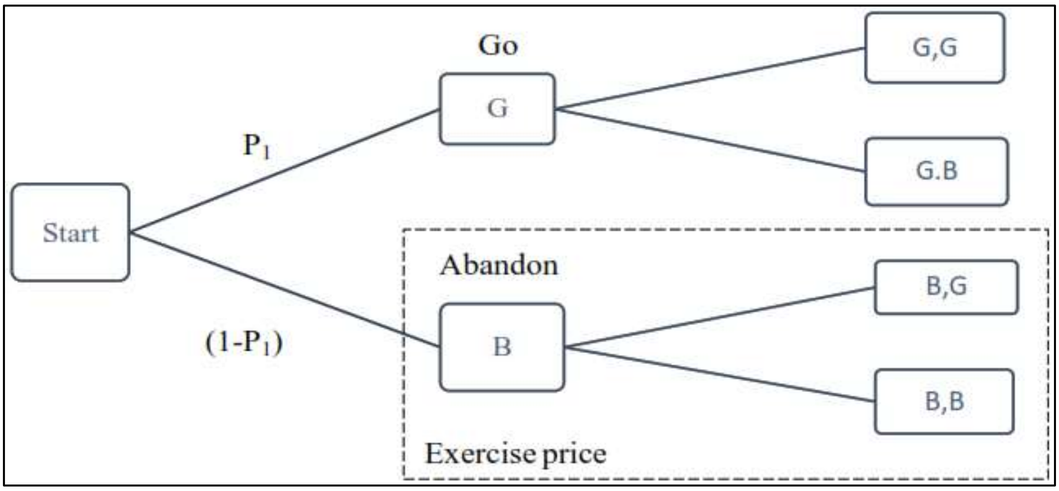

Figure 8 Illustration of decision tree with abandon options
(Copeland, et al., 1994)

As shown in Figure 8 above, we can find that if the bad outcome turns up at the end of the first period, the manager may decide to abandon the project and realize the expected salvage value.

c. Sequencing options

This option is related to the initiation option, although entails flexibility as to the timing of more than one inter-related projects. The analysis here is as to whether it is advantageous to implement these sequentially or in parallel.

3. Options relating to project operation:

a. Output mix options

The option to produce different outputs from the same facility is also known as product flexibility. These options are particularly valuable in industries where demand is volatile or quantities demanded in total for a particular good are typically low, and management would wish to change to a different product quickly if required.

b. Input mix options

This option allows management to use different inputs to produce the same output as appropriate.

c. Operating scale options

Management may have the option to change the output rate per unit of time or to change the total length of production run time for example in response to market conditions. These options are also known as intensity options.

The division of real options are presented in Table 3 is the outcome of the analysis of available classification (Koller, et al., 2020; Dzyuma, 2012):

Table 3 The division of real option

Type of Option	Financial Equivalent	Typical Features
Option to abandon, exit option	Put option	The decision maker has the right to abandon the venture in a situation when there are unfavourable external conditions (for example prices) or internal ones (financial situation), that is when there is clear and lasting deterioration of market situation and the company does not want to bear fixed costs.
Option to defer, option to delay	Call option	Depending on the company situation, it may defer the decision to invest. Sometimes, in order to minimize investment risk, it is worth waiting for the development of the situation in the market environment and when it develops positively – investing.
Options to change the volume of activities	Call or put option	Option to change the volume of activity covers both contracting and expanding the volume of investment venture. The former one could be compared to the financial option to sell, the latter to the option to purchase.

Type of Option	Financial Equivalent	Typical Features
Option to contract	Put option	In changing market condition, it is useful for the company to have a possibility to actively manage the production volume. The expected benefit is the reduction of some costs.
Option to expand	Call option	Option to expand exists when a company has a possibility to speed up the project realization. Realization of option to expand requires additional investment expenditure.
Option to switch, flexibility option	Portfolio of call and put options	It is usually defined as flexibility option, as it allows us to adjust to varied demand structure through changes in production, service or technology range.
Growth option	Call option	Growth option mostly concerns the projects whose realization gives the investor the possibilities to undertake other related ventures. It usually requires additional expenditure.
Staging option	Series of options on options	It is a developed form of growth option. It consist in completing successive stages which lead to increasing the volume of activity dependant on the previous project results, as well as it allows us to avoid the necessity to lay out all expenditure for given venture at once.

Source: (Koller, et al., 2020; Dzyuma, 2012)

The division of options into their types allows us to distinguish American and European options. The American type can be used at any time in the option life, while the European one can only be used after its expiration (Fierla, 2008).

2.4 The Comparison of Real Option to Discounted Cash Flow Valuation Methods

Traditional approaches to valuation assume static ability to make decisions while real options predict a dynamic series of future decisions, in which a managing person has a lot of flexibility in acting and thus can quickly adjust to changes taking place in the economy. The DCF method does not take into account active management of the company related to flexibility and enabling us to modify the strategy during its execution, due to changing internal or external conditions. In practice, managers make investment decisions in constantly changing circumstances and the option available to them are to make, defer, or resign from a particular course of action (Urbanek, 2008).

The exemplifies of the main differences between DCF valuation and RO valuation can be seen in Figure 9 below.

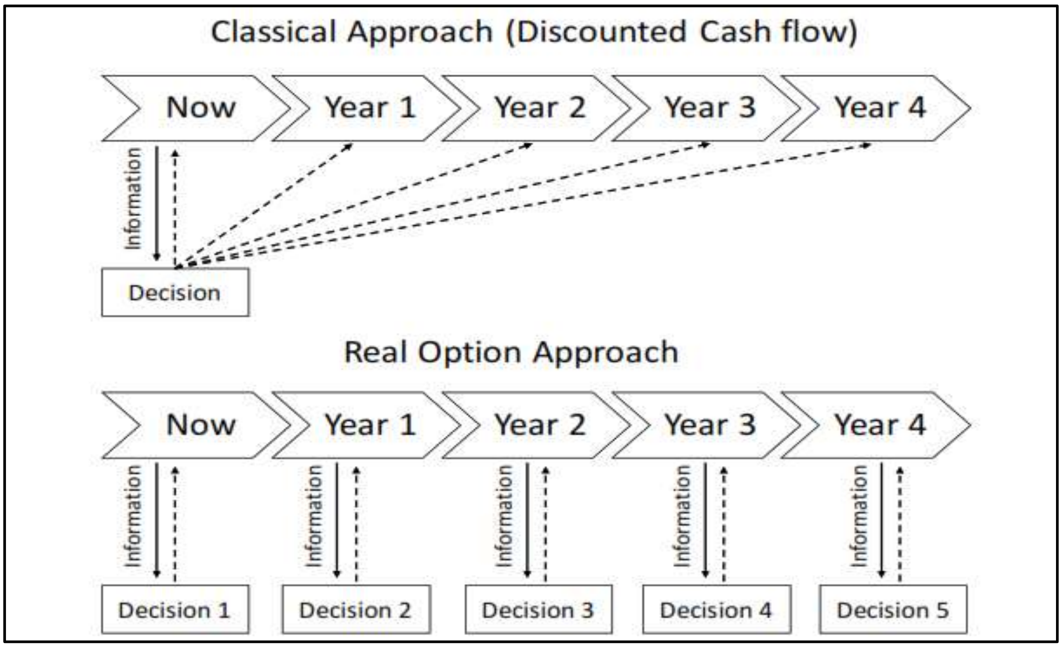

Figure 9 Classical approach (i.e., DCF) vs the RO approach (Locatelli, et al., 2020)

As shown in Figure 9 above, we can find that the classical approach in this case is discounted cash flow analysis determine the decision for the life of operations from present information while the real option approach actively determine the the decision for the life of operation from each updated information.

The highlights key differences between DCF valuation and RO valuation can be seen in Table 4 below.

Table 4 Key differences between DCF and RO

Discounted Cash Flow	Real Option
Uncertainties and risks are not adequately considered. Monte Carlo simulation, sensitivity analysis or changes in the discount rate are techniques to echance the DCF analysis by considering uncertainties and risks	Uncertainty is the key factor that creates the option value
All decisions are taken at the beginning of the development of the project	Decisions can be made at different times
All decisions are fixed and independent of future events. DCF does not capture the value of managerial flexibility during the project life cycle. DCF does not capture the dynamic nature of uncertainties	Flexibility is implemented as the management/decision makers can do actions to alter the course of the project
The expected payoff is discounted at a rate adjusted for the risk. The level of risk is expressed through the increment of a discount rate	Risks are expressed through the probability distribution of the payoff

Source: (Kozlova, et al., 2019; Kodukula & Papudesu, 2006)

The DCF model is a static valuation method, therefore decisions are made on the basis of possessed information about future events. Meanwhile the real option model provides flexibility in the process of making decisions that depend on changes taking place in the economy (Panfil, 2009).

The comparison of DCF analysis and RO analysis can be seen in Table 5 below.

Table 5 Comparison of DCF analysis and Real Option approach

Categories	DCF analysis	RO analysis
Uncertainty	Low	High
Mental model	Risk reduction	Opportunity exploration

Categories	DCF analysis	RO analysis
Managerial flexibility	No flexibility, static role of management	Flexible, dynamic role of management
Theoretical assumptions	Restrictive	Robust
Complexity of investment	Simple	Complex
Time value of money	Uses weighted average cost of capital	Uses risk-free rate
Complexity of method	Simple	Complex
Familiarity of decision maker	High	Low
Objective	Shareholder value creation	

Source: (Pivorienė, 2017), according to (Schachter & Mancarella, 2016; Pivorienė, 2015; Ghahremani, et al., 2012; Wang & Halal, 2010; Topal, 2008; Trigeorgis, 2000; Slater, et al., 1998).

Table 5 above presents a detailed comparison of DCF analysis and ROA, applying the criteria that are important for strategic investment project assessment methodologies.

Despite the fact that real options have significant advantage over classical methods, the following points are the situations in which the real option concept cannot be used (Scholleova, 2005):

1. The decisions made are certain and risk-free, in this case the value of options disappears, and real option valuation brings the same results as the DCF valuation.
2. There is no possibility of modifying or deferring in time investment decisions in the course of the project.
3. Low budget projects in which the value of assessed option would exceed total costs of the project.
4. Double options, in case of which the value of options would be assessed for a bigger number of mutually dependent projects.

2.5 The Real Option Process

The critical steps in performing real options valuation can segregate into the following steps (Mun, 2002):

1. Qualitative management screening

The first step of real option analysis is Qualitative management screening. In this step, the management decide which projects, assets, initiatives, or strategies are viable for further analysis in accordance with the firm's mission, vision, goal, or overall business strategy. This step can be seen as section A of Figure 10.

2. Base case net present value analysis

   In this step, a DCF model is created for each project that passes the initial qualitative screens which will serves as the base case analysis, where a net present value is calculated for each project. This step can be seen as section B of Figure 10.

3. Monte Carlo simulation

   Monte Carlo simulation may be employed because the static DCF produces only a single-point estimated result. A sensitivity analysis is first performed on DCF model to tracing back all precedent variables and see the effect on the resulting NPV. The uncertain key variables that drive the NPV and hence the decision is called critical success drivers which are the prime candidates for Monte Carlo simulation. This step can be seen as section C of Figure 10.

4. Real Option problem framing

   Based on the overall problem identification occurring during the initial qualitative management screening process, certain strategic optionalities would have become apparent for each particular project. Based on the identification of strategic optionalities that exist for each project or at each stage of the project, the analyst can then choose from a list of options to analyse in more detail. This step can be seen as section D of Figure 10.

5. Real option modelling and analysis

   The resulting stochastic DCF model through the use of Monte Carlo simulation will have a distribution of values. In real options, we assume that the underlying variable is the future profitability of the project, which is the future cash flow series. An implied volatility of the future free cash flow or underlying variable can be calculated through the results of a Monte Carlo simulation previously performed. Usually, the volatility is measured as the standard deviation of the logarithmic returns on the free cash flows stream. In addition, the present value of future cash flows for the base case DCF model is used as the initial underlying asset value in real option modelling. This step can be seen as section E of Figure 10.

6. Portfolio and resource optimization

   If the analysis is done on multiple projects, management should view the results as a portfolio of rolled-up projects. Portfolio optimization is an optional step in the analysis. The analysis will provide the optimal allocation of investment across multiple projects. This step can be seen as section F of Figure 10.

7. Reporting

   In this step reports are generated with clear, concise, and precise explanations transform a difficult black-box set of analytics into transparent steps. This step can be seen as section G of Figure 10.

8. Update analysis

   The analysis is usually done ahead of time and thus ahead for such uncertainty and risks. Therefore, when these risks become known, the analysis should be revisited to incorporate the decisions made or revising any input assumptions.

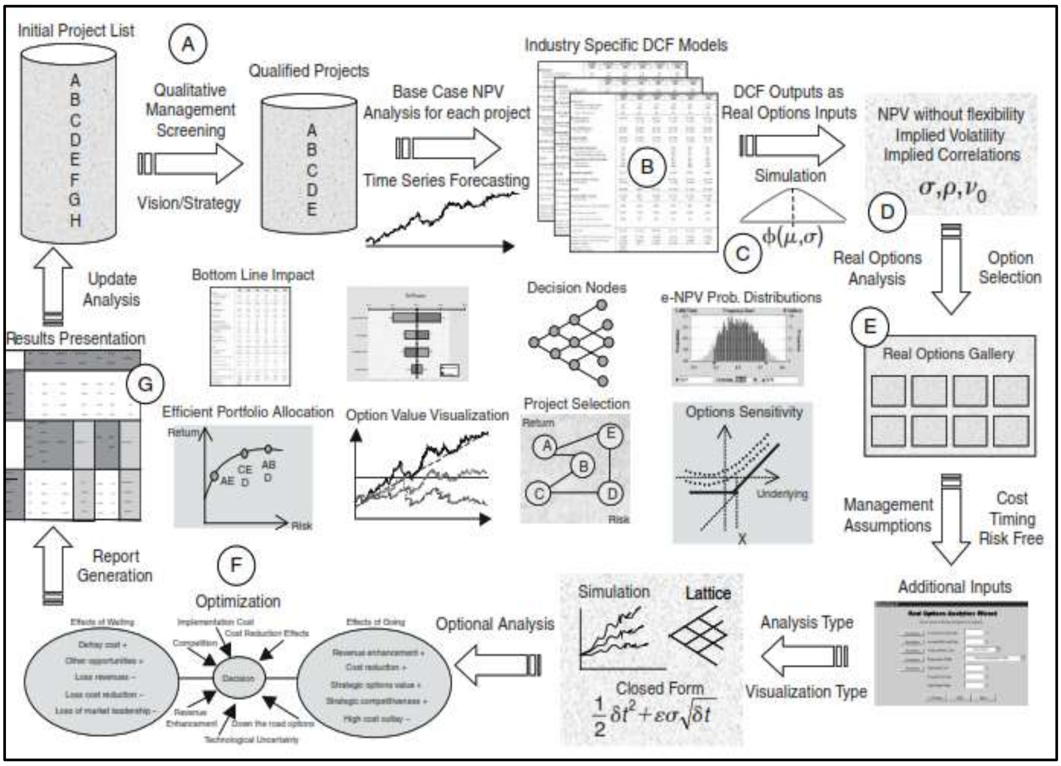

Figure 10 Real option process (Mun, 2002)