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Master in Supply Chain Management - SCM

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# **“Evaluating new projects using Real Options”**

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# “Evaluating new projects using Real Options”

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# Abstract

The current global panorama, characterized by the volatility and ambiguity stemming from recent widespread health concerns and ongoing geopolitical challenges, has exerted a profound influence on the assessment of investments. The consequences of these occurrences have been particularly conspicuous in sectors directly affected by the health concerns or geopolitical challenges, including but not limited to the tourism industry or companies with extensive operations in the affected regions. These sectors may encounter a decline in the value of their assets due to the unfavorable circumstances they confront. Conversely, certain sectors possess the potential to derive advantages from these circumstances. Industries such as healthcare or security services may witness an appreciation in the value of their assets because of heightened demand for their services.

The valuation of investments in these sectors may be positively impacted by the prevailing circumstances surrounding the health concerns or geopolitical challenges. Amidst such arduous circumstances, the utilization of Real Options confers upon investors an enhanced degree of flexibility. Real Options pertain to the strategic choices available to investors, empowering them to respond to fluid market conditions and uncertainties. Notably, the incorporation of a real option to abandon or defer an investment proves particularly valuable during periods of heightened uncertainty, as it enables investors to mitigate potential losses and adapt their strategies correspondingly.

The objective of this thesis is to conduct a comprehensive exploration of the concept of Real Options and to analyze their integration within decision-making paradigms. By delving into the intricacies of Real Options, this study seeks to illuminate their potential benefits and implications for investment strategies. Through an enhanced understanding of the role played by Real Options, investors can make more astute decisions and effectively navigate the intricate and uncertain investment landscape shaped by recent transformative events, such as widespread health concerns and geopolitical conflicts.

**Keywords**

Real Options, flexibility, resilience, risk management, decision-making, project evaluation, Net Present Value, Monte Carlo simulation, linear accelerator.

# "Αξιολόγηση νέων έργων χρησιμοποιώντας Πραγματικά Δικαιώματα"

**Ευδοξία Πικούνη**

## Περίληψη

Η παρούσα παγκόσμια κατάσταση, που χαρακτηρίζεται από αστάθεια και αβεβαιότητα προκύπτουσες από πρόσφατες εκτεταμένες ανησυχίες για την υγεία και τις διαρκείς γεωπολιτικές προκλήσεις, έχει έντονη επίδραση στην αξιολόγηση των επενδύσεων. Οι συνέπειες αυτών των γεγονότων εμφανίζονται ιδιαίτερα έντονα σε κλάδους που επηρεάζονται άμεσα από τα προαναφερόμενα, όπως ο τουριστικός κλάδος ή οι εταιρείες με εκτεταμένη δραστηριότητα στις πληγείσες περιοχές. Αυτοί οι κλάδοι ενδέχεται να αντιμετωπίσουν μείωση της αξίας των περιουσιακών στοιχείων τους. Αντιστρόφως, ορισμένοι κλάδοι μπορούν να επωφεληθούν από αυτές τις συνθήκες. Κλάδοι όπως η υγεία ή οι υπηρεσίες ασφάλειας μπορεί να διαπιστώσουν αύξηση της αξίας των περιουσιακών στοιχείων τους λόγω της αυξημένης ζήτησης για τις υπηρεσίες τους.

Σε τέτοιο πλαίσιο, η χρήση των πραγματικών δικαιωμάτων ως μέθοδος αξιολόγησης παρέχει στους επενδυτές αυξημένη ευελιξία. Τα πραγματικά δικαιώματα αφορούν τις στρατηγικές επιλογές που είναι διαθέσιμες στους επενδυτές, επιτρέποντάς τους να προσαρμόζονται σε μεταβαλλόμενες συνθήκες αγοράς και αβεβαιότητες. Ειδικότερα, η ενσωμάτωση ενός πραγματικού δικαιώματος εγκατάλειψης ή καθυστέρησης μιας επένδυσης αποδεικνύεται ιδιαίτερα χρήσιμη κατά τη διάρκεια περιόδων αυξημένης αβεβαιότητας, καθώς επιτρέπει στους επενδυτές να αναχαιτίσουν πιθανές απώλειες και να προσαρμόσουν τις στρατηγικές τους αναλόγως.

Ο στόχος αυτής της διατριβής είναι η λεπτομερής εξέταση της έννοιας των πραγματικών δικαιωμάτων και η ανάλυση της ενσωμάτωσής τους στα παραδείγματα λήψης αποφάσεων. Μέσω της εμβάθυνσης στις λεπτομέρειες των πραγματικών δικαιωμάτων, αυτή η μελέτη επιδιώκει να αναδείξει τα δυναμικά οφέλη και τις συνέπειες τους για τις στρατηγικές επενδύσεις.

**Λέξεις κλειδιά**

Πραγματικά Δικαιώματα, ευελιξία, ανθεκτικότητα, διαχείριση κινδύνου, λήψη αποφάσεων, αξιολόγηση έργου, καθαρή παρούσα αξία, προσομοίωση Monte Carlo, γραμμικός επιταχυντής.

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# List of Abbreviations & Acronyms

| | |
|---|---|
| Net Present Value | NPV |
| Internal Rate of Return | IRR |
| Real Option Valuation | ROV |
| Monte Carlo Simulation | LSM |
| Research and Development | R&D |
| Binomial Real Option Valuation | BROV |
| Expected Net Present Value | ENPV |
| Weighted Averaging Operators | OWA |
| Information Technology | IT |
| Human Resources | HR |
| Multinational Corporation | MNC |
| Time Value of Money | TVM |
| Discounted Cash Flow | DCF |
| Weighted Average Cost of Capital | DCF |
| Real Options Reasoning | ROR |
| Real Options Theory | ROT |
| Transaction Cost Economics | TCE |
| Binomial Options Pricing Model | BOPM |
| Image Guided Radiotherapy | IGRT |
| Intensity Modulated Radiotherapy | IMRT |
| Volumetric Modulated | VMAT |
| Stereotactic Ablative Radiotherapy | SART |
| Surface Guided Radiotherapy | SGRT |
| Hellenic Society of Radiation Oncology | H.S.R.O. |
| Linear Accelerator | LINAC |
| National Organization for Health Care Services Provision | EOPYY |

# 1 Introduction

In assessing the viability of a new initiative, financial analysts typically employ tools such as Net Present Value (NPV) or Internal Rate of Return (IRR) to gauge financial appeal or choose among various project alternatives. The conventional NPV methodology assumes all influencing factors to be stable, thereby rendering it a static approach. However, this fails to accommodate the future value fluctuations of pivotal elements like demand and price. Over recent decades, an innovative methodology has emerged, incorporating techniques typically used in financial Options assessment. This approach, known as Real Options, uniquely acknowledges the full spectrum of variability inherent in crucial factors, as opposed to a single forecasted value (Bowman E. H.; Moskowitz G. T., 2001).

This dissertation undertakes an exhaustive analysis of the described strategy, meticulously scrutinizing the diverse techniques employed in the appraisal of Real Options. Furthermore, it operationalizes this strategy within the context of an empirical case derived from the healthcare sphere, placing it in comparative context with established paradigms. Chapter 2 commences with a demystification of Real Options, elucidating fundamental terminologies and concepts. Subsequently, an extensive survey of pertinent literature constructs the foundation for comprehending the landscape of Real Options. Methodological insights are then expounded upon, encompassing research approaches, tools, data collection, and analysis techniques employed in Real Options studies. Anticipated challenges, practical contributions, and inherent limitations of Real Options research are duly considered.

Chapter 3 unveils the intricate interdependencies among Real Options, flexibility, resilience, and risk management. Strategic flexibility pertaining to operational and supply chain resilience is meticulously investigated, while the interrelationships connecting Real Options, risk management, and flexibility are scrutinized. The manifold advantages that emerge from integrating Real Options within the realm of risk management are prominently underscored. Furthermore, a critical examination of the linkage between flexibility and resilience, coupled with an exploration of the potential of flexibility in supply chain management and human resource management, serve to illuminate the intricate connectivity between Real Options, flexibility, and resilience.

In chapter 4 an integrated approach encompassing Real Options, strategic decision-making, and project evaluation in organizational contexts is presented to effectively navigate the uncertainties inherent in decision-making processes and maximize value. This encompasses a comprehensive discussion on the tools employed for project evaluation, including a comparative analysis of Net Present Value (NPV) and Real Options. The sequential phases involved in investing in Real Options are delineated, alongside an examination of the predominant strategies for managing Real Options. The conditions under which Real Options are applicable are delineated, and their fundamental categorizations are expounded upon. Moreover, the Monte Carlo technique is introduced as a quantitative methodology for gauging susceptibility to risk, accompanied by a detailed exposition of its rudimentary steps. The Black Scholes equation and the novel price, dating back to 1997, are rigorously examined, culminating in illustrative examples showcasing the valuation of Real Options using both NPV and Real Options in diverse expansion scenarios.

Chapter 5 encompasses an intricate case study focusing on a linear accelerator, delving into the National Registry of Neoplastic Diseases, the operational mechanics of a linear accelerator, and the intricacies of radiotherapy treatments. The current situation concerning radiation in Greece is meticulously assessed, while real option valuation is applied to decision-making processes pertaining to the linear accelerator. A comprehensive example elucidating the evaluation of the linear accelerator employing Monte Carlo simulation is furnished, featuring a meticulous exposition of the simulation process.

In chapter 6, concluding this discourse, significant issues and extensions arising from the preceding discussions are meticulously addressed, with particular emphasis on abandonment value.

Ultimately, this manuscript offers a profound reflection on the relationship between Real Options and reality, underscoring the practical implications of Real Options within the context of decision-making processes.

# 2 Unlocking Value: An Integrated Approach to Real Options in Decision-making

## 2.1 Demystifying Real Options : A Comprehensive Explanation of Key Terms and Concepts

Real Options incorporate financial reasoning into investment appraisal techniques. They represent the entitlement, albeit not the compulsion, to engage in a future course of action. Corporations function within an uncertain milieu, possessing the prerogative, but not the requirement, to invest. Real Options meticulously address the asymmetry between boundless profits stemming from investments and restrictions on potential losses. The demarcation of loss constraints will dictate the decision to undertake the investment risk. Ambiguity enhances the value of options. Investment strategies generate projections for future cash flows and Real Options (Zeng S., Zhang S., 2011). Consequently, companies confront the challenge of predicting future cash flows. An optimal approach to mitigate this issue, is to develop multiple scenarios to accommodate potential variations (Kaka A., Lewis J., 2003).

Another concern arises from the assumption that investment decisions must be made at a specific point in time. Often, this predetermined moment is dictated by the administrative director and is predominantly subjective in nature.

Additionally, the scale of investment can be substantial, potentially leading to catastrophic consequences if the actual outcomes do not align with investors' expectations.

Real Options provide solutions to investment challenges by adhering to key principles. They allow for contingent decisions to be made after uncertainties are reduced through a thorough examination of facts. The evaluation of Real Options is market-aligned, as it employs financial market methodologies. Companies can identify and assess their rights, then strategically exercise them, whether to invest at the optimal time or to abstain from investing.

Real Options can be classified into various categories, including the right to defer investment, time to build option, the right to modify the scale of operation, the right of withdrawal, the right of substitution, growth options, multiple interacting rights, operational options, investment and disinvestment options, and contractual options. These categories enable a flexible approach to decision-making in the face of uncertainty (Jae-Han L., Dong-Joo L., Jae-Hyeon A., 2001).

In addition, a company can use Real Options to convert uncertainty to real opportunity through flexibility. Flexibility can bring resilience and increase the value of the company (Mayer Z., Kazakidis V., 2007).

## 2.2 Real Options Landscape: A Review of Relevant Literature

In our research, we gather information from a variety of sources, including books, journal articles, conference proceedings, government publications, and corporate reports. Some noteworthy papers in the field of Real Options and investment decision-making are as follows:

1. Dixit, A.K., & Pindyck, R.S (1994). "Investment under uncertainty". Princeton University Press in this textbook, the authors, draw on financial market option theory to construct a dynamic framework, demonstrating its significance for understanding firms' behavior, implications for industry dynamics and government policy, and its applicability to specific business issues and industries.
2. Trigeorgis, L (1996). "Real Options : Managerial flexibility and strategy in resource allocation". MIT Press.
   The author consolidates scattered knowledge and research on the dynamic paradigm of Real Options, a shift from static cash-flow approaches, which has revolutionized capital budgeting since the 1970s and 1980s. Trigeorgis details an options-based approach that quantifies managerial flexibility, considering strategic values of new technology, project interdependence, and competitive interactions, thus profoundly transforming corporate resource allocation and the future of capital budgeting textbooks.
3. Schwartz, E.S., & Trigeorgis, L (Eds.) (2004). "Real Options and investment under uncertainty: Classical readings and recent contributions". MIT Press.
   In addition to the theoretical approach, a broad spectrum of practical applications is also explored, encompassing the valuation of natural resources, research and development, along with empirical data drawn from oil leasing, land pricing, and discontinued operations.
4. Copeland, T.E., & Antikarov, V (2001). "Real Options : A practitioner's guide".
   Texere. The text in Part I begins with an introduction to the topic, followed by a discussion on the change process. It then moves on to an exploration of Net Present Value before comparing

it with decision trees and Real Options. Part II introduces numerical methods for simple options, delves into compound and switching options, and considers the progression from one step per time to many. This part also outlines a four-step process for valuing Real Options, proposes a consolidated approach to estimating volatility, and underscores the importance of keeping uncertainties separate. Practical case examples are then provided before the section concludes with final thoughts and a consideration of unfinished business.

5. McDonald, R.L., & Siegel, D.R (1986). "The value of waiting to invest. The Quarterly Journal of Economics", 101(4), 707-727.

   They critically challenge the conventional investment guideline that advocates investing when the benefits of an investment exceed the costs. Their study emphasizes the significance of incorporating the option value associated with delaying investment. Employing simulations, the authors illustrate that this option value holds substantial importance. Remarkably, their findings indicate that, given plausible parameter values, it may be optimal to defer investment until the benefits outweigh the costs twofold. Furthermore, the authors conduct a comparative static analysis to examine the impact of varying both the valuation formula and the criteria for initiating investments.

6. Black, F., & Scholes, M (1973). "The pricing of options and corporate liabilities. Journal of Political Economy", 81(3), 637-654.

   The authors of this study argue that in an efficient market with accurate option pricing, the possibility of guaranteed profits through the construction of portfolios comprising long and short positions in options and the corresponding underlying stocks should be eliminated. With this premise in mind, the authors develop a theoretical valuation formula for options. Importantly, as many corporate liabilities can be viewed as combinations of options, the derived formula and the associated analytical framework can be applied to various types of corporate liabilities, such as common stock, corporate bonds, and warrants. Specifically, the formula can be utilized to calculate the appropriate discount rate for a corporate bond, accounting for potential default risk. By extending the reach of their model to encompass a broad range of corporate liabilities, the authors contribute to the understanding and evaluation of financial instruments in the context of an efficient market.

7. Bart J. A. Willigers; Thomas Lyse Hansen; Project Valuation in The Pharmaceutical Industry: A Comparison of Least-Squares Monte Carlo Real Options Valuation and Conventional Approaches, Wiley-Blackwell: R&D Management, 2008 (IF: 3).

   Despite its ability to handle complex valuation scenarios involving multiple uncertainties and compounded American-type options, the pharmaceutical industry has underutilized the technique of least-squares Monte Carlo Simulation (LSM) for Real Options valuation. This is particularly noteworthy given the industry's requirement for accurate project valuation due to the high-risk nature of investments, extended payback periods, rising development costs, and shrinking profit margins. The limited application of Real Option Valuation (ROV) in this sector calls for attention, considering the significant benefits that LSM offers in managing such intricate valuation circumstances.

   The LSM model developed in this study is an expansion of a standard discounted cash flow model, offering familiarity to economists in the pharmaceutical industry. This research employs LSM, ROV, Binomial Real Option Valuation (BROV), and expected Net Present Value, (ENPV) (techniques in evaluating several pharmaceutical projects. The varying results these methodologies produce is elucidated through differences in risk assumptions and the capability to quantify the value of flexibility. This analysis not only provides a foundational understanding of Real Option pricing to those without expertise in the area, but also demonstrates the LSM model's potential for commercial assessment in real-world scenarios, given its adaptability to specific business issues.

8. Paolo Pertile; Investment in Health Technologies in A Competitive Model with Real Options, Journal of Public Economic Theory, 2008.

   This paper employs a Real Options approach to examine the optimal timing for health care providers to invest in innovative technologies, while also considering their competitive quest for patients and the impact of different payment systems on the adoption decision. The pioneering technology promises improved health outcomes, thus potentially attracting a larger patient base. However, during its initial stages, the technology is assumed to come with higher uncertainties and costs. The role of the payment system in this context is complex and not always intuitive. Specifically, the study reveals that a more generous payment scheme does not invariably lead to earlier technology adoption. The paper also contrasts the competitive solution with the socially optimal timing for technology adoption, drawing out some policy implications from this comparison. The study's findings can provide valuable insights for decision-makers in health care and policy. Copyright © 2008 Wiley Periodicals, Inc.

9. Christer Carlsson; Robert Fullér; Possibility for Decision - A Possibilistic Approach to Real Life Decisions, 2011 (IF: 3)

   The monograph presents their significant contributions to possibility distributions and decision-making in the first decade of the 21st century. The focus of their work lies in the domain of fuzzy thinking and averaging operators. The authors delve into theoretical aspects, including the principle of expected value for functions on fuzzy sets, as well as the concepts of variance, covariance, and correlation of possibility distributions. Additionally, they explore the principle of 'falling shadows' and examine weighted lower and upper possibilistic mean values and variance of fuzzy numbers. The authors establish the consistency of these concepts with the extension principle and the notions of expectation and variance in probability theory.

   The monograph further discusses various models and techniques, such as the application of ordered Weighted Averaging Operators (OWA) in decision-making processes. They highlight the utilization of fuzzy Real Option models for strategic decision-making in industry, portfolio selection under imprecise future data, and risk assessment in grid computing by predictive probabilities. The authors also explore the application of fuzzy ontologies to address semantic meaning within an uncertain and inconsistent world. They showcase the application of these ontologies in the Knowledge Mobilization project.

10. Johnathan Mun; Modeling Risk: Applying Monte Carlo Risk Simulation, Strategic Real Options, Stochastic Forecasting, and Portfolio Optimization, 2012 (IF: 3).

    The work provides a comprehensive examination of risk management, starting with the identification of risk, its evaluation, quantification, and prediction, and then focusing on risk diversification, mitigation, and overall management. It introduces the concept of moving beyond uncertainty and towards a model of risk. The subsequent sections delve into the methods of risk evaluation, with guides to model-building etiquette and practical applications of risk simulator tools. Further, the author explores the applications of these theories in various industries, such as pharmaceuticals, biotech negotiations, oil and gas exploration, financial planning, and hospital risk management. The later sections focus on risk prediction, emphasizing the use of past data to inform future outcomes, and the search for optimal decisions under uncertainty. The concept of Real Options and their applications are also critically examined, using the Real Options Super Lattice Solver software. More practical applications are presented in diverse fields, including real estate, banking, military strategy, and IT security. The final part discusses the signs of risk, and the need for a cultural shift within corporations towards better risk management.

11. Jussi Vimpari; Seppo Junnila; Valuing Green Building Certificates as Real Options, Journal of European real Estate Research, 2014 (IF: 3). This study focuses on assessing the feasibility of employing Real Options analysis (ROA) for valuing green building certificates. Specifically, the study aims to estimate the Real Option value associated with a green building certificate in the context of a typical office building. Green buildings are widely recognized as profitable strategies for climate mitigation, yet there is a lack of consensus regarding the valuation of green buildings and their associated certificates.

    The research methodology employed in this study comprises both theoretical and empirical components. The theoretical portion of the research identifies the option characteristics inherent in green building certificates and proposes a contemporary Real Option valuation method for their implementation. Subsequently, the empirical section of the study demonstrates the application of this proposed method through an embedded multiple case study design. The analysis includes two distinct building cases, one with a green certificate and another without, and incorporates eight independent cash flow valuations provided by industry professionals.

12. Giampiero Favato; Gianluca Baio; Alessandro Capone; Andrea Marcellusi; Francesco Sav erio Mennini; A Novel Method to Value Real Options in Health Care: The Case of A Mul ticohort Human Papil-lomavirus Vaccination Strategy, Clinical Therapeutics, 2013 (IF: 3).

    This study challenges the prevailing dominance of cost-effectiveness for a single cohort of 12-year-old girls in the Real Option valuation of a multi-cohort HPV vaccination strategy. The co-vaccination of two cohorts of 12 and 15-year-old girls demonstrated a Real Option value (€17.723) comparable to that of a single cohort of 12-year-old girls (€17.460). All four vaccination strategies considered showed positive Real Option values, but a national vaccination program targeting two cohorts is the most favorable implementation strategy, considering its impact on access, coverage, and time to prevention of HPV-induced diseases. The study urges policymakers to reassess the value created by a two-cohort HPV vaccination program for both boys and girls aged 12. The study also outlines four key advantages of the fuzzy payoff method for valuing the cost-effectiveness of healthcare interventions: its use of expert-generated cash flow scenarios, its focus on value rather than cost, its intuitive simplicity, and its perspective of management as an evolutionary process of successive decision-making that adds value over time, thereby creating a new decision-making space.

The payoff method presents unique benefits in assessing the cost-effectiveness of various healthcare interventions, primarily through its innovative use of fuzzy numbers in place of the conventional non-fuzzy numbers typically utilized in cost-effectiveness analysis models. This approach provides a foundation for the Real Option pricing method. By valuing uncertainty through the Real Option approach, policymaking in healthcare is transformed into an evolutionary process, thereby generating a fresh arena for decision-making choices.

## 2.3 Methodological Insights: Research Approach, Tools, Data Collection, and Analysis in Real Options Studies

This thesis provides a comprehensive exploration of Real Options and their significance for trustworthy investment evaluation. We compare Real Options to traditional valuation methods, such as the Net Present Value (NPV), which is the basic method found in most business and economic manuals. We illustrate how flexibility can enhance business value by providing ample evidence that humanity is currently experiencing unprecedented changes in a short period of time, including environmental changes, technological revolutions, and robotics, among others. As a result, businesses must adapt to many fields, making flexibility a cornerstone for their sustainability. We analyze the main categories of Real Options and present the most important evaluation methods, such as the binomial model, Black-Scholes equation, and Monte Carlo simulation, highlighting their respective advantages and disadvantages and recommending the most suitable approach on a case-by-case basis. Finally, we apply these methodologies to a case study in the hospital sector and analyze their impact on strategic decision-making.

# 3 Unveiling the Synergies: Interrelations among Real Options, Flexibility, Resilience, Risk Management

## 3.1 Enhancing Organizational Resilience: Assessing Strategies and Performance in the Face of Disruptions

To infuse resilience into our operational and supply chain structures, it is imperative to integrate a degree of flexibility. Resilience denotes the capacity to recuperate from adversities, predominantly focusing on the mitigation of downside risks. Strategic resilience encompasses the capacity to alter the business model in the face of disruptions. This implies that an enterprise must possess the requisite flexibility to adjust its strategy in line with evolving circumstances and to discover novel methodologies when confronted with unforeseen obstacles (Martin C., Peck H., 2004).

Operational resilience pertains to the preservation of existing core activities and the reduction of costs when met with disruptions. This necessitates that an enterprise must have contingency strategies devised for an array of scenarios and possess the ability to promptly modify its operations in reaction to unexpected challenges. By prioritizing flexibility and incorporating resilience into all echelons of the organization, we can adapt more proficiently to unforeseen challenges and construct a more robust system (Ignacio T., Ruiz-Moreno A, Verdú A, 2008).

M. Baghersad, C. Zobel, (2021), in their research, leverage insights from the field of system resilience to introduce three distinct measures designed to assess an organization's resilience performance in the face of disruptions: initial disruption-induced loss, peak loss, and cumulative loss over a specified duration. To demonstrate the practical applicability of these conceived metrics, we employ them to scrutinize the efficacy of two resilience enhancement strategies: the retention of operational slack and the expansion of operational scope. This is achieved through an empirical investigation of manufacturing firms, which underwent disruptions during the timeframe spanning from 2005 to the conclusion of 2014. The findings reveal that sustaining elements of operational slack and augmenting both business and geographic scope can influence these metrics in varying manners. These outcomes furnish risk management decision-makers with a more nuanced comprehension of the circumstances under which the suggested strategies can indeed bolster an organization's resilience, as well as the methods by which they may accomplish this.

## 3.2 Real Options within the Realm of Risk Management: Unraveling the Interrelationships with Resilience and Flexibility

In the wider context of Risk Management, the concept of Real Options (sometimes referred to as Real Rights) can be integrated as a strategic approach to decision-making under uncertainty. Real Options provide a framework to evaluate, manage, and mitigate business risks by considering the value of flexibility and adaptability in the face of dynamic market conditions, changing technology, or evolving consumer preferences (Alexander J. Triantis A., 2000).

Risk Management encompasses the uncertainties and potential adverse outcomes that organizations face in their pursuit of growth, profitability, and value creation (Aven, 2016). These risks can arise from various sources, such as market fluctuations, regulatory changes, operational disruptions, or competitive pressures (Miller, 1992). Effective risk management requires organizations to assess and prioritize these risks and devise strategies to address them (Aven, 2016).

Real Options theory offers a valuable perspective on risk management by extending traditional investment appraisal methods, such as discounted cash flow (DCF) analysis, to account for the value of flexibility and the option to adapt, modify, or abandon investments or projects in response to changing conditions (Dixit & Pindyck, 1994). By viewing business decisions as a series of options, rather than fixed commitments, organizations can better assess the potential returns and risks associated with different strategic choices (Trigeorgis, 1996).

## 3.3 Maximizing Value: The Advantages of Integrating Real Options in the Context of Risk Management:

The integration of Real Options within the context of risk management confers notable advantages upon organizations. Specifically,

- Enhance Decision-Making: Real Options analysis enables organizations to incorporate uncertainty and potential future events into their decision-making processes (Dixit & Pindyck, 1994). By considering various scenarios and their potential outcomes, decision-makers can better evaluate the risks and rewards associated with different investments or projects.

- Foster Flexibility and Adaptability: Real Options encourage organizations to prioritize flexibility and adaptability, which can help them respond more effectively to business risks (Trigeorgis, 1996). By investing in projects with embedded Real Options, firms can capitalize on emerging opportunities or mitigate adverse effects of market changes, technological advancements, or competitor actions.
- Mitigate Business Risks: Real Options can help organizations manage business risks by offering strategic alternatives in response to unexpected events or changing conditions (Dixit & Pindyck, 1994). By maintaining a portfolio of Real Options, organizations can hedge against risks, diversify their investments, and enhance their overall resilience.
- Improve Resource Allocation: By recognizing the value of flexibility and adaptability, Real Options can assist organizations in allocating resources more efficiently (Trigeorgis, 1996). This can lead to more effective risk management, as firms can prioritize projects and investments that offer the greatest potential for adaptation and growth, even in the face of uncertainty.

In summary, the inclusion of Real Options in the wider context of business risk can provide organizations with valuable insights and strategies for managing uncertainty, fostering flexibility and adaptability, and mitigating potential adverse outcomes. By incorporating Real Options analysis into their decision-making processes, organizations can make more informed choices, allocate resources more effectively, and enhance their overall performance in a dynamic and uncertain business environment.

## 3.4 Nurturing Resilience through Flexibility: A Critical Examination of their Connection

Resilience is the ability of a system, organization, or individual to absorb shocks, adapt to change, and recover from adverse situations (Holling, 1973; Walker et al., 2004). It involves the capacity to prepare for, respond to, and learn from disruptions to maintain or improve overall performance (Adger, 2000).

Flexibility refers to the capability of adapting to changing circumstances, requirements, or constraints (Golden & Powell, 2000). It entails being open to change, having the capacity to reorganize or modify processes, and responding effectively to new or unexpected situations (Sanchez, 1995). Flexibility can be observed in various forms, such as organizational structures, decision-making processes, or individual mindsets (Volberda, 1996). Is the ability to bend without breaking or to adapt to change to both downside and upside risk. in general, flexibility refers to the ability of a system to changes or reacts with little effect on time, the paid effort, implementation cost and performance.

Flexibility improves resilience through pooling and increases value by exploiting upside variation. There are several sectors where flexibility can act as a light in the tunnel. These include the globalized activity of companies, induced costs resulting from transitions in production, competition, global trends, digitization of society, globalization, world trade, liberalization, exponential growth of foreign exchange, and the mobility of population flows.

The ongoing demographic shift, marked by the continued increase in life expectancy of the general population and the labor force, also means that commercial, labor, law, and competition committees will have to adapt to rapid technological changes. To succeed in this changing landscape, three types of flexibility need to be developed along the chain.

The first type of flexibility is liturgical flexibility, which refers to the ability to handle operational fluctuations in the short term. The second type is tactical flexibility, which involves the ability to adapt to changes in the medium term, such as shifts in the market or emerging trends. The third type is strategic flexibility, which is the ability to make significant changes to the business model and long-term plans in response to major disruptions or changes in the industry.

By developing all three types of flexibility, companies can better adapt to the changing landscape and build resilience into their operations. This will enable them to thrive in an increasingly dynamic and competitive environment (Gallien J., 2020).

## 3.5 Empowering the Supply Chain: Unleashing the Potential of Flexibility

Tiwari (2015) asserts that a supply chain attains flexibility when it demonstrates the capacity to guarantee an uninterrupted and seamless flow of products from suppliers to customers amid circumstances marked by uncertainty and risk. This flexibility is further characterized by the minimization of variations between supply and demand at every level of the chain, thereby ensuring operational continuity. Crucially, this objective is pursued while mitigating any significant impact on chain resources and the associated costs borne by chain assets. in essence, the empowerment of the supply chain hinges upon the ability to cultivate and harness flexibility, which engenders resilience and adaptability in the face of dynamic and unpredictable market conditions.

## 3.6 The Human Factor: Exploring the Role of Flexibility in Human Resource Management

Flexibility in Work force can be succeeded through new skills especially soft skills such as critical thinking, creativity bought about by digital technology (big data, cloud, IA) due to new forms of production and work organization and new forms of work like flexible working hours. An empirically examination of the relationship between the components of HR flexibility, distinct from high performance work practices, and financial indicators of firm performance (Bhattacharya M., Gibson D., Doty D., 2005).
“The major issue of the future is going to be the employment rate between robots and humans which will change drastically” (Shaukat K, 2008).

## 3.7 Bridging the Gap: Real Options ' Linkage with Flexibility and Resilience

We review Real Options by combining and analyzing features, drivers, pros, and cos. Through examples from the wider business environment, we identify opportunities and challenges that Real Options can provide to businesses. in many cases, Real Options become a great managerial tool to come to the right decision. Real Options help businesses to be resilient and flexible because they show other aspects of evaluating investments beyond the narrow limits of the Net Present Value. Real Options give answers to strategic decisions, like market entry timing, modes of entry, organizational forms, foreign investment, and Multinational Corporation (MNC) performance, cooperation versus competition tradeoffs, outsourcing or insourcing and so on.
Real Options Theory can open new roads to heterogeneity of firms (e.g., Peteraf, 1993), decisions for borrowing and lending (e.g., Capron and Mitchell, 2012), cooperation versus competition

tradeoffs arising in many market and technology contexts (e.g., Smit and Trigeorgis, 2004), head-quarters role in multinational firms (e.g.,Rumelt, Schendel, and Teece, 1994).

We commence by defining Real Options, by explaining why they are "options,'' and why they are "real''. An option is a right, but not an obligation, to take some future particular action at a pre-agreed cost.

Myers (1977) suggested that the theory of financial options can be applied to strategic decision making.

# 4 Navigating Uncertainty and Maximizing Value: An Integrated Approach to Real Options, Strategic Decision Making, and Project Evaluation in Organizational Contexts

## 4.1 Tools for evaluating a project

Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period, and Discounted Payback Period are well-established methods for evaluating projects. These techniques primarily rely on future cash flows or cash returns. However, risk is a significant factor that cannot be overlooked, as it measures the variability of cash returns used in the decision-making process (Lohmann J., Baksh S., 1993).

Various tools can be employed to incorporate risk analysis into capital investment projects. One such category is informal methods, which do not require complex mathematical calculations but instead rely on common sense. For instance, if a project has a low level of risk, a lower rate of return should be calculated, while a higher rate of return should be determined for high-risk projects. Adjustments must be made to present proposals with and without risk to management. As an example, a risk-free proposal might be worth €100.000, while the same proposal with risk could be valued at €500.000, resulting in a risk premium of €400.000 (Pan H., 2023).

Mechanical engineers designing engines often utilize computer simulations that incorporate all necessary variables for engine construction. By altering the variables, they can test the efficiency of the project. A similar methodology can be applied to investment evaluation by inputting variables into the model and assessing their impact on the Net Present Value. Simulations are typically recommended for large-scale projects, as they can be quite costly. Alternatively, sensitivity analysis or what-if analysis can be employed to determine how changes in a single variable affect NPV. The graphical representation of magnitude correlation illustrates the sensitivity of NPV to various variables. in this case, the point of intersection at 2.250 units represents the project value. for example, if a 1% change in a variable result in a 50% alteration in NPV, it indicates that NPV is overly sensitive to that variable (Pringles R., Olsina F., Garces F., 2015).

Such a technique is the Monte Carlo simulation, which generates individual values of a random variable. Real Options, also known as managerial or strategic options, help mitigate the risk associated with an investment project. These options provide the flexibility to influence the amounts and risk of a project's cash flows, determine its duration, or delay its implementation. Typically, Real Options are integral components of significant strategic projects and involve tangible rather than financial assets. The distinction between a project's Net Present Value (NPV) without the option and its NPV with the option determines the worth of a project or its true NPV. The value of the Real Option can be approximated, albeit not precisely, using the Black-Scholes formula. (Smit H., Trigeorgis L., 2018).

Incorporating flexibility in the decision-making process can enhance project adaptability. This may include options to abandon a project early if it proves unprofitable, delay implementation in anticipation of favorable market conditions, expand or scale back operations, modify inputs or outputs, enter new markets, or launch new products. Risk tolerance is another crucial factor in decision-making, as companies may vary in their willingness to accept higher levels of risk for potentially greater profits, as opposed to adopting a more conservative approach due to fear of losses ( Sivarajan S., De Bruijn O., 2020).

A large conglomerate operating in various industries may employ risk-adjusted discount rates when evaluating investment decisions. Such conglomerates might accept investments with internal rates of return lower than their overall cost of capital if they align with strategic objectives. Conversely, investments with internal rates of return higher than the cost of capital may be rejected if they do not support the conglomerate's strategic vision (Ammann M., Verhofen M., 2005).

## 4.2 NPV

The Net Present Value rule embodies the principle that managers and investors of companies ought to exclusively allocate resources towards projects or engage in transactions that yield a positive Net Present Value (NPV). It is imperative to abstain from investing in ventures that exhibit a negative Net Present Value. This principle naturally emanates from the underlying theory of Net Present Value (Elmaghraby S., Herroelen W., 1990).

In accordance with the theory of Net Present Value, investing in ventures that yield a Net Present Value greater than zero is expected to logically augment a company's earnings. In the case of an investor, such an investment should contribute to the enhancement of the shareholder's wealth. Companies may also undertake projects with a neutral NPV when they entail potential future intangible benefits that are currently immeasurable or when they enable ongoing investments.

While the Net Present Value rule is generally adhered to by most companies, there exist circumstances wherein it may not be a decisive factor. For instance, a company confronted with substantial debt issues may forsake or postpone the pursuit of a project with a positive NPV. In such a resolution of an immediate and pressing debt matter (Elmaghraby S., Herroelen W., 1990).

Additionally, inadequate corporate governance can lead to a company disregarding or miscalculating the NPV, Net Present Value, frequently encountered in capital budgeting projects, incorporates the concept of the Time Value of Money (TVM), (Parvez M., 2006). Time Value of Money posits that future funds possess diminished value relative to presently available capital, owing to the earnings potential associated with present funds. A business entity employs a discounted cash flow (DCF) calculation, which factors in the potential alteration in wealth resulting from a specific project. This computation incorporates the time value of money by discounting the projected cash flows to their present value, utilizing the company's Weighted Average Cost of Capital (WACC), (Fernandez P., 2010). The NPV of a project or investment equates to the present value of net cash inflows anticipated to be generated by the project, minus the initial capital outlay required. Throughout the decision-making process of a company, the Net Present Value rule serves as a guiding principle to determine the pursuit of a project, such as an acquisition. Should the calculated NPV of a project be negative (< 0), it signifies an anticipated net loss for the company. Consequently, and in accordance with the rule, the company ought not to proceed with the project. Conversely, if a project's NPV is positive (> 0), the company can expect a profit and should contemplate progressing with the investment. If a project's NPV is neutral (= 0), it implies that the project is not anticipated to yield any substantial gain or loss for the company. In such cases, management incorporates non-monetary factors, such as intangible benefits created, to make an informed decision regarding the investment (Tuovila A., 2021).

To calculate NPV, one must first estimate the future cash inflows and outflows associated with the investment. These cash flows are typically projected over a specific time horizon, taking into consideration factors such as revenues, expenses, taxes, and salvage value. Next, a discount rate or required rate of return is applied to convert these future cash flows into present value terms. The discount rate represents the opportunity cost of capital and reflects the risk associated with the investment.

The NPV formula can be expressed as follows:

$NPV = -Initial\ Investment + (Cash\ Flow\ Year\ 1 / (1 + Discount\ Rate)^{1}) + (Cash\ Flow\ Year\ 2 / (1 + Discount\ Rate)^{2}) + \ldots + (Cash\ Flow\ Year\ n / (1 + Discount\ Rate)^{n})$

Where:

Initial Investment refers to the upfront cost of the investment.

*Cash Flow Year 1, Cash Flow Year 2,..., Cash Flow Year n represent the expected cash flows in each respective year*.

Discount Rate is the required rate of return or discount factor applied to future cash flows.

It is noteworthy to mention that NPV serves as a criterion for investment decision-making. If the calculated NPV is positive, it indicates that the investment is expected to generate a net gain and is considered financially viable. Conversely, a negative NPV suggests that the investment may not generate sufficient returns to cover the initial cost and may be deemed financially unfavorable (Brealey, R. A., Myers, S. C., & Allen, F. 2017, Ross, S. A., Westerfield, R. W., & Jordan, B. D. 2018).

## 4.3 NPV versus Real Options

Real Options bring a strategic element into decision making by allowing to incorporate decisions in points in the future such as expand, abandon, delay. We make the first step, we observe, learn from it, adapt our behavior, and think for the next step.

NPV is a very valuable metric to evaluate investments, but it has a flow as assumes that once you undertake an investment at a time zero there are no additional adjustments that should be made, no additional options you can avail. NPV can underestimate the value of an asset. Usually, we use a discount rate that doesn't reflect the risk of the project in which we want to invest, but the risk

of the corporation. As a result, the estimation of cash flows Option pricing valuation is not an alternative to discounted cash flow valuation, it's an augmentation. We must apply a discounted cash flow valuation before we embark an option pricing (Zhe Lu, Liebman A., Dong Z.,2006)
When referring to the term options in a nonfinancial context, it can have a different meaning from financial options. Real Options many times have no formulated market to be exchanged. in other cases, they have no objective reality for example R&D or patent.
The concept of shadow or hidden options (Bowman and Hurry, 1993), suggests that a company must reveal and value the bounds that exist among future opportunities and past investments.
In addition, terms of Real Options are not clear. For instance, expiration date, underlying price, strike price, discount rate. The same asset can have different value from company to company due to heterogenous firm behavior (Marek K., Wiktor P., 2003).
Moreover, various forms of uncertainty influence Real Options value (e.g., see Dixit and Pindyck, 1994; Folta, 1998; Trigeorgis, 1996; Vassolo et al., 2004).
There are exogenous uncertainties such us market demand, random entry (e.g., Dixit and Pindyck (1994)), and endogenous uncertainties such us technological uncertainties (e.g., Oriani, 2007; Oriani and Sobrero, 2008). Due to these uncertainties, Real Options are picked as tool from management, additional to established valuation methods.
We must consider that Real Options include action rights on real tangible or intangible assets and that these rights can be shared with other parties. Sometimes a company can have exclusive rights (Trigeorgis, 1996). Property rights are exclusive and disappear if company don't exercise them. In cases of shared options from many firms, Real Options can be lost, due to competition, because companies are going to exercise their option very soon.
The reward of waiting is not associated only with our opponents acts, but it depends on how irreversible our decision is to enter a market. If the technology and the assets that are committed are easy to be sold, there is no need for further demand signals. If the case is different, we must wait for markets signals to obtain the reward of waiting (Dixit and Pindyck, 1994)
Competitive threats, no exclusivity of option, no irreversibility, degree of uncertainty can determine the decision of making an investment.

## 4.4 Phases of investing in Real Options

The phases of investing in Real Options encompass a structured approach to evaluate investment opportunities and ascertain the optimal timing for execution. These phases provide a conceptual framework for comprehending the dynamic nature of Real Options and elucidate how they augment decision-making in the face of uncertainty.

1. Valuation and modeling

   We begin with the collection of main input data. Then we apply Standard Discounted Cash Flow (DCF) assessment and determination of a pure basic case present value (NPV) as a base (reference point). After estimating additional entry based on selection estimates, the analysis is proceeding using a modeling of a Real Options, such as the Binomial Trees (eg, Cox, Ross, and Rubinstein, 1979) or simulation, to assess expanded NPV. An "expanded" NPV analysis may involve performing sensitivity or scenario analysis to ex amine how changes in key assumptions such as discount rates, cash flow projections, or market conditions affect the NPV. This can provide valuable insights into the potential risks and uncertainties associated with the project or investment, enabling better decision-making.

2. Implementation planning

   After we suggest for a strategic investment, management may generate a plan for a possible decision, pointing out situations for the practice of major importance options in different conditions and develop an affective policy and significant stages of decisions in all investment phases.4.

3. Identification of stages in the life of the option

   Along with the above basic phases of the real choice analysis applied to organizations, research in ROT identifies stages in the life of the option (e.g., Bowman et Hurry, 1993). Each of these stages implicit opportunities for business to gain value.

   The initial stage is acknowledging the existence of shadow or hidden options that are present in a company's operations. By recognizing these options, a business can begin to explore and take advantage of the value that they may offer.

4. The next stage involves creating or acquiring Real Options by investigating and collect ing details about funds, assets, and materials. This stage is crucial in identifying potential opportunities and determining the feasibility of pursuing them.

The third stage involves administering, keeping, and reinforcing Real Options while bearing maintenance and incremental costs. This requires careful monitoring and management of the options to ensure that they remain valuable and continue to contribute to the business's success.

Finally, the fourth stage involves utilizing Real Options. This is where businesses can realize the value of their options by acting and making strategic decisions based on the opportunities that the options present. By following these stages, businesses can effectively apply Real Options Theory to their operations and make more informed decisions that contribute to their overall success.

The above phases can be executed in a different order, but it is extremely important to follow them as they can reveal gaps, regarded as unlikely to exist.

Phase one is especially important and demand managerial insight and perspicacity because it can contribute to achievements such as flexibility that can add real value and competitive advantage to a business. Few studies have addressed phase 2.

## 4.5 Dominant ways of dealing with Real Options

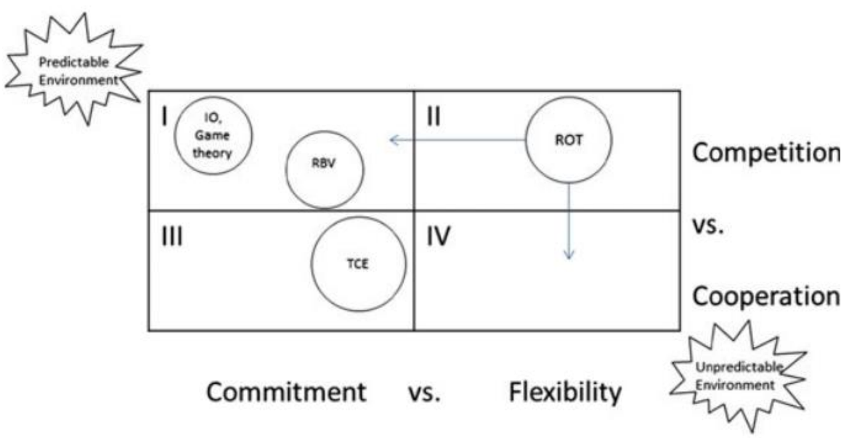
Reasoning involves making inferences and drawing conclusions based on existing information by examining facts and evaluating what conclusions can be drawn from them. It's a conscious and evolving process that allows for the consideration of multiple perspectives and the revision of previously held beliefs or ideas., (Pennington N., Hastie R. 1993).

Real Options Reasoning (ROR) is more appropriate when the basic drivers of Real Options can be specified and composed (McGrath, 1997), even when option cannot officially be valued. ROR helps organizations better establish their strategic investment decisions in uncertain environments. ROR targets in utilizing qualitive knowledge Real Options Theory (ROT). This is the reason why ROR can be applied to technology management, entrepreneurship.

Real Options Theory (ROT) is a framework that encourages firms to consider undertaking uncertain investments that may have negative Net Present Values (NPVs) in the short term but have the

potential to yield positive outcomes in the long run. According to ROT, these uncertain investments are viewed as Real Options that provide firms with flexibility and strategic advantages in managing unfavorable events. This approach allows companies to make low-cost incremental investments and build Real Options portfolios that can be adjusted over time, helping to improve their resilience and adaptability in a constantly changing business environment. Research conducted by McGrath, Ferrier, and Medelow (2004) suggests that ROT can help firms to manage uncertainty more effectively and identify opportunities for value creation, while Trigeorgis (1996) emphasizes the importance of managing Real Options portfolios with low-cost incremental investments to achieve long term success. By adopting a Real Options perspective, companies can gain a competitive advantage by being more flexible, adaptive, and innovative in the face of uncertainty. For Real Option Theory (ROT) to evolve as key player in decision making, ROT must be involved in fundamental issues of business strategy (e.g. Rumelt et al., 1994).
Kogut and Zander (1992) and Penrose (1959) claim that firms carry unique knowledge, resources and this fact determines the way they treat Real Options (Bowman and Hurry, 1993).

**Figure 4.1: ROT positioning in strategic management relative to key strategy dilemmas.**




Source: adapted from Trigeorgis and Baldi (2014)

## 4.6 TCE (transaction cost economics)

It may be harmful for a company to exercise a right prematurely. But commitment in unstable environment would be beneficial when the investment is progressive, opens new opportunities or choices, can go in or turned toward the direction opposite to that previously stated, part of uncertainty is endogenous and can be solved with new investments. Wait, is in some cases, a smarter movement in unstable environment especially when we deal with transaction cost economics with nonlinear performance (Abel and Eberly, 1994).

Not only there must be settlement of the dispute between commitment and flexibility by mutual concession, but a settlement must be succeeded between competition and collaboration. These options are not mutually exclusive, but many circumstances impose decision making that include both tactics. for instance, some companies participate in joint research but when they launch the product that is the result of this research, they are antagonistic due to huge cost of R&D.

## 4.7 When Real Options are applicable

As the focus shifts from Real Options associated with tradable assets to those linked to strategic opportunities contingent upon firm actions, the clear delineations between investment stages begin to blur. Consequently, the application of Real Options encounters heightened analytical and organizational complexities.

In scenarios where firm actions lead to the identification of new possibilities, the ability to specify opportunities in advance becomes arduous or even undesirable. Negative outcomes stemming from initial initiatives can still suggest alternative courses of action or potential markets that were not initially envisioned. for instance, the inability of a technology development endeavor to meet a specific technical threshold within a given time horizon does not preclude subsequent efforts or alternative approaches. Similarly, if a newly introduced product fails to gain traction in a particular target market, it may still find success in other potential markets that had not been initially considered (Bowman E. H., Moskowitz G., 2001).

Fundamentally, the vast array of possibilities associated with strategic investment initiatives presents a challenge akin to Popper's proposition on hypothesis testing1. Popper's proposition on hypothesis testing, often referred to as the falsification principle or falsifiability, is a key concept in the philosophy of science. According to Popper, scientific hypotheses should be formulated in a way that they are potentially falsifiable or refutable. Popper argued that the distinguishing characteristic of scientific theories is that they make specific predictions that can be tested and potentially proven false through empirical evidence. He believed that scientific knowledge progresses through a process of conjecture and refutation, (Wilkinson M., 2013).

In contrast to verification or confirmation, which seeks to prove a hypothesis or theory true, Popper emphasized the importance of attempting to falsify or reject hypotheses. According to his proposition, a hypothesis or theory that withstands repeated attempts at falsification through rigorous testing gains credibility and can be provisionally accepted as scientific knowledge. However, Popper emphasized that no theory can be conclusively proven true, as new evidence may always arise that could potentially refute it. in summary, Popper's proposition on hypothesis testing asserts that scientific theories should be formulated in a way that allows for empirical testing and potential falsification. The focus is on attempting to disprove hypotheses rather than seeking to confirm them, with the aim of progressing scientific knowledge and promoting a critical and self-correcting approach to scientific inquiry.

Accordingly, it is only possible to demonstrate the viability or non-viability of a specific technology or product within a particular context. Negative evidence does not negate the potential viability of other application areas or future refinements of the technology. This inherent inability to definitively prove failure is a fundamental characteristic of firm initiatives operating under conditions of uncertainty. It poses a fundamental challenge to the applicability of the Real Options framework. Furthermore, as actors within an organization possess diverse perspectives on the attractiveness of a given opportunity, disagreements arise regarding the appropriate framing of termination decisions. Thus, the open-ended nature of the search for success presents organizational hurdles that can discourage firms from exercising the very flexibility that initially made the Real Options approach enticing.

The level of circumscription in project scope plays a crucial role in determining the degree of flexibility and the potential directions of an initiative. A highly circumscribed initiative, characterized by specific target markets and well-defined temporal and technical boundaries, limits the scope for flexible decision-making. However, imposing stringent criteria for abandoning initiatives may result in the underutilization of valuable discoveries made during failed endeavors that introduce promising possibilities not initially envisioned (Adner R., Levinthal D. A., 2002)

## 4.8 Basic categories of Real Options

The basic categories of Real Options, as described by Trigeorgis in 1996, include the following:

- Investment Options: These options involve the decision to invest in a particular project or asset. Investment options allow flexibility in timing and scale of investments, enabling companies to delay or expand investment based on changing market conditions or new information.
- Abandonment Options: Abandonment options provide the right to discontinue or abandon a project before its completion. This option allows companies to cut losses and redirect resources if the project becomes unprofitable or if market conditions change unfavorably.
- Expansion Options: Expansion options involve the decision to expand a project or business in the future. This option enables companies to capitalize on positive market developments, increased demand, or successful outcomes by scaling up operations or investing in additional capacity.
- Switching Options: Switching options allow companies to switch between different business strategies or technologies. It provides the flexibility to adapt to changing market dynamics, technological advancements, or competitive pressures by shifting focus or reallocating resources.
- Flexibility Options: Flexibility options encompass a range of options that provide general flexibility in decision-making. These can include options to change pricing, modify production processes, adjust product specifications, or enter strategic alliances. Flexibility options enable companies to respond effectively to unforeseen events or take advantage of new opportunities.

- Timing Options: Timing options involve the ability to choose the timing of certain actions, such as the initiation of a project, the exercise of an option, or the entry into a market. This option allows companies to wait for more favorable conditions or gather more information before making critical decisions.
- Switching Options: Switching options pertain to the ability to transition between distinct business domains, markets, or technologies. They furnish the flexibility to reorient focus and allocate resources in response to shifting market dynamics or the emergence of more favorable prospects.
- Compound Options: Compound options entail a series of interconnected decisions wherein the outcome of one decision influences subsequent options. They encompass an amalgamation of Real Options interwoven within a project or investment, thereby allowing for sequential decision-making informed by evolving information and circumstances.

## 4.9 Monte Carlo technique - A quantitative approach to ascertain the magnitude of our susceptibility to risk

The Monte Carlo simulation is a technique, named after the renowned gambling establishments in Monte Carlo, that project managers employ to evaluate the risk associated with timelines and budgets. In this process, each task is scrutinized for potential durations, costs, revenues, and so on, and a probability range is ascribed to each. Consequently, for every task, it is requisite to establish a probability distribution that conveys the range of potential schedule deviations from the primary estimate. If one were to consider that each task could have a range of potential durations, and their likelihood can be expressed as a distribution, this distribution is often depicted as a distribution function. This distribution function can be most conveniently visualized as a graph (Ulam S. 2023). The most adopted form of distribution function in project management is what mathematicians call the Beta function. This function demonstrates that the most probable schedule deviations are concentrated around the forecasted schedule. A narrow range of deviations implies that the task is likely to be completed before the planned schedule, while an extensive range of deviations that extends significantly beyond the anticipated or planned schedule suggests a delay.

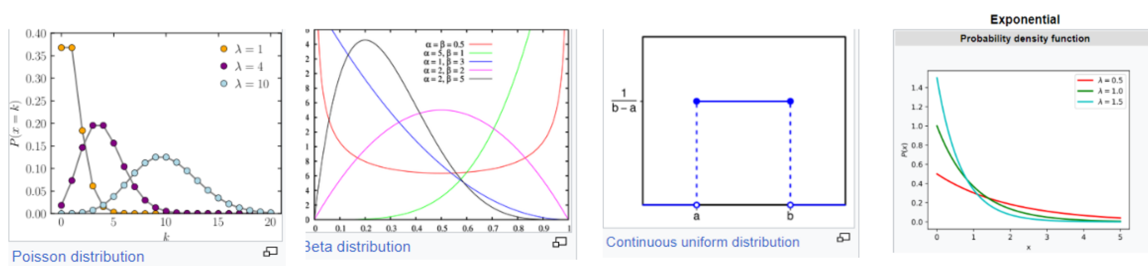
In a Real Options simulation, various types of probability distributions are used to model the uncertainties and risks associated with investment decisions (Tao J., Gang Z., Hua.ng Z, Hui Huang, 2012)

Types of distributions used in Real Options simulation can be categorized as follows:

- Normal Distribution: Also known as the Gaussian distribution, the normal distribution is widely used in Real Options simulations due to its symmetrical bell-shaped curve. It is characterized by two parameters: mean (μ) and standard deviation (σ). The normal distribution is often used to model returns on assets, changes in interest rates, and other continuous variables that tend to follow a symmetric pattern.
- Lognormal Distribution: The lognormal distribution is frequently used to model variables that are strictly positive, such as stock prices, commodity prices, or other financial variables. It is derived from the natural logarithm of a normally distributed random variable, ensuring that its values remain positive. It is characterized by a positively skewed shape, with a long tail on the right side.
- Poisson Distribution: The Poisson distribution is a discrete probability distribution that models the number of events occurring within a fixed interval of time or space. It is commonly used to simulate rare events, such as defaults or bankruptcies, in Real Options analysis. The Poisson distribution is characterized by a single parameter, λ, which represents the average rate of events occurring in the given interval.
- Binomial Distribution: The binomial distribution models the number of successes in a fixed number of independent Bernoulli trials with the same probability of success. It is often used in Real Options simulations for modeling discrete outcomes, such as the success or failure of a project or the likelihood of reaching specific milestones. The binomial distribution is characterized by two parameters: the number of trials (n) and the probability of success (p).
- Exponential Distribution: The exponential distribution models the time between events in a Poisson process, characterized by a constant rate of occurrence. It is used in Real Options simulations to model variables such as waiting times, project durations, or time to equipment failure. The exponential distribution has a single parameter, λ, which represents the average rate of events.

- <u>Uniform Distribution</u>: The uniform distribution assigns equal probability to all possible outcomes within a specified range. It can be used in Real Options simulations to model variables with limited information or where there is no reason to assume any pattern in the data. The uniform distribution is characterized by two parameters: the lower bound (a) and upper bound (b) of the range.
- <u>Beta Distribution</u>: The beta distribution is a continuous probability distribution defined on the interval [0,1]. It is frequently used to model probabilities, proportions, or rates in Real Options simulations. The beta distribution is highly flexible and can assume various shapes, depending on its two shape parameters: alpha (α) and beta (β).) (Pannell R., 2022).

**Figure 4.2: Lists of probability distributions**




Source: https://en.wikipedia.org/wiki/List of probability distributions

Monte Carlo utilizes substantial computational resources to approximate the potential results of an uncertain event. It operates by simulating the likelihood of various outcomes in a process or system that is difficult to predict accurately due to the introduction of random variables.

It uses random sampling. By repeating each simulated project will have a wide range of different outcomes for each task but that will give a probability distribution for the end date of the project or any budget parameter. The difficult part of Monte Carlo simulation is making sensible estimates of the distributions and of the primary schedule estimates for each and very many activities. This is particularly challenging task and errors in this process will cost errors in predictions. in the and we finally get the precision and error we put in the system. Another disadvantage of Monte Carlo method is that assumes that its activity is separate and independent of all others. for instance, if an activity is delayed by three days, Monte Carlo does not assume delay in another activity, something that does not apply.

What described above for duration can applied for budgets parameters.

Monte Carlo Simulation finds widespread utilization across various domains, with portfolio management, investment planning, risk analysis, option pricing, and spare capacity planning being among its most renowned applications. Employing millions of simulations, investors can acquire a more comprehensive understanding of their portfolio's potential performance across diverse market scenarios.

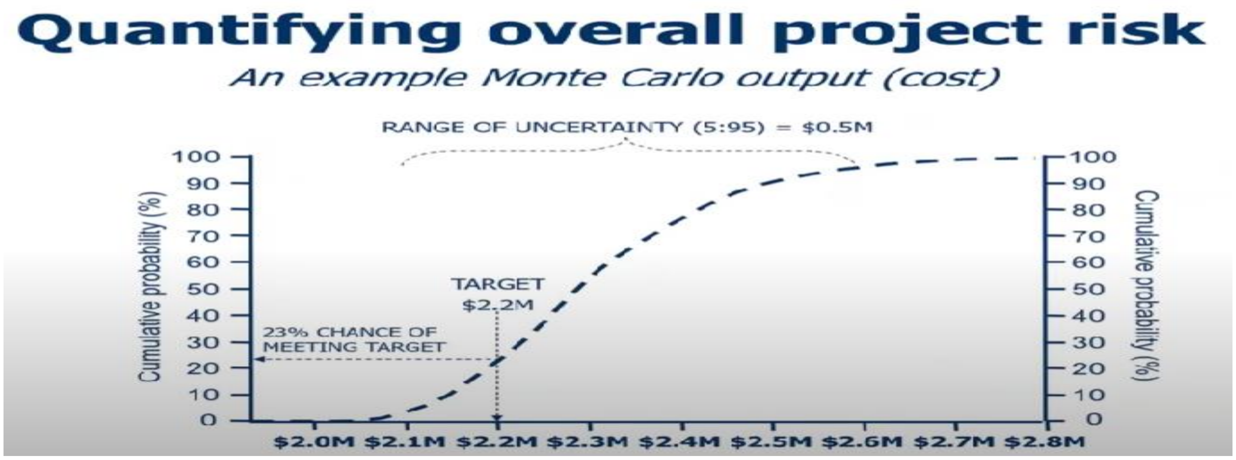
## 4.10 Basic steps of Monte Carlo technique

Monte Carlo techniques encompass several crucial steps essential for the precision of the predictive model. The initial step entails establishing the predictive model itself, wherein the dependent variable to be forecasted is identified alongside the independent variables that will shape the predictions. Subsequently, the probability distribution for each variable must be specified, achieved through either historical data or subjective assessments provided by analysts, delineating a range of plausible values, and assigning corresponding probability weights. Once the probability distributions are defined, the simulation can be executed by generating random values for the independent variables. Lastly, accurate measurement of the sample's dispersion necessitates the calculation of variance and standard deviation. These measures are commonly employed to ascertain the extent of variation within a sample, enabling the identification of potential sources of risk and uncertainty within the model (Hesterberg T.,2002).

Below, we present a diagram depicting a Monte Carlo outcome.

The diagram below depicts the variation of potential output of project costs in relation to cumulative probability of these costs to be done. We see that these costs cannot be below 2 million and above 2,8 million. We must quantify success in these two parameters that we are measuring. From the diagram we see that the probability of spending 2,2 million for the project is 23%.

**Figure 4.3: Predicted total project cost**




Source: QRA for overall risk – Dr David Hillson [https://www.apm.org.uk/news/the-value-of-quantita](https://www.apm.org.uk/news/the-value-of-quantita)

This suggests that 23% of our results are below 2,2 million and 77% are above 2,2 million.
We can state that the overall success of the project related to the cost parameter is 23%. We focus on a range of uncertainty between 5% and 95%. In this example the risk that stakeholders are exposed to is 0,5million. We can extract various confidence levels from this diagram. The realistic best case (fifth percentile) is near 2,1 million (+4% below budget) and the realistic worst case (5th percentile) is near 2,6 million (+18% over budget), given the target of 23 million.
This method can be applied to profitability, time, and other measurable parameters of the project. Once the risk has been quantified, it becomes imperative to address the subsequent query pertaining to the approach we shall undertake in mitigating the identified risk (Harrison, R. L.,2013).

## 4.11 Black Scholes equation/Novel price in 1997

The analysis explores the variables, assumptions, criticisms, and applications of the Black Scholes model in institutional and retail trading. The Black Scholes model is a mathematical formula used to calculate the fair price of European stock options, considering variables such as volatility, option type, underlying stock price, strike price, time until expiration, and risk-free interest rate. The model assumes a random walk or Brownian motion for price movements, lognormal distribution for stock prices, and constant volatility over time. It also assumes a frictionless market without dividends, transaction costs, or arbitrage opportunities, (Conecny J, Vicha T.Dohnal M.(2010).

Despite its underlying assumptions and limitations, the Black Scholes model remains a valuable tool in trading. It provides a fair price for options, but its application in the institutional world involves more complex strategies beyond simple calculations. The model has received criticism for its unrealistic assumptions, such as constant volatility and normal distribution of returns. However, traders have developed strategies that take advantage of the model's assumptions and limitations, such as volatility skewness strategies.

Understanding Brownian motion is essential to comprehend the origins of the Black Scholes model. Brownian motion was first observed by biologist Robert Brown, and it describes the random movement of particles suspended in a fluid. French mathematician Louis Bachelier drew an analogy between Brownian motion and the movement of financial assets, which later led to the development of the Black Scholes model. The model is a consequence of Ito's Lemma, and its assumption of Brownian motion captures the constant fluctuations in asset prices caused by buying and selling (Rathnayaka R., Wei J., Seneviratna D.,2014).

Despite its unrealistic assumptions, the Black Scholes model has been addressed using option Greeks, which are partial derivatives of the model. Option Greeks, such as delta, gamma, theta, vega, and rho, help measure different types of risks associated with options positions. Institutional traders focus on managing and hedging various types of risks rather than predicting price direction. Institutional traders, particularly in banks, utilize the Black Scholes model by understanding the isolated effects of each variable and breaking down financial risk into manageable types. They often focus on volatility prediction rather thdan price direction. By understanding institutional trading strategies, one can gain a deeper insight into how the Black Scholes model is used in the market.

## 4.12 Example of Valuation using NPV and Real Options in case of expansion

Consider a conventional capital budgeting exercise wherein a project necessitates an initial investment of €12.000 with the expectation of generating €3.000 annually in an optimistic scenario. Within the framework of standard capital budgeting, the evaluation of whether this investment is deemed worthwhile or not is predicated upon the calculation of the Net Present Value (NPV), determining whether it exceeds zero. For instance, in the context of an investment in a restaurant, where the initial year entails an influx of €12.000 it becomes apparent that NPV fails to capture the additional value arising from the success of the establishment. The NPV metric proves insufficient in accounting for the supplementary value that may be derived from the exercise of alternative options available throughout the investment's lifespan, such as the option to expand or scale the business, or to discontinue the investment altogether. Hence, it becomes imperative to assess a project in which the option to augment its success is present and, more significantly, to ascertain the value associated with such an option.

In case of having the option to expand

Back to our example we estimate that there are 50% possibility to have inflows of 3.000 € per year in perpetuity with a 20% discount rate of return and 50% possibility to have inflows of 1.000 € per year in perpetuity with a 20% discount rate of return. In this case we have a NPV of *((12.000€+3.000€/0,2) x 0,5)+((12.000€+1.000€/0,2) x 0,5) = (3.000€ x 0,5) (7.000€ x 0,5) =2.000 €.*

So, we have an overall NPV which is negative, and we are not going to proceed with the investment. But if we consider the fact that in case of success, we can expand by investing in 10 more restaurants, we immediately increase the value of the investments as follows

*(12.000€+(10.000€)/0,2) x 0,5 x 10.000€+(12.000€+(1.000€/0,2) x 0,5=30.000€ x 0,57.000€ x 0,5=11.5000 €.*

**Table 4.1: Table of data using NPV**

| years | scenario/ inflows | investment | possibility | NPV | Real Options / expand 10 times |
|---|---|---|---|---|---|
| discount rate | 20,00% | -12.000,00 € | | | |
| perpetuity/ optimistic | 3.000,00 € | | 50,00% | 3.000,00€=<br>-12.000 €<br>+(3000€/0,2) | 30.000,00€=<br>-(12.000,00 x 10)<br>+(3.000 x 10/0,2) |
| perpetuity/ pessimistic | 1.000,00 € | | 50,00% | -7.000,00€=<br>-12.000€+<br>(1.000€/0,2) | -7.000,00 € |
| | | | | -2.000,00€=<br>(3.000€ x 0,5)<br>-7.000€ x 0,5) | 11.500,00€=<br>(30.000€ x 0,5<br>-7.000€ x 0,5) |

Source: Author's calculations

## 4.13 Example of valuation using NPV and Real Options in case of abandonment

If we have an optimistic scenario of 6.000 € per year inflows and pessimistic scenario of -2.000 inflows, applying NPV and Real Options with the option to abandon in 1 year, we get the following results. From negative NPV -.2.000 € we turn to positive 2.166,67 € with Real Options.

**Table 4.2: Table of data using Real Options**

| years | scenario/ inflows | investment | possibility | NPV | Real Options / |
|---|---|---|---|---|---|
| discount rate | 20,00% | -12.000,00 € | | | |
| perpetuity/optimistic | 6.000,00 € | | 50,00% | 18.000,00€=<br>-12000€+<br>(6000€/0,2) | 18.000,00 € |
| perpetuity/pessimistic | -2.000,00 € | | 50,00% | -22.000,00€=<br>-12.000€+<br>(-2.000€/0,2) | -13.666,67 €=<br>-12.000-<br>(2.000/1,2$^{1}$) |
| | | | | -2.000,00€=<br>(18.000€ x 0,5)<br>-(22.000€ x 0,5) | 2.166,67€=<br>(18.000 x 0,5)+<br>(13.666,67 x 0,5) |

Source: Author's calculation

## 4.14 Example of Real Option valuation using NPV and Real Options in case of having the option to delay

In the realm of investment, a Real Option that may appear unfavorable in the present could potentially yield favorable outcomes in the future. Consequently, possessing the prerogative to exercise such an investment can be deemed valuable. This particular investment affords us the opportunity to penetrate a novel market and engender a highly valuable new product.
When contemplating the acquisition of securities, one may opt to purchase a call option if a future surge in share prices is anticipated, or a put option if a decline in share prices is presumed.
Consider the scenario wherein we encounter an investment with a negative Net Present Value (NPV) and an Internal Rate of Return (IRR) inferior to its hurdle rate, yet its exclusive rights bear significance. Alternatively, we may find ourselves in a situation where we are obliged to procure the exclusive rights to a seemingly insignificant technology. in instances where the value of the project falls below the initial investment, it can be categorized as an out-of-the-money option. Let us suppose that we currently possess a negative Net Present Value for this investment. However, the possession of exclusive rights presents us with a choice: if the value of expected cash flows escalates in the future, due to factors such as market conditions or advancements in technology, and if said increase surpasses the initial investment, we could seize the opportunity to bridge the gap and consequently transform a negative present value into a positive Net Present Value. Nevertheless, it is plausible that the investment may ultimately prove unviable, thereby necessitating the payment for exclusive rights.
To further comprehend the valuation of businesses, let us explore two real-world examples that serve as illuminating illustrations.

## 4.15 Value a pattern

A product pattern provides a firm with the right to develop a product and market it.
The company will proceed with the production of the product only if the present value of the future cash flows is positive (revenues greater than cost of development and production, marketing et)
A pattern is the cost of research and development and gives you the exclusive right to develop a product. It is not an obligation. Many patterns have not converted into products. As we have said

earlier, the bigger the risk the more valuable the options. R&D will give us better results when is directed to areas with more uncertainty. We need the inputs for the option pricing model. Above is the process to estimate these inputs.

The Net Present Value of cashflow will get if we develop the patent. This is the s in our model or the value of underlying asset.

We can look the past variance and when there is not, we can apply Monte Carlo simulation which allow us to make assumption to variances not just in point number, but we can get a distribution and a standard deviation or variance of that value. The shortcut we can use is industrial average variances. There are public traded companies our example and can use these public traded companies' prices to back into variance. Is not the perfect solution but it's easy to get.

The strike price is relatively simple. We must answer to the question how much will cost us to convert this patent into a commercial product and presumably the remaining inputs fall out of the option.

For the life of the option, we are going to look to the remaining life of the patent. We have t years left for the patent and that will become the life of the option. The risk-free rate is the rate over that life (Jones D., 2017).

As a real example (Damodaran A., 2015), consider a valuation of Avonex, a drug for treating multiple sclerosis developed by Biogen in the late 1990s. To obtain the inputs for the option pricing model, internal company data is required, which is not always accessible. in this case, the company had projected cash flows from immediately developing the drug, with a present value of those cash flows amounting to €3.422 million. The cost to convert the drug into a commercial product was estimated at €2.875 billion. With traditional capital budgeting, the Net Present Value of this project would be €547 million. However, as the investment had not yet been made, it was still an option.

Considering the remaining life of the option (17 years), the variance from publicly traded biotechnology companies, and introducing a cost of delay to encourage early exercise of the option, the Black-Scholes model provided a value of € 907 million for the option. The difference of €360 million between the Net Present Value and the value of the option is the option premium. This approach may be valuable when valuing small biotechnology companies or pharmaceutical companies with few products in the pipeline.

To value a patent using the Black-Scholes model, you need to calculate the $d_1$ and $d_2$ values and then use the cumulative normal distribution function (N) to find the value of the option.

First, let's calculate d1 and d2:

$d_1 = (ln(S/K) + (r + (s^2)/2) \times t) / (s \times \sqrt{t})$

$d_2 = d1 - s \times \sqrt{t}$

Where:

*S = 3.422 (PV of cash flows from introducing the drug now)*

*K = 2.875 (PV of the cost of developing the drug for commercial use)*

*t = 17 (patent life)*

*r = 0,067 (17-year risk-free rate)*

$s^2$ *= 0,224 (industry average firm variance for biotech firms)*

*y = 0,06 (expected cost of delay=1/17)*

*First, find the standard deviation (s):*

$s = \sqrt{(s2)} = \sqrt{0,224)} \approx 0,473$

*Next, calculate d1 and d2:*

$d_1 = (ln(3.422 /2.875) + (0,067 + (0,224 / 2)) \times 17) / (0,473 \times \sqrt{17})) \approx 0,990$

$d_2 = 0,990 – 0,473 \times \sqrt{17} \approx -0,259$

Now, we can use the cumulative normal distribution function (N) to find the value of the option. in this case, we have:

$N(d_1)$*= NORM.S.DIST(0,990;1)≈ 0,839*

*N(d1) = NORM.S.DIST(-0,259;1)≈ 0,398*

Finally, calculate the value of the option (Patent Value):

*Patent Value =* $S \times N(d_1) - K \times e(-r \times t) \times N(d_2)$

Plug in the values:

*Patent Value = 3.422 x exp(0,589) x 17 x 0,839 – 2.875 x e(-0,067 x 17) x 0,398 ≈ 2.869.758 – 1.676.762 ≈ 1.192.996*

So, the estimated value of the patent using the Black-Scholes model is approximately €1.193 million (Damodaran A., 2015).

## 4.16 Binomial Options Pricing Model

The Binomial Options Pricing Model (BOPM), established by Cox, Ross, and Rubinstein in 1979, is a prevalent method employed in the field of finance for the valuation of options. Contrasting with the Black-Scholes model, the BOPM provides increased adaptability by addressing the dynamic nature of financial markets.

To calculate an option's value, the BOPM constructs a binomial lattice or tree, which represents the potential underlying asset prices across discrete time intervals. Each tree node signifies a specific underlying asset price at a particular moment. The model presumes that the asset price can solely exhibit upward or downward movements at each stage, adhering to a designated probability distribution.

The valuation commences with the computation of the option's payoffs at the expiration date, corresponding to each conceivable final price of the underlying asset. These payoffs embody the option's intrinsic values upon expiration. Subsequently, the model progresses in a reverse manner through the lattice, determining the option's value at each prior node by discounting the anticipated value of the option derived from the following nodes.

The BOPM considers an array of factors, including time to expiration, risk-free interest rate, underlying asset price, exercise price, and asset volatility, to ascertain the value of an option. The binomial model's flexibility facilitates the accommodation of various option types, such as American-style options that permit exercise before the expiration date.

While the BOPM demands greater computational effort compared to the Black-Scholes model, its capacity to account for early exercise opportunities and shifting market conditions renders it an indispensable instrument for option valuation.

Binomial Option Pricing Model demonstrates the basics, behind derivatives pricing and some of the fundamental concepts within quantitative finance. It is used to derive to Black Sholes formula. (Luiz E. Brandão, James S. Dyer, Warren J. Hahn, 2005).

## 4.17 Significant Matters and Extensions Arising from the Preceding Discourses/Abandonment value

Companies that practice Real Options, pivot on the risks connected with revenues, disregarding cost risks. Furthermore, assessments based on Real Options don't consider that the action or process of investing money for profit or material that might be deserted, does not disappear completely, but has a bargain value, (Berger Ph., Ofek E., Swary I, 1996).

But as we would not count on Discounted Cash Flows (DCF) as they postulate very likely trends, we must find a model that complement and the assessment methods and overcomes their disadvantages. It should be clear that a Real Options approach can only be applied on collaborative enterprise that is carefully planned to achieve a particular aim that is shaped to offer options. The DCF valuation creates the basic framework, and the option valuation imports the effect of the useful contingent risk. Many times, managers use high rates for discount. This method could drive them to very conservative estimates but on the other hand could lead to wrong choices by losing real opportunities.

It is not on all occasions needed to estimate DCF and Real Options. We deal with a nondemanding case if DCF is large. If on the other hand the DCF is small or below zero, we must use Real Options as ancillary decision tool. A big negative DCF is a strong indication to reject a project. In the gray zone, where DCF if not satisfying, managers must use option tools to support or dismiss as inadequate their instincts.

There are two matters regarded as unwelcome or harmful and needing to be dealt with and overcome when we use Real Options.

The first one is to detect representative input variables especially when we are reasoning about innovative projects because data concerning past events are difficult to find.

Second, Managers are subjective to mistakes relating to or based on mental concepts. In Real Options if profits vary, the project has a bigger evaluation. This means that option is going to give bigger value to a project with more fluctuations in income and expenses than to a project with more steady cost and revenue elements.

Common sense states that instability must decrease the value of a project.

When it comes to revenue, a rapid unpredictable change can lead to positive or favorable as well as negative result. But for cost, changes commonly lead to negative results.

Especially when companies undertake innovative projects and they don't have experience in the field, can't control costs appropriately. As Nobel Prize winning psychologists Daniel Kahneman and Amos Tverky shown, enterprises assess risk projects with more confidence than they should. From a time in the past until the time under consideration, costs are liable to change in dissimilar mode than revenue. To overcome this difficulty, we can apply an adjusted option value that depicts the disturbing basic or inherent features of riskiness by estimating option value of revenue, apart from the option value of costs.

Managers must not ever forget that firms have limited resources, skills, and capacities.

A formula that can help us overboard these problem is

*adjusted volatility = project volatility x (revenue volatility / cost volatility)*

For example, we have following numbers to apply to the formula.

*project volatility=45%*

*revenue volatility=40%*

*cost volatility=60%* .

*adjusted volatility=45% x 40%/60%) =30%*

The above adaptation has the results in downsizing the option value. If revenue volatility is bigger than cost volatility, there is no need for alterations.

The second issue mentioned above to which the administrations do not give due attention is the abandonment value of the project (ABV), (Kang Y, 2009). Managers realize that they can replenish some of the losses in case of deserting a plan as in many cases, the initial investment has a significant residual value that cannot be ignored. Here is the mathematical relationship or rule expressed in symbols.

*TPV = NPV + AOV + ABV*

*TPV=Total Present Value*

*NPV= Net Present Value*

*AOV=Adjusted Option Value*

*ABV= Abandonment value of the project*

*The formula TPV = NPV + AOV + ABV* represents the Total Project Value of an investment project, which is composed of three components:

1. NPV (Net Present Value): This is the present value of all expected future cash flows from the project, discounted to their present value using a chosen discount rate. NPV represents the value of the project's future cash flows after accounting for the time value of money and the project's cost of capital.
2. AOV (Adjusted Option Value): This is the value of any Real Options embedded in the project, which give the project owner the right but not the obligation to take certain actions in the future. Examples of Real Options include the ability to expand the project if market conditions are favorable or to delay the project if market conditions are unfavorable.
3. ABV (Abandonment Value): This is the value that could be realized from disposing of the project or its assets if the project is terminated prematurely. ABV represents the minimum value that the project could generate, even in the worst-case scenario.

By adding these three components together, we can arrive at the Total Project Value, which represents the overall value of the investment project, including any Real Options and the potential value of abandonment. This formula is often used in capital budgeting and investment analysis to help evaluate the potential value of an investment project and make investment decisions based on the expected return and risk profile of the project.

Abandonment value refers to the potential value that can be realized from disposing of an asset or investment that is no longer useful or profitable. This value can take many forms, such as the sale of equipment or real estate, the salvage value of a scrapped asset, or the tax benefits of writing off a loss. Abandonment value is an important consideration when making investment decisions, as it represents the minimum value that an investment is likely to generate, even in the worst-case scenario.

An investment or asset that is abandoned by one firm may still hold value for another firm or in a joint venture. For example, a company may choose to abandon a particular product line or technology that is no longer profitable, but another firm in a different industry or market may see potential value in it. Similarly, in a joint venture, one partner may choose to exit the partnership and abandon their investment, but the other partner(s) may still see value in continuing the venture. However, it's important to note that the value of an abandoned investment or asset will depend on a variety of factors, including market conditions, the condition of the asset, and the potential uses for it.

The valuation of residual value is extremely important and is obvious in cases of joint ventures where the parts straggle to gain 1% to gain management.

The part with the higher participation will force for liquidation or aquation of the other's party share. For the valuation, managers usually use the Black Scholes Merton formula. The price we get by applying this formula is the exercise price. The decisive factor for the volatility of the exercise price is the historical facts and statistics collected for reference or analysis.

Let us assume that managers estimate abandonment value at €15 million in joint venture case, a risk-free interest at 3% and a Black Scholes Merton calculation of abandonment value at €983.000. Data concerning history give as a volatility of 45% and a value of €15 million in liquidation. If we negotiate at 51%, we must not pay more than *€983.000 x 0,51=€501.330* (for now, we are not considering the possible gains from control acquisition.

Estimating abandonment value involves determining the potential value that can be realized from disposing of an asset or investment if it is no longer useful or profitable. The abandonment value can be estimated using a variety of methods, including the following:

1. Liquidation Value: This method involves estimating the amount of money that could be obtained by selling the asset or investment in a liquidation sale. Liquidation value is often used as a benchmark for estimating abandonment value.
2. Salvage Value: This method involves estimating the value of any components or materials that could be salvaged from the asset or investment if it were to be scrapped or dismantled.
3. Tax Benefits: This method involves estimating the tax benefits that could be obtained by writing off the loss of the asset or investment on a company's tax return.
4. Market Analysis: This method involves researching similar assets or investments that have been abandoned or sold in the past and using that information to estimate the potential value of the current asset or investment.
5. Black Scholes Merton Model: This method involves using a financial model to estimate the value of a financial option, which can be used to estimate the potential value of an abandoned investment.

When estimating abandonment value, it is important to consider a variety of factors, such as market conditions, the condition of the asset or investment, and the potential uses for it. By taking a comprehensive approach to estimating abandonment value, investors can make more informed decisions about when to dispose of an asset or investment and how to maximize its value.

The Black Scholes Merton Model is a financial model that can be used to estimate the value of a financial option, including the potential value of an abandoned investment. Here's an example of how the model might be used to estimate abandonment value:

Assume that a company has invested in a joint venture with an estimated abandonment value of €10 million. The investment has a remaining life of 3 years, and the current risk-free interest rate is 2%.

Using the Black Scholes Merton Model, the estimated value of the abandonment option can be calculated as follows:

- Estimate the volatility of the investment. Assume a volatility of 30%.
- Calculate the time to abandonment using the remaining life of the investment. in this case, the time to abandonment is 3 years.
- Use the risk-free interest rate to calculate the present value factor. At a risk-free interest rate of 2%, the present value factor for 3 years is 0,9423.
- Use the Black Scholes Merton formula to estimate the value of the abandonment option. The formula is:

  Abandonment Value = Present Value Factor x [Asset Value x N($d_1$) Strike Price x N($d_2$)]

  Where:
- *$d_1$ = [ln(Asset Value/Strike Price) + (Risk-Free Rate + (Volatility$^2$)/2) x Time to Abandonment] / (Volatility x $\sqrt{Time\ to\ Abandonment}$)*
- *$d_2$ = $d_1$ (Volatility x sqrt(Time to Abandonment))*

  Plugging in the relevant values, we get:

  *$d_1$ = [ln(10.000.000/10.000.000) + (0,02 + (0,30$^2$)/2) x 3] / (0,30 x $\sqrt{3}$) = 1.1455 $d_2$ = 1,1455 (0.30 x $\sqrt{3}$) = 0,2781 N(d1) = 0,8729 N($d_2$) = 0,3922*

  *Abandonment Value = 0,9423 x [10,000,000 x 0.8729 10,000,000 x 0.3922] = €4.287.462*

  $\sqrt{3}$

In this example, the estimated abandonment value using the Black Scholes Merton Model is €4.287.462. This value can be used to make informed decisions about whether to continue with the investment or abandon it based on the expected return and risk profile of the project.

# 5 Case Study: Linear Accelerator

Cancer encompasses a collection of ailments distinguished by the unbridled proliferation and dissemination of cells. It has the potential to manifest in virtually any organism within the human physique (https://www.who.int/news-room/fact-sheets/detail/cancer, 2022).

An array of cancer types exists, encompassing dermal, pulmonary, mammary, prostatic, colonic, and rectal malignancies, to mention but a few.

The etiology of cancer comprises manifold and intricate factors. Genetic components, environmental influences (such as tobacco usage, solar irradiation exposure, or toxic chemical exposure), specific infections, and insufficient dietary practices may all be encompassed.

The manifestations of cancer may fluctuate contingent upon the neoplasm's classification and the disease's advanced stage. Frequently encountered indications include weight loss, fatigue, diminished appetite, pain, voluntary dermal modifications, and additional symptomatic presentations.

Diverse overarching classifications exist for the therapeutic management of cancer. Noteworthy categories encompass surgical intervention, chemotherapeutics, radiological interventions, immunomodulatory approaches, and targeted therapeutics.

Surgical intervention entails the excision of the neoplasm and its adjacent affected regions. This therapeutic modality may serve as monotherapy or in concert with other modalities.

Chemotherapeutics employ pharmacological agents to counteract and eradicate neoplastic cells disseminated throughout the organism. This modality may be implemented prior to or after surgical intervention or in conjunction with alternative therapeutic strategies.

Radiological interventions harness high-energy radiation to exert influence upon cancerous cells, inhibiting their proliferation. This therapeutic modality can be employed independently or in synergy with other treatment modalities.

Immunomodulatory approaches bolster the host's immune system to mount a robust anti-cancer response, thereby facilitating the elimination of malignant cells. This therapeutic avenue encompasses pharmacotherapeutic agents that enhance the immune response against cancer.

Targeted therapeutics proffer pioneering and innovative strategies for cancer treatment, encompassing interventions that specifically target susceptible genetic loci, combination therapies, and mixed-mode radiation protocols.

The therapeutic categories are selectively employed based on the cancer type and the advanced stage of the disease, with the overarching objective of eradicating the neoplasm and augmenting both survival rates and the quality of life for affected individuals.

## 5.1 National Registry of Neoplastic Diseases

We are among the final quintet of European nations devoid of any cancer registry, be it on a national or local scale. It is crucial for us to accelerate our progress and bridge the gap, striving to match the advancements achieved by the most sophisticated European health systems.

What we can do

The General Secretariat for Health Services has developed a comprehensive program for Digital Health, characterized by its ambitious nature and built upon four foundational pillars:

- The National Digital Patient Record
- The Digital Upgrade of Clinics
- Telemedicine
- Digital Program for the treatment of Cancer

Benefits

Patients will experience enhanced capabilities in handling their health data, as it has become evident that patients possess the entitlement to conveniently access their medical information and avail themselves of the necessary assistance through a structured digital application ecosystem. Furthermore, the acquisition of more comprehensive and superior cancer data will facilitate their utilization in health policy development and scientific research endeavors on both Greek and European scales. Additionally, the management of data emanating from the scientific community shall be undertaken.

In 2019, the operation of Patient Registries was institutionalized, while the legislation on the operation of oncology councils' dates to 2012. The Pediatric Cancer Registry has been in operation for about a year.

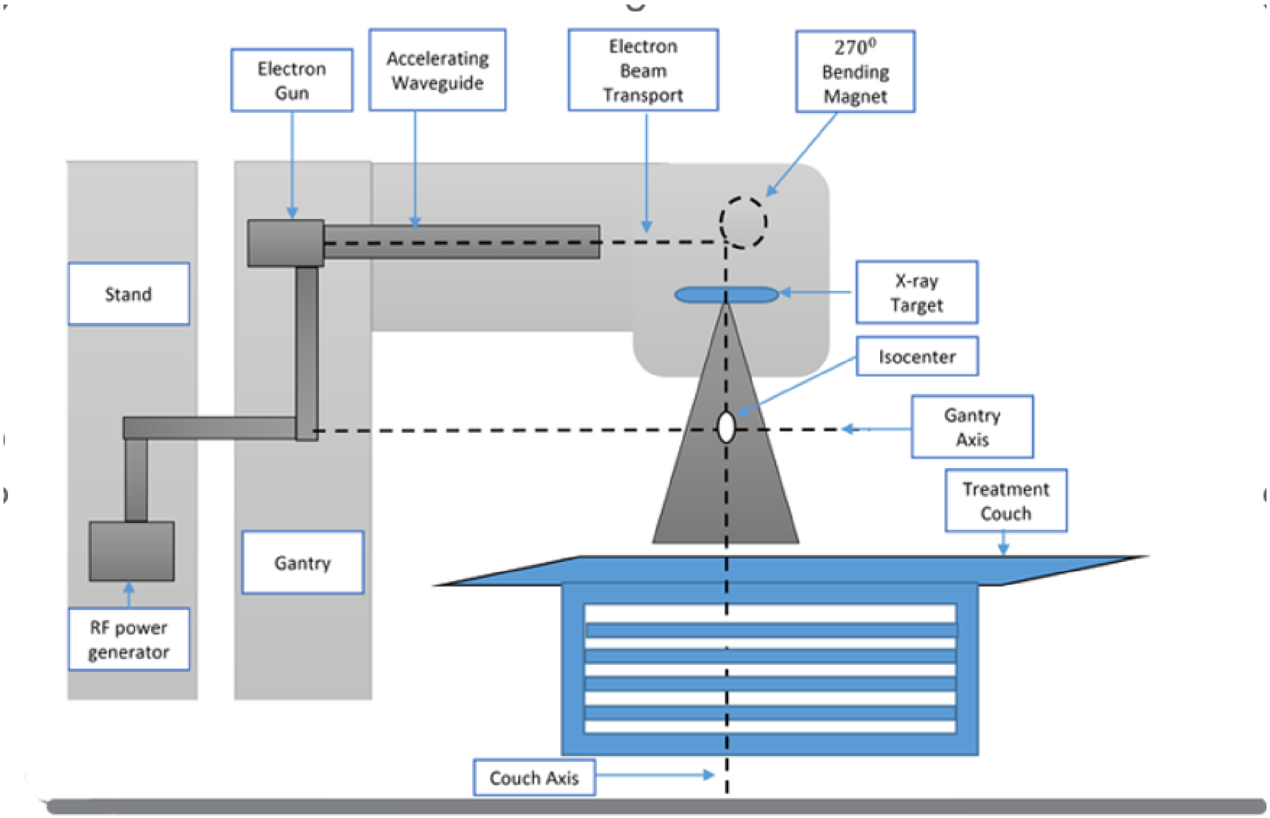
Although various scientific and academic bodies occasionally take initiatives to record various neoplastic diseases, these efforts remain fragmented and short-lived. Clinics make limited use of clinical information systems, while they lack specialized applications for the management of oncology patients. Finally, in relation to national systems, e-prescription does not apply to treatments administered in Clinics, while EOPYY (National Organization for the Provision of Health Services) applies the process of electronic pre-approval of treatments, a process that has several problems as stated by the competent doctors and we would like it to be modernized, he commented (Kotsiopoulos I., 2022).

## 5.2 How a Linear Accelerator works

A linear accelerator operates by guiding electrons towards a specific target. The guiding mechanism involves a waveguide consisting of a sequence of copper cells. These cells are connected by small openings or irises that allow the electrons to traverse along the waveguide while assisting in focusing the beam. To prevent interference from other particles, a vacuum is established to ensure unimpeded movement of the electron beam.

The trajectory of the negatively charged electron beam is regulated by two sets of quadrupole magnets known as steering coils, which encompass the waveguide. Additionally, two sets of focusing coils aid in refining the electron beam, resulting in a narrow diameter resembling that of a pinhead upon reaching the target. To maintain optimal operating conditions, the entire system is cooled using water. As the electrons exit the waveguide, they enter the flight tube, where the beam is redirected towards the designated target (Vretenar M. 2013)

**Figure 5.1: The schematic Diagram of Linear Accelerator**




Source: ResearchGate

## 5.3 Radiotherapy Treatments

New forms of radiotherapy can now more accurately target the affected area, killing fewer health cells. This accuracy also means that higher doses can be given safely if required.

IGRT Image Guided Radiotherapy: This involves collecting images to check tumors condition before treatment is given. With IGRT the risk of part of tumor being missed by xray beams is reduced.

IMRT Intensity modulated radiotherapy: This specialized way is now used to treat many different types of cancer. Is a way of radiographer molding and varying the strength of each beam to match the size, shape and position of a tumor and can do this more precisely than conventional or conformal radiotherapy. This allows the treatment to be just affective while reducing the side effects.

VMAT Volumetric Modulated: Arc Therapy is a new type of intensity modulated therapy. It works by delivering a continuous beam of radiotherapy while machine is moving, changing the beam shape and the treatment dose as it moves.

SART Stereotactic Ablative Radiotherapy: delivers a focused and high dose of radiotherapy to a tumor in fewer sessions, offering some patients longer decease and symptoms control. It is also used when surgery isn't an option.

SGRT Surface Guided Radiotherapy: uses sophisticated 3d camera technology to accurately target treatment. It does this by continuously and accurately monitoring a patients position during treatment using the surface of the patient to do this. Without this, people need tattoos (permanent reminder of the treatment with all the phycological effects) to line up the beams. It ensures precision at the submillimeter level when administering our therapeutic interventions.

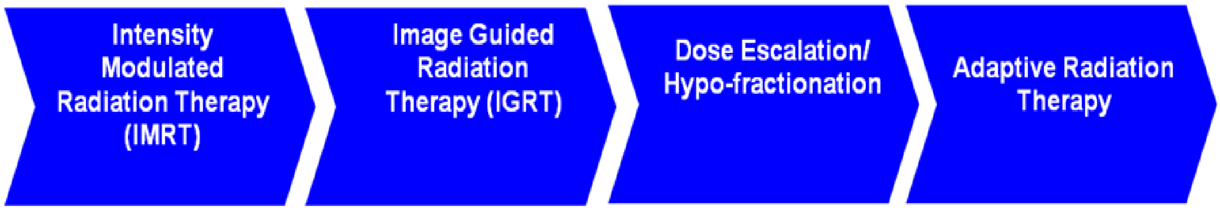
These therapeutic procedures are employed for malignancies affecting the cranial and skull regions, prostate gland, rectum, genitals, as well as gynecological cancers following surgical interventions. Additionally, they are utilized in cases requiring re-irradiation of patients, encompassing pancreatic, gastric, biliary, esophageal, and pediatric malignancies.

Generally, radiation therapies are implemented after surgical interventions, predominantly in the context of mastectomies.

In the realm of therapeutic interventions, we encounter the practice of internal radiation therapy, also known as brachytherapy. This treatment modality exhibits the potential for synergistic integration with preceding therapeutic approaches. Notably, the internal radiation therapy assumes a primary role in initiating tumor volume reduction, while the subsequent application of brachytherapy aims to optimize the delivery of localized radiation doses.

In each clinical scenario, it is imperative to convene scientific councils comprising the relevant experts from various specialized fields. These multidisciplinary consultations involve esteemed professionals such as radiation oncologists, oncologists, and pathologists. Furthermore, depending on the specific circumstances, additional advisory involvement of professionals from diverse specialties may be warranted. for instance, the inclusion of cardiologists could be necessary to assess the patient's suitability for the proposed treatment regimen, while the incorporation of geriatric specialists is crucial when considering the patient's advanced age and potential geriatric considerations (CWang W,, Zhu X,, Hong J., Zheng D, 2019).

**Figure 5.2: pros and cons of Radiotherapy Treatments**




Intensity Modulated Radiation Therapy (IMRT):
- Adjusting the intensity of the radiation
- Conformal dose distribution according to the shape of the target volume
- It does not consider changes in anatomy during treatment

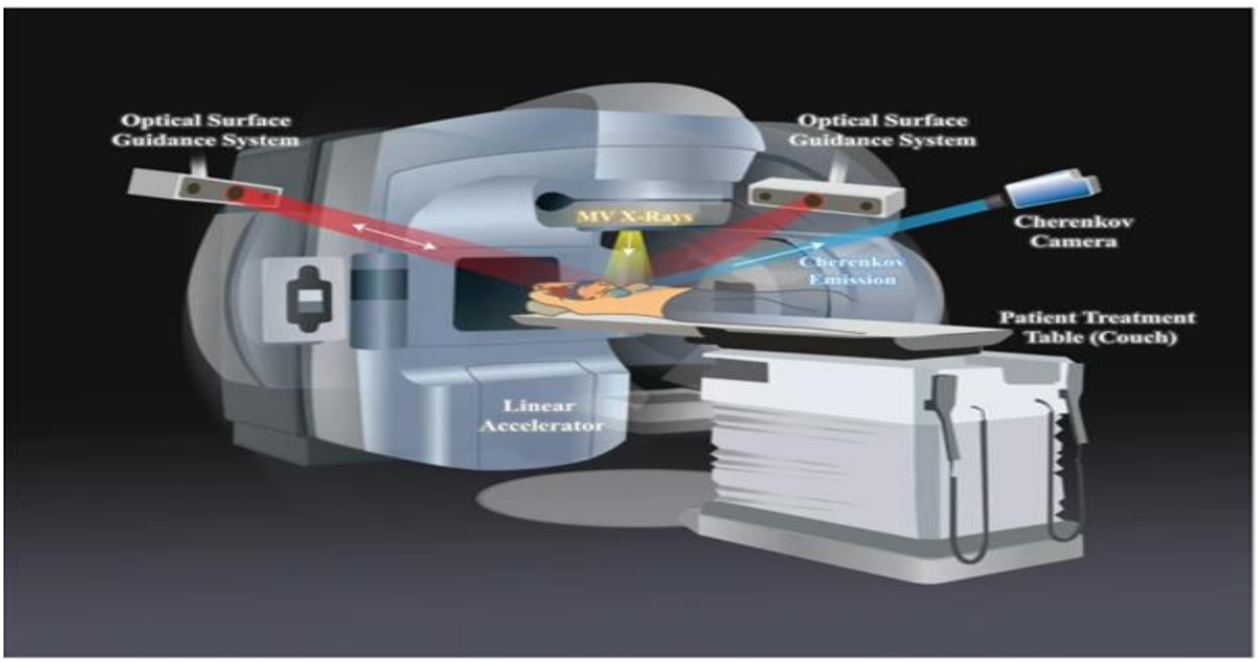
Image Guided Radiation Therapy (IGRT):
- IMRT requires imaging for accurate radiation delivery
- Ideally, imaging should be 3D

Dose Escalation/ Hypo-fractionation:
- The total number of sessions is limited and the dose per session is increased
- So far, it has been reliably used in limited cases
- It includes Radiosurgery.

Adaptive Radiation Therapy:
- Maximum accuracy through daily CT imaging
- The treatment plan is adjusted according to anatomical changes and the dose that was given 'Personalized' treatments

Source: Author's presentation

**Figure 5.3: Study setup and patient positioning in Linear Accelerator**




Source: https://www.nature.com/articles/s41467-020-16031-z

## 5.4 The current situation in Greece regarding radiation which justifies the investment

In the public sector, out of a total of 31 machines, 12 (39%) will be less than two years old, while 18 (58%) will be less than five years old. in the private sector, out of 17 machines, 3 (17%) will be less than two years old, and 8 (47%) will be less than five years old. The estimated requirement stands at approximately 70 machines.

According to data from the Hellenic Statistical Authority, cancer ranks as the second leading cause of mortality in Greece, following cardiovascular diseases. Unfortunately, precise figures regarding the annual incidence of new cases are unavailable due to the absence of a national cancer registry in our country.

It is noteworthy that more than half of cancer patients, in general, receive treatment for their condition. Radiation therapy, either as a standalone or in conjunction with other modalities, contributes to the management of 40% of these cases, while approximately 60% of patients will require radiation therapy at some point during their illness. The primary objective of radiation therapy is to administer a highly focused dose of radiation to the tumor, minimizing the impact on surrounding healthy tissues. The desired outcome is the eradication of the tumor, potentially leading to remission or improved survival rates and enhancing the patients' quality of life, while minimizing adverse effects.

Various contemporary radiation therapy techniques available to radiation oncologists, such as conformal radiotherapy (CRT), intensity-modulated radiotherapy (IMRT), stereotactic radiosurgery (SRS), stereotactic radiotherapy (SRT) and stereotactic body radiotherapy (SBRT), image-guided radiotherapy (IGRT), and 4D radiotherapy, aim to optimize local disease control and reduce treatment-related toxicity. It is crucial to note that these techniques represent distinct approaches within the realm of radiation therapy, rather than comprising different forms of radiation.

The aim of radiotherapy is simple. To destroy cancer cells, leaving normal health cells unaffected. Cancer cells are more vulnerable than cancer cells and we exploit these through treatment by carefully planning and targeting the area to be treated. (Hellenic Society of Radiation Oncology (H.S.R.O.), 2018)

The average lifespan of an accelerator is approximately 10 years. Presently, the mean age of linear accelerators in the 18 public and military Clinics across Greece is 7,4 years, whereas in the 8 private Clinics, it is approximately 8,5 years.

The training of personnel and the maintenance of equipment are vital components of radiation therapy. Each year, more than 28.000 individuals in Greece require radiation therapy, with 4.000 patients remaining on waiting lists due to the limited number of available machines.

In Greece, there are currently 3,8 radiation therapy machines per million population, while the corresponding average in European Union countries ranges from 6,5 to 7.

The figures clearly demonstrate that around 30.000 patients in Greece necessitate radiation therapy annually. Out of this number, 12.000 to 13.000 individuals receive treatment in private centers. in the Attica region, which serves a significant proportion of cancer patients from Central Greece and the Peloponnese, there are 14 radiation therapy machines in public Clinics and 15 in private Clinics.

Efforts are underway to tackle this issue, such as providing explicit instructions in prescriptions for radiation therapy that clearly indicate zero patient cost participation, and ensuring the prominently displayed decision in private clinics stating that radiation therapy incurs no expense for patients. Moreover, measures are being taken to establish afternoon radiation therapy sessions to expedite waiting lists in public healthcare facilities.

A further obstacle impeding the expedited progression of waiting lists in public institutions is the restricted operating hours for radiation therapy.

In the specified region, the sole operating Radiotherapy Department is housed within a state-run hospital, supplemented by our own clinical department. Together, they provide services not only to the local population but also to individuals hailing from various Greek islands, the greater Greece, and patients from overseas. These services are facilitated through a variety of contracts and international agreements established by our institution.

Given these conditions, the necessity of implementing an additional linear accelerator becomes evident. Such an installation would effectively fill the existing service gap in health provision and cancer patient treatment within the larger region.

Thus, the decision to procure a state-of-the-art linear accelerator is propelled by two primary reasons:

- The clear inability to fully service the needs of cancer patients with the current resources.
- The Clinic's goal to provide a more comprehensive array of health services, as it is currently offering diagnostic and therapeutic (including surgical) services to several cancer patients.

## 5.5 Applying Real Option Valuation to decision making about Linear Accelerator (Linac)

Real Option valuation is a rigorous approach utilized to assess the economic worth of investment opportunities while considering their inherent flexibility. Within the domain of linear accelerators, employing Real Option valuation enables the estimation of the investment's value by accounting for potential future opportunities that may emerge.

The valuation of a linear accelerator using Real Option valuation is influenced by various critical factors, encompassing:

Real Option valuation, a method for appraising investment opportunities, offers a comprehensive framework for evaluating the value of a linear accelerator while considering its inherent flexibility. Various factors of paramount importance contribute to the valuation process, including:

Anticipated future demand for the linac's services, encompassing the need for radiation therapy or research prospects.

The capital outlay required for constructing and operating the linac, along with potential maintenance expenses.

The possibility of emerging technologies or advancements within the field that may influence the linac's value.

The potential impact of regulatory changes or market fluctuations on the demand for linac services.

Real Option valuation, characterized by its rigorous methodology, involves the construction of models that encompass potential future scenarios and the subsequent calculation of the expected value associated with each scenario, considering their respective probabilities. The culmination of this analysis yields the comprehensive assessment of the investment opportunity's overall value.

Various approaches can be employed to execute Real Option valuation for a linear accelerator, including decision tree analysis, Monte Carlo simulation, and Black-Scholes option pricing models. Each approach enables the assessment of the investment's potential outcomes, providing valuable insights for valuation purposes.

To effectively evaluate the worth of a linear accelerator through Real Option valuation, meticulous scrutiny of conceivable future scenarios, as well as the inherent risks and uncertainties, is indispensable.

Real Option valuation for linear accelerators can be approached using the binomial option pricing model, a method that enables the determination of option values based on a range of conceivable future scenarios.

To apply this model to the valuation of a linear accelerator investment, the following sequential steps can be undertaken:

Begin by ascertaining the initial investment cost, encompassing the expenses associated with procuring and installing the linear accelerator and its accompanying infrastructure.

Proceed to identify the potential future scenarios that possess the capacity to influence the investment, such as changes in patient demand, reimbursement rates, or technological advancements.

Estimate the probabilities associated with the occurrence of each scenario, drawing upon available data and expert opinions to inform these assessments.

Delve into the determination of potential outcomes for each scenario, encompassing the revenue generated as well as the costs associated with expansion or modification of the linear accelerator.

Proceed to calculate the present value of each potential outcome by employing a discount rate that factors in both the time value of money and the risk profile associated with the investment.

Employ the binomial option pricing model to quantitatively evaluate the value of the Real Options linked to the investment, including options for expansion or the decision to delay the investment.

Integrate the present value of potential outcomes with the value derived from the Real Options analysis to obtain the comprehensive assessment of the total value of the investment (Oliveira A., Zambujal-Oliveira J., 2017)

## 5.6 Example of evaluating linear accelerator Monte Carlo simulation

A hospital is considering investing in a linear accelerator to provide radiation therapy services. The initial investment cost is **€ 2.350.000**.

The hospital conducted a feasibility study, a comprehensive and rigorous document that assesses the feasibility and efficacy of a proposed project or business venture. Its primary objective is to furnish authoritative information and meticulous analysis to facilitate decision-making by regulatory bodies or other pertinent entities.

Typically, a feasibility study encompasses the following essential components:

Project or business initiative description, outlining its nature and scope.

Sector-specific market analysis, encompassing relevant trends and dynamics.

Technical evaluation, encompassing meticulous scrutiny of essential resources, technological aspects, and implementation strategies.

Economic evaluation, encompassing meticulous cost and revenue analysis, rigorous assessment of Net Present Value (NPV), Internal Rate of Return (IRR), and other pertinent efficiency indicators.

Thorough risk analysis, accompanied by the formulation of viable mitigation strategies.

Comprehensive assessment of the social and environmental ramifications associated with the proposed project or initiative.

Conclusive findings and informed recommendations for the decision-makers' consideration.

A superlative feasibility study ought to be characterized by objectivity, meticulousness, and reliance on sound and trustworthy information sources. Typically, it is submitted for meticulous scrutiny and ultimate approval by regulatory authorities or other relevant entities prior to the commencement of the project or business venture.

The therapeutic interventions are executed through daily sessions. The quantity of feasible sessions is ascertained by the temporal exigency inherent to each individual session, contingent upon the nature of the specific therapeutic modality.

**Table 5.1: Calculation of Maximum Number of Patients per Year**

| | |
|---|---:|
| Working Days | 250 |
| Shifts | 2 |
| Shift Hours | 7 |
| Treatment Time in Minutes | 12 |
| Average Number of Sessions per Patient | 21 |
| Maximum Number of Patients | 833 |

**Table 5.2: Leasing Cost**

| | |
|---|---|
| Investment Cost (Excluding VAT) | 2.350.000 € |
| Repayment Period (in years) | 7 |
| Base Interest Rate | 8,00% |
| Initial Down Payment | 822.500 € |
| Annual Leasing Installment | 293.390 € |

Source: Financial Data of Feasibility Study of hospital and author's calculation

**Table 5.3: Calculate NPV**

| Years | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Patients | 300 | 330 | 330 | 330 | 330 | 330 | 330 |
| Revenue | 894.000 € | 983.400 € | 983.400 € | 983.400 € | 983.400 € | 983.400 € | 983.400 € |
| Expenses | | | | | | | |
| Leasing installments | 1.115.890 € | 293.390 € | 293.390 € | 293.390 € | 293.390 € | 293.390 € | 293.390 € |
| Construction-related costs | 50.000 € | 50.000 € | 50.000 € | 50.000 € | 50.000 € | 50.000 € | 50.000 € |
| Remuneration/ salary | 132.800 € | 136.784 € | 140.888 € | 145.114 € | 149.468 € | 153.952 € | 158.570 € |
| Maintenance | | | 140.000 € | 140.000 € | 140.000 € | 140.000 € | 140.000 € |
| Reservation of Collection | 44.700 € | 49.170 € | 49.170 € | 49.170 € | 49.170 € | 49.170 € | 49.170 € |
| Other expenses | 50.000 € | 50.000 € | 50.000 € | 50.000 € | 50.000 € | 50.000 € | 50.000 € |
| Cash Flow | -499.390 € | 404.056 € | 259.952 € | 255.726 € | 251.372 € | 246.888 € | 242.270 € |
| Discount Factor | 1 | 0,93 | 0,87 | 0,82 | 0,76 | 0,71 | 0,67 |
| Present Values | -499.390 € | 377.622 € | 227.052 € | 208.749 € | 191.770 € | 176.028 € | 161.435 € |
| ***NPV*** | ***843.266 €*** | | | | | | |

Source: Hospital data and author´s calculation

Based on the provided financial data of a feasibility study, an elaborate analysis can be constructed as follows:

The data underpins a systematic evaluation of the maximum feasible number of patients per year, considering the number of working days, shifts, shift hours, treatment time in minutes, and average number of sessions per patient. Specifically, with 250 working days, 2 shifts per day, each shift lasting 7 hours, a treatment duration of 12 minutes, and an average of 21 sessions per patient, the infrastructure can accommodate a maximum of 833 patients annually.

Furthermore, a detailed cost analysis pertaining to the leasing cost has been presented, including the initial investment cost, repayment period, base interest rate, initial down payment, and annual leasing installment. The leasing cost analysis indicates an investment cost of €2.350.000 (excluding VAT) with a repayment period of 7 years at a base interest rate of 8,00%. With an initial down payment of €822.500, the annual leasing installment comes to €293.390.

The study progresses to assess a 7-year financial projection, considering the number of patients, revenue, and various categories of expenses including leasing installments, construction-related costs, remuneration or salary, maintenance, reservation of collection (5%), and other expenses. It is projected that the number of patients will rise from 300 in the first year to a steady 330 from the second year onward. This rise in patient count translates to a revenue increase from €894.000 in the first year to €983.400 in the subsequent years.

Various expense categories such as leasing installments and construction-related costs remain constant throughout the 7-year period. The remuneration or salary expenses rise gradually over the years, starting from €132.800 in the first year to €158.570 in the seventh year. From the third year, a maintenance cost of €140.000 is introduced, and the reservation of collection stands at 5% of the revenue. The study also includes an additional category for 'other expenses' amounting to €50.000 annually.

The analysis then proceeds to calculate the annual cash flow, showing a negative balance of €499.390 in the first year, turning into a positive cash flow from the second year, ranging from €404.056 in the second year to €242.270 in the seventh year. The present values are calculated using a discount factor, which declines over the years from 1 in the first year to 0,67 in the seventh year. The net present value (NPV) is given as €843.266, which represents the profitability of the project. The feasibility study thus presents a comprehensive financial forecast, considering both revenues and costs, and suggests a profitable endeavor over the examined period.

## 5.7 Applying Monte Carlo simulation

The subsequent analytical inquiry juxtaposes the charge per patient, as delineated by the EOPYY price list, with the uncertainty factor and the interest rate. Upon careful review, the interest rate yields an average of 8%, with potential fluctuations ranging from 3% to 16%. Moreover, the uncertainty factor constitutes a palpable 50% deviation. To encompass the scope of possible patient numbers per annum, a probabilistic model was implemented, thereby introducing a spectrum from a minimum of 150 to a maximum of 450 patients.

Using the data, an array of potential outcomes was envisaged over a period of seven years. This stochastic approach was subsequently applied to calculate the Net Present Value (NPV), considering various expenses, including leasing, investment, payroll, maintenance, revenue reservations, and other sundry costs.

A complex function was also utilized to discern the optimum value. This function stipulates that if the cumulative probability falls below the lower range over the total range, the minimum value plus the square root of the product of the cumulative probability, lower range, and total range is computed. Alternatively, if the cumulative probability surpasses this threshold, the maximum value less the square root of the product of one minus the cumulative probability, the higher range, and the total range is calculated.

To further scrutinize the robustness of the project, a Monte Carlo simulation was employed, wherein 10.000 iterations were executed. Regarding the critical parameter of breaking-even, we can discern from the data that the breaking-even position occurs at the 803rd instance. in terms of percentage outcomes, 8,03% of the instances resulted in breaking-even or less, hence representing an unfavorable outcome, whilst the balance of 91,97% of instances yielded a return that was at least breaking-even, if not more, thus reflecting a predominantly favorable scenario. This conclusion leads us to infer that despite the broad range in potential outcomes, the preponderance of data points leans towards a positive NPV, thereby making the investment proposition under consideration appear fundamentally sound from a statistical perspective.

**Table 5.4: Apply ranges**

| | | Mean | min | max |
|---|---|---|---|---|
| Interest Rate | 12% | 8% | 3% | 16% |
| Uncertainty Factor | 50% | | | |

| Years/ Patients | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| mean | 300 | 330 | 330 | 330 | 330 | 330 | 330 |
| min | 150 | 165 | 165 | 165 | 165 | 165 | 165 |
| max | 450 | 495 | 495 | 495 | 495 | 495 | 495 |

Source: Hospital data and author´s calculation

**Table 5.5: Screenshot from running Argo simulation application of Monte Carlo**

| Years | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Patients | 319 | 467 | 356 | 394 | 218 | 327 | 280 |
| Revenue | 950.620 | 1.391.660 | 1.060.880 | 1.174.120 | 649.640 | 974.460 | 834.400 |
| **Cost** | | | | | | | |
| Leasing | 1.115.890 | 293.390 | 293.390 | 293.390 | 293.390 | 293.390 | 293.390 |
| Construction | 67.346 | 84.967 | 87.482 | 59.009 | 93.193 | 97.156 | 81.433 |
| payroll | 132.800 | 136.784 | 140.888 | 145.114 | 149.468 | 153.952 | 158.570 |
| maintenance | | | 140.000 | 140.000 | 140.000 | 140.000 | 140.000 |
| Revenue Reservations (5%) | 47.531 | 69.583 | 53.044 | 58.706 | 32.482 | 48.723 | 41.720 |
| Other Expenses | 50.000 | 50.000 | 50.000 | 50.000 | 50.000 | 50.000 | 50.000 |
| Cash Flow | -462.947 | 756.936 | 296.076 | 427.901 | -108.893 | 191.239 | 69.287 |
| Discount Factor | 1 | 0,9 | 0,8 | 0,72 | 0,65 | 0,58 | 0,52 |
| Present Values | -462.947 | 678.783 | 238.093 | 308.573 | -70.418 | 110.901 | 36.031 |
| **NPV2** | **839.015** | | | | | | |

Source: Hospital data and Authors calculations

**Table 5.6: Statistics from applying the model**

| | |
|---|---|
| n | 10.000 |
| ENPV | € 806.074,97 |
| Min NPV | € (1.269.172,12) |
| Max NVP | € 2.840.566,58 |
| P10 | € 62.720,34 |
| P90 | € 1.548.233,58 |
| Breaking even | |
| position | 803 |
| BE or Less | 8,03% |
| BE or more | 91,97% |

Source: Authors calculations

**Table 5.7: Bins for Histogram and Target Curve**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| max | 2840566,58 | | | | | | For Histogram | | For Target Curve | |
| min | -1269172,1 | | Bins | Bins | Frequency | Cumulative % | Mid-Value | Percent | Mid-Value | Cum. Percent |
| range | 4109738,69 | 1 | -1.132.181 | -1.132.181 | 3 | 0,03% | -1.132.181 | 0,03% | -1.132.181 | 0,03% |
| | | 2 | -995.190 | -995.190 | 4 | 0,07% | -995.190 | 0,04% | -995.190 | 0,07% |
| | | 3 | -858.198 | -858.198 | 2 | 0,09% | -858.198 | 0,02% | -858.198 | 0,09% |
| number of bins | 30 | 4 | -721.207 | -721.207 | 14 | 0,23% | -721.207 | 0,14% | -721.207 | 0,23% |
| | | 5 | -584.216 | -584.216 | 30 | 0,53% | -584.216 | 0,30% | -584.216 | 0,53% |
| | | 6 | -447.224 | -447.224 | 69 | 1,22% | -447.224 | 0,69% | -447.224 | 1,22% |
| range of bins | 136991,29 | 7 | -310.233 | -310.233 | 118 | 2,40% | -310.233 | 1,18% | -310.233 | 2,40% |
| | | 8 | -173.242 | -173.242 | 188 | 4,28% | -173.242 | 1,88% | -173.242 | 4,28% |
| | | 9 | -36.251 | -36.251 | 280 | 7,08% | -36.251 | 2,80% | -36.251 | 7,08% |
| | | 10 | 100.741 | 100.741 | 397 | 11,05% | 100.741 | 3,97% | 100.741 | 11,05% |
| | | 11 | 237.732 | 237.732 | 527 | 16,32% | 237.732 | 5,27% | 237.732 | 16,32% |
| | | 12 | 374.723 | 374.723 | 657 | 22,89% | 374.723 | 6,57% | 374.723 | 22,89% |
| | | 13 | 511.715 | 511.715 | 802 | 30,91% | 511.715 | 8,02% | 511.715 | 30,91% |
| | | 14 | 648.706 | 648.706 | 849 | 39,40% | 648.706 | 8,49% | 648.706 | 39,40% |
| | | 15 | 785.697 | 785.697 | 933 | 48,73% | 785.697 | 9,33% | 785.697 | 48,73% |
| | | 16 | 922.689 | 922.689 | 934 | 58,07% | 922.689 | 9,34% | 922.689 | 58,07% |
| | | 17 | 1.059.680 | 1.059.680 | 887 | 66,94% | 1.059.680 | 8,87% | 1.059.680 | 66,94% |
| | | 18 | 1.196.671 | 1.196.671 | 815 | 75,09% | 1.196.671 | 8,15% | 1.196.671 | 75,09% |
| | | 19 | 1.333.662 | 1.333.662 | 687 | 81,96% | 1.333.662 | 6,87% | 1.333.662 | 81,96% |
| | | 20 | 1.470.654 | 1.470.654 | 547 | 87,43% | 1.470.654 | 5,47% | 1.470.654 | 87,43% |
| | | 21 | 1.607.645 | 1.607.645 | 446 | 91,89% | 1.607.645 | 4,46% | 1.607.645 | 91,89% |
| | | 22 | 1.744.636 | 1.744.636 | 294 | 94,83% | 1.744.636 | 2,94% | 1.744.636 | 94,83% |
| | | 23 | 1.881.628 | 1.881.628 | 215 | 96,98% | 1.881.628 | 2,15% | 1.881.628 | 96,98% |
| | | 24 | 2.018.619 | 2.018.619 | 135 | 98,33% | 2.018.619 | 1,35% | 2.018.619 | 98,33% |
| | | 25 | 2.155.610 | 2.155.610 | 81 | 99,14% | 2.155.610 | 0,81% | 2.155.610 | 99,14% |
| | | 26 | 2.292.601 | 2.292.601 | 46 | 99,60% | 2.292.601 | 0,46% | 2.292.601 | 99,60% |
| | | 27 | 2.429.593 | 2.429.593 | 25 | 99,85% | 2.429.593 | 0,25% | 2.429.593 | 99,85% |
| | | 28 | 2.566.584 | 2.566.584 | 8 | 99,93% | 2.566.584 | 0,08% | 2.566.584 | 99,93% |
| | | 29 | 2.703.575 | 2.703.575 | 4 | 99,97% | 2.703.575 | 0,04% | 2.703.575 | 99,97% |
| | | | | More | 3 | 100,00% | 2.772.071 | 0,03% | 2.703.578 | 100,00% |

Source: Authors calculations

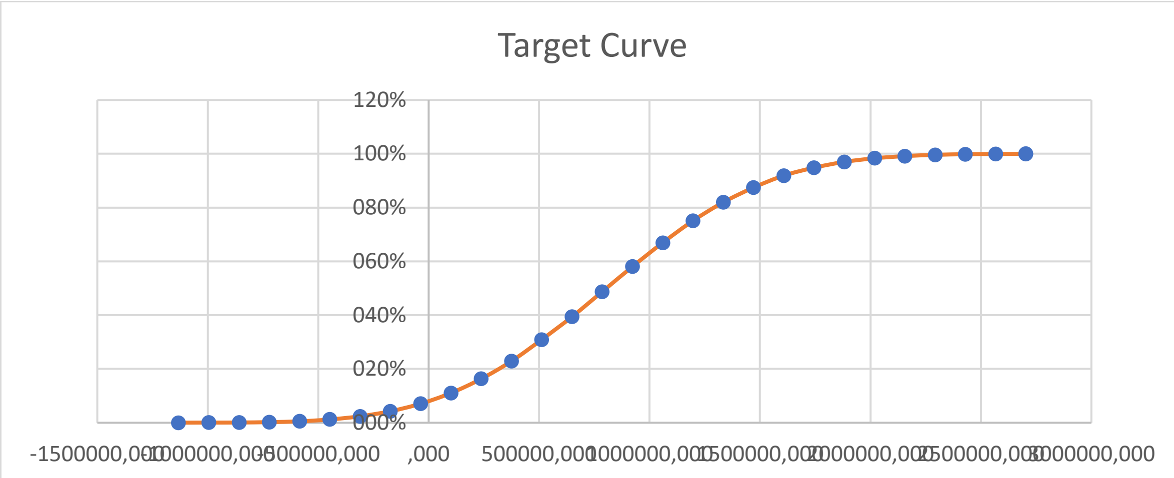
The data provided represents a frequency distribution histogram and target curve for a given data set, categorized into 30 bins. The range of values extends from -1.269.172 to 2.840.567 with each bin spanning an average of 136.991 units.

Upon initial observation, it's clear that the data follows a normal distribution pattern, as indicated by the bell shape of the frequency distribution. The frequency of values gradually increases, peaking in the middle, and then decreases, with the most frequent values located around the mid-value 922.689 (Bin 16) and 1.059.680 (Bin 17). These bins have the highest frequency of 934 and 887, respectively, contributing to 58,07% and 66,94% of cumulative percentage.

The cumulative percentage increases steadily with each bin, suggesting a steady accumulation of values throughout the data set. The bin labeled "More" represents a catch-all for any values exceeding the 30th bin (2.703.575). Here, the cumulative percentage reaches 100%, confirming all data points are accounted for.

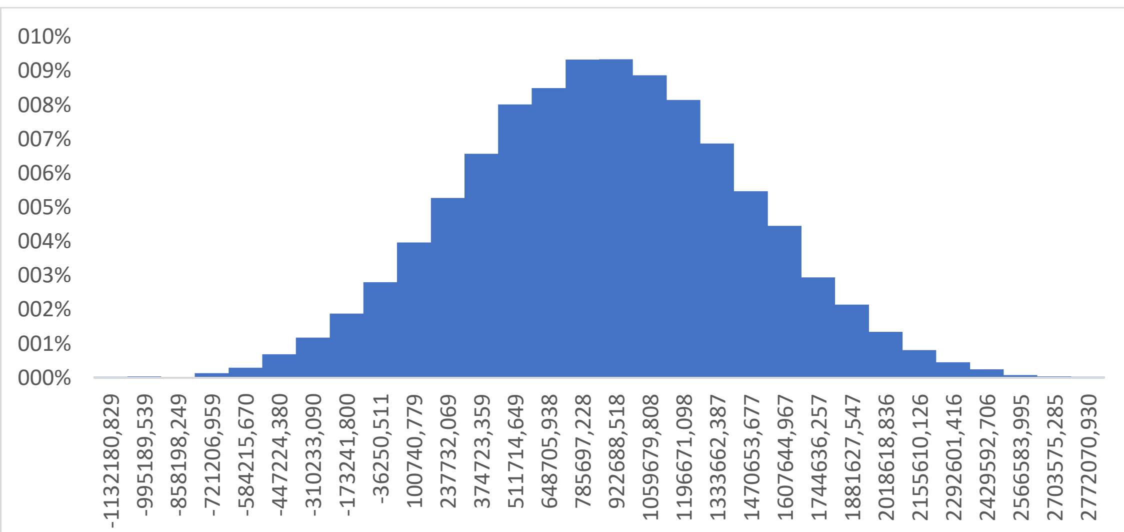
To conclude, this analysis indicates the data is distributed in a manner like a standard normal distribution, with the bulk of data points situated around the mid-point and tapering off at the extremes. The data spans a large range of over 4 million units, suggesting substantial variation in the values of the dataset.

**Figure 5.4: Target Curve**




Source: Author's calculations

**Figure 5.5: Histogram**




Source: Author's calculations

# 6 Conclusion/Real Options and reality

The rapid tempo of technological advancement imposes an obligation on corporations to maneuver through escalating levels of uncertainty, exacerbated by elements like the paucity of historical data, ferocious competition, unpredictable timelines of technological depreciation, and the prospective obsoleteness of the same. This environment often necessitates substantial capital commitment to procure a strategic edge.

In such an environment, Real Options emerge as a potent instrument within the managerial strategy repertoire. It is crucial for corporate leadership to acknowledge that investment is not synonymous with reckless speculation. Real Options are linked to capital commitments that can be prematurely discontinued at a nominal cost, and possibly diverted towards alternate sectors or sold to different enterprises.

Leadership should ideally pilot test Real Options in experimental schemes, particularly where there exists a potent intuitive conviction about the project's prospective success, notwithstanding whether this belief is supported by deliberate rationality, and even in situations where the Discounted Cash Flow (DCF) is modest.

For an exhaustive comprehension of capital allocation amidst uncertainty, peruse foundational literature such as Robert K. Dixit and Robert S. Pindyck's "Investment Under Uncertainty" (Princeton University Press, 1994) and Lenos Trigeorgis' "Real Options : Managerial Flexibility and Strategy in Resource Allocation" (MIT Press, 1996).

## 6.1 Challenges and Impact: Anticipated Problems, Practical Contributions, and Limitations of Real Options Research

Practical constraints, including ethical considerations such as accessing confidential research or hearing new ideas during presentations or informal conversations. Additionally, finding credible sources for case studies, especially in cases involving innovative products or companies that are reluctant to provide data, can be challenging. The results of forecasting models may also be highly susceptible to instability caused by global pandemics or breaking news, limiting the practical contribution and impact of our research.

However, the primary focus of our thesis is to identify gaps in research, particularly in the case study, and propose topics for future investigation and analysis. We aim to gain a better understanding of the direction of modern research in Real Options, given the importance of flexibility in this methodology. Ultimately, the limitations of our research may serve as the foundation for future studies and further exploration of this important area of research.

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