HELLENIC OPEN UNIVERSITY

School of Social Sciences

Supply Chain Management (SCM)

Postgraduate Dissertation

Decision-making under uncertainty in Technology Lifecycle Management (TLM) through the real options lens

Katsarou Eleftheria

Supervisor: GIAKOUMATOS STEFANOS

Patras, Greece, January 2024

Decision-making under uncertainty in Technology Lifecycle Management (TLM) through the real options lens

KATSAROU ELEFTHERIA

Supervising Committee

Supervisor:
GIAKOUMATOS STEFANOS

Co-Supervisor:
KAZANTZI VASILIKI

Patras, Greece, January 2024

"My family and loved ones who supported me"

Abstract

The present study delves into the realm of Technology Lifecycle Management (TLM) and its implications on decision-making under conditions of uncertainty, with a specific focus on the integration of Real Options Approach (ROA) and Net Present Value (NPV). The inquiry commences with a comprehensive examination of TLM, elucidating its essence and delineating the various stages comprising the technology life cycle. The subsequent analysis delves into the evaluation methodologies pertaining to technology investments, wherein particular emphasis is placed on the pivotal role played by Net Present Value (NPV) and Real Options.

The comprehensive analysis of the concept of net present value encompasses an in-depth examination of its definition, as well as a comprehensive exploration of its associated benefits and drawbacks. Concurrently, the study examines authentic alternatives, emphasizing technological investments as tangible prospects and providing elucidations on their advantages and disadvantages. The present study also undertakes an examination of the nuanced distinctions between financial and real options in relation to investments in technology.

The assessment of value for the client using the net present value (NPV) framework constitutes a pivotal component of this research endeavor, centering on the evaluation of projects or products, the analysis of associated risks, and the facilitation of the decision-making process. Furthermore, an examination is conducted on the perspective of the consumer regarding the concept of net present value (NPV), with due consideration given to the temporal value of money, computations of NPV, and the ramifications of non-monetary and emotional factors.

In an effort to enhance decision-making in TLM, the study progresses to the integration of NPV and ROA. Drawing from studies on the concepts and applications of ROA, the research presents a characteristic comparison with NPV. A case study is employed to illustrate the combined use of NPV and ROA in evaluating a technology investment, with a focus on results comparison.

The findings underscore the potential benefits of employing a real options lens in TLM decision-making, highlighting the synergies derived from integrating NPV and ROA. The study concludes by discussing the implications for businesses, offering real-world examples to illustrate the practical relevance of the proposed approach. Ultimately, this research contributes to the evolving landscape of decision-making in TLM, providing a nuanced perspective for navigating the uncertainties inherent in technology investments.

Keywords

Technology Lifecycle Management, Net Present Value, Real Options Approach, Decision-making, Valuation methods.

Λήψη αποφάσεων υπό αβεβαιότητα στη Διαχείριση Κύκλου Ζωής της Τεχνολογίας (TLM) υπο την οπτική των πραγματικών δικαιωμάτων

ΚΑΤΣΑΡΟΥ ΕΛΕΥΘΕΡΙΑ

Περίληψη

Η παρούσα διλωματική διερευνά τη Διαχείριση Κύκλου Ζωή της Τεχνολογίας (TLM) και τις επιπτώσεις της στη λήψη αποφάσεων υπό συνθήκες αβεβαιότητας, με ιδιαίτερη έμφαση στην ενσωμάτωση της μεθόδου των Πραγματικών Δικαιωμάτων (ROA) και της Καθαρής Παρούσας Αξίας (NPV). Η έρευνα ξεκινά με μια ολοκληρωμένη εξέταση του TLM, διευκρινίζοντας την ουσία του και σκιαγραφώντας τα διάφορα στάδια που περιλαμβάνουν τον κύκλο ζωής της τεχνολογίας. Η επακόλουθη ανάλυση εμβαθύνει στις μεθόδους αξιολόγησης που σχετίζονται με επενδύσεις τεχνολογίας, όπου δίνεται ιδιαίτερη έμφαση στον κεντρικό ρόλο που διαδραματίζουν η Καθαρή Παρούσα Αξία (NPV) και τα πραγματικά δικαιώματα.

Η ολοκληρωμένη ανάλυση της έννοιας της καθαρής παρούσας αξίας περιλαμβάνει μια σε βάθος εξέταση του ορισμού της, καθώς και μια ολοκληρωμένη διερεύνηση των σχετικών πλεονεκτημάτων και μειονεκτημάτων της. Ταυτόχρονα, σε αυτή τη διπλωματική εξετάζονται εναλλακτικές λύσεις, δίνοντας έμφαση στις τεχνολογικές επενδύσεις ως προοπτικές ανάπτυξης και παρέχοντας περαιτέρω έρευνα για τα πλεονεκτήματα και τα μειονεκτήματά τους. Η παρούσα διπλωματική εξετάζει επίσης τις διαφορές μεταξύ χρηματοοικονομικών και πραγματικών δικαιωμάτων οσον αφορά τις επενδύσεις στην τεχνολογία.

Ο υπολογισμός της αξίας για τον πελάτη χρησιμοποιώντας το πλαίσιο της καθαρής παρούσας αξίας (NPV) αποτελεί βασικό στοιχείο αυτής της ερευνητικής προσπάθειας, με επίκεντρο την αξιολόγηση έργων ή προϊόντων, την ανάλυση των σχετικών κινδύνων και τη διευκόλυνση της διαδικασίας λήψης αποφάσεων. Επιπλέον, εξετάζεται η οπτική γωνία του καταναλωτή σχετικά με την έννοια της καθαρής παρούσας αξίας (NPV), με τη δέουσα προσοχή στη χρονική αξία του χρήματος, στους υπολογισμούς του NPV και στις επιπτώσεις μη νομισματικών και συναισθηματικών παραγόντων.

Σε μια προσπάθεια ενίσχυσης της λήψης αποφάσεων στο TLM, η μελέτη προχωρά στο συνδυασμό των NPV και ROA. Αντλώντας πληροφορίες από μελέτες για τις έννοιες και τις εφαρμογές του ROA, η έρευνα παρουσιάζει μια σε βάθος σύγκριση με το NPV. Χρησιμοποιείται μια μελέτη περίπτωσης όπου συνδυάζεται η NPV και ROA στην αξιολόγηση μιας τεχνολογικής επένδυσης, με ιδιαίτερη έμφαση στη σύγκριση αποτελεσμάτων των δυο μεθόδων.

Τα ευρήματα υπογραμμίζουν τα πιθανά οφέλη από τη χρήση των πραγματικών δικαιωμάτων στη λήψη αποφάσεων TLM, τονίζοντας τις συνέργειες που προκύπτουν από το συνδυασμό των NPV και ROA. Η μελέτη ολοκληρώνεται συζητώντας τις επιπτώσεις για τις επιχειρήσεις, προσφέροντας παραδείγματα από τον πραγματικό κόσμο για να καταδειχθεί η πρακτική συνάφεια της συγκεκριμένης προσέγγισης. Τελικά, αυτή η έρευνα συμβάλλει στο εξελισσόμενο τοπίο της λήψης αποφάσεων στο TLM, παρέχοντας μια διαφοροποιημένη προοπτική για την εξερευνηση των αβεβαιότητων που υπάρχουν στις τεχνολογικές επενδύσεις..

Λέξεις – Κλειδιά

Διαχείριση Κύκλου Ζωής της Τεχνολογίας, Καθαρή Παρούσα Αξία, Προσέγγιση πραγματικών δικαιωμάτων, Λήψη Αποφάσεων, Μέθοδοι Αποτίμησης.

Table of Contents

List of Figures

List of Tables

List of Acronyms

BOT	Build-Operate-Transfer
CAPM	Capital Asset Pricing Model
CCGT	Combined Cycle Gas Turbine
DCF	Discounted Cash Flow
EV	Electric Vehicle
HVAC	Heating, Ventilation and Air Conditioning
IC	Integrated Circuit
MRG	Minimum Revenue Guarantee /Marginal Revenue Growth
MWh	Megawatt-hour
NPV	Net Present Value
P-P	Price to Performance
PPP	Public-Private Partnerships
R&D	Research and Development
ROA	Real Option Approach
WACC	Weighted Average Cost of Capital

Introduction

Organizations managing their technology lifecycles face an ever-increasing degree of uncertainty in today's quickly shifting technical ecosystem. Making confident strategic judgments is difficult due to market dynamics, unanticipated upheavals, and the unrelenting speed of innovation. Many firms are using a new perspective called the "real options lens" to improve their Technology Lifecycle Management (TLM) decision-making processes in order to traverse this complexity.

In the rapidly evolving world of technology, this lens provides a flexible and dynamic framework that enables firms to successfully manage uncertainty, take advantage of opportunities, and reduce risks. Using the real options lens, we will examine the idea of decision-making under uncertainty in TLM in this exploration, illuminating how it enables organizations to make well-informed decisions that not only maximize their technological investments but also establish them as adaptable and durable participants in the contemporary technological landscape (Tarik Driouchi & Leseure, 2005).

As we navigate the intersection of NPV and Real Options, the dissertation ventures into the implications for businesses, offering real-world examples that underscore the practical relevance of the proposed approach. The integration of NPV and ROA is showcased through studies on concepts and applications, and a characteristic comparison is drawn, providing a foundation for a case study that exemplifies the combined use of NPV and ROA.

In more detail, in chapter 1 we analyze the definition of TLM, its stages and structure. In Chapter 2, we navigate through the definition of the valuation methods of NPV and Real Options highlighting their advantages and disadvantages and how they affect decision making process. Lastly, in Chapter 3, we emphasize in studies on concepts and applications of ROA and we showcase the characteristic comparison of NPV and ROA.

1. Technology Lifecycle Management

1.1 Definition of Technology Lifecycle Management (TLM)

The Technological Life-Cycle (TLC) delineates the monetary yield of a product throughout its crucial existence, encompassing both its financial returns during its "vital life" and its commercial gains incurred during the research and development phase. A technology lifecycle management strategy encompasses a comprehensive plan that encompasses all facets of technological assets throughout their lifespan, encompassing deployment, operation, maintenance, and eventual obsolescence. As per the scholarly work of Hüseyin Doğan et al. (2009), the subject matter encompasses the entirety of technical advancement, spanning from the initial stages of strategic planning and extensive research to the eventual decline and subsequent retirement. The utilization of Technology Lifecycle Management (TLM) facilitates leaders in making optimal decisions and effectively overseeing their enduring technology investments. The amalgamation of profound technological acumen, discerning business methodologies, and proficient engineering and financial provisions within a robust business framework has facilitated agencies in proactively addressing systematic budgetary concerns and undertaking long-term administration of their IT infrastructures.

If organizations have a clear picture of how the IT infrastructure may change over the next one, three, or five years, they may match their technology acquisition strategy with a financial model that will allow them to realize the full value of their technical assets. For this reason, it is imperative that businesses understand the processes associated with each of the following TLM phases: assessment, business purpose selection, and appropriate technology utilization. purchasing technology that is suited to the requirements of the IT infrastructure, When integrated and executed by qualified engineers, Support services include system monitoring, help desk support, customized warranty and maintenance plans, Refreshing technology will guarantee timely and pertinent updates, and asset sales will follow pre-arranged conditions. Technology and product life cycles have four stages: technological awareness, growth, technological maturity, and a decline in interest (Hartwell et al., 2019).

Technology lifecycle management (TLM) is a strategic approach employed to effectively govern and administer the information technology (IT) infrastructure within an organization. This comprehensive framework encompasses the entirety of the process, commencing with the initial phases of strategic planning and meticulous research pertaining to the acquisition of a technological solution, and culminating in the subsequent stages of obsolescence and eventual decommissioning of said technology. Leaders can enhance their ability to effectively manage their long-term technology expenditures and make well-informed purchase decisions through the utilization of Technology Lifecycle Management (TLM), as proposed by Karunathilake et al. (2019). The process of Technology Lifecycle Management (TLM) can present a complex undertaking for prominent manufacturing or technology entities. Trademarks and patents may potentially be implicated, thereby enabling the utilization of an innovative methodology until such time as the remaining market aligns with the aforementioned approach. However, it is important to consider that the useful lifespan of patented technology could potentially be diminished as a result of the disclosure of confidential components (Hartwell et al., 2019).

1.2 Stages of technology life cycle

TLM consists of the strategy that deals with all aspects of the technology during its useful life, including deployment, operation, maintenance and expiration (Lodder, 2022). According to Lodder (2022), the four stages of the technology and product life cycles are the following:

- Innovation stage: As the sources of advantage for established players disappear, technological developments present opportunities for entrepreneurs to launch new ventures and generate competitive advantages. Technological innovation exposes incumbents to risk and uncertainty since its exact outcomes are unpredictable. The creation of commercial value is the aim of innovation. Value can be characterized in a number of ways, including the lowering of costs, the development of entirely new goods and services, or the slight modification of previously existing ones.
- Ascent/Growth stage: This stage encompasses the commercialization and demonstration of a novel technology, which may manifest as a product, material, or process with significant potential for immediate application. Numerous conceptual frameworks find themselves relegated to the confines of research and development laboratories. A minute proportion of these items are made available for purchase.
- Diffusion/Maturity stage: This elucidates the process by which a nascent technological advancement permeates the market, owing to the embrace of the innovation by prospective consumers. However, it is important to note that various factors pertaining to both the supply and demand aspects intricately intertwine, thereby exerting an influence on the rate at which diffusion occurs. The significance of novel technologies can be elucidated by their extensive utilization across diverse user demographics, applications, and geographical regions. The diffusion of technological

innovations among domestic and global manufacturers is an essential condition for achieving and maintaining long-term economic expansion.

- Decline/Substitution stage: This final phase serves as an indication of the gradual decline and subsequent replacement of a particular technology by another. The velocity of substitution is influenced by a multitude of technological and non-technical variables. The duration of the substitution stage is contingent upon the market's dynamics (Haupt et al., 2007).

1.3 The Nature and Structure of Technology Life Cycles

The product life cycle, widely recognized as the most abbreviated and renowned life cycle, holds paramount significance (Mousavi et al., 2022). In a broad sense, it is customary for a fundamental and all-encompassing technological framework to function as the bedrock upon which a series of subsequent iterations of products are built. A plethora of technological platforms, which are predicated upon substantial advancements in the underlying scientific domain, emerge and dissipate over protracted temporal intervals. When multiple iterations of platform cycles are amalgamated, they give rise to a phenomenon known as a "major cycle," alternatively denoted as a "grand cycle" or "wave," with a temporal extent that can encompass multiple decades. As per the scholarly work of Huenteler et al. (2016), scholars within the field of business analysis have extensively examined the intricacies of the product life cycle over a significant duration.

The findings of Huenteler et al. (2016) study elucidate a discernible pattern that emerges over the duration of a product cycle, wherein the foundational technology of the product undergoes a gradual process of standardization. Consequently, the process of standardization engenders a deceleration in the rate of change observed in specific product features. This observation implies that the reservoir of prospective novel applications that can be derived from the fundamental technological framework has reached a state of near-exhaustion.

The ultimate outcome is the emergence of a product that is progressively becoming more commoditized. The assemblage of constituents and, consequently, the characteristics of the product progressively solidify with each successive iteration. In the later stages of the life cycle of generic technology, the competition gradually moves away from significant product innovation and toward small-scale adjustments and process innovation. Price is becoming a more important factor in competition as a result of the increased focus on process efficiency (Abemathy, 1975). Over the course of a major technology's life cycle, important innovations are made based on recurring advancements in the generic technology platform that underpins them. For instance, after some product cycle experience, the drawbacks of standalone transistors linked together (speed, heat, weight) were evident. The integrated circuit (lC), a new general-purpose circuit technology, was created in response to the requirement to enhance these three characteristics. Subsequent to this occurrence, an extraordinary upsurge ensued in the realm of product cycles centered on the integrated circuit (IC), owing to the progressive advancement of this novel semiconductor platform technology, which found its way into numerous commercial applications. Moreover, there has been an emergence of parallel platforms such as "charged couple devices" commonly observed in digital cameras, as well as "quantum electronic devices" which are prevalent in semiconductor lasers and light emitting diodes. The incorporation of multiple platforms in the development of products introduces a heightened level of intricacy, and it is worth noting that the lifespan of a technological platform does not necessarily terminate upon the emergence of a successor. Given the ongoing significance of both the integrated circuit (IC) and the transistor as integral components within advanced electronic technologies, it is evident that the semiconductor technology platform has experienced sustained expansion.

This progress has been made in response to technological opportunities. The key idea is that, as complex technological systems are used to meet final-demand goods and services, every system components' performance has to improve at roughly the same rate (Taylor & Taylor, 2012).

These examples imply a number of other points. The imperative to enhance the efficacy of industrial development at the product level necessitates the widespread accessibility of generic technology. In order to facilitate the simultaneous progression of innovation and technological advancements within a system, it is imperative to ensure the accessibility of overarching platform technologies that pertain to each individual component of said system. It can be inferred that the ultimate objective is being pursued, given that the system assumes responsibility for fulfilling the ultimate requirement. The concept of "advanced manufacturing" serves as a compelling exemplification within the present context, wherein a multitude of product and process innovations are being concurrently cultivated. The issue that has been previously elucidated presents a significantly more intricate quandary for the administration of policies (Crespo, 2011).

The temporal duration of a technology platform cycle and the level of competitiveness exhibited by the domestic industry during these cycles hold particular significance for "general-purpose" technologies such as semiconductors. This is primarily due to the fact that these technologies serve as the foundation for a diverse range of innovative industries, including but not limited to computers and communications equipment, which collectively exert a substantial influence on the overall economic landscape. Hence, economies that endorse comprehensive growth strategies facilitating the acquisition of economies of scope from various technology platforms within a significant cycle are confronted with substantial opportunities. However, in order to maintain elevated long-term growth rates, it is imperative to fully grasp the constituents that give rise to the S-shaped growth curves that delineate the lifecycles of platform technologies, as well as to adeptly navigate the impediments that hinder efficient progress (Pajchrowski et al., 2014).

Although this paradigm may seem abstract at first, technology-based countries are increasingly concentrating their plans on quickening the first stages of these cycles to gain an advantage over their competitors in terms of scientific advances. The interplay among various technology-driven economies engenders a phenomenon wherein the temporal span of the life cycle is compressed, while the nadir of the growth curve assumes a steeper trajectory. Consequently, the initial phases of the cycle are curtailed, thereby accelerating the pace of innovation within the confines of the domestic economy (Pajchrowski et al., 2014).

A plethora of designations have been ascribed by researchers to delineate the various stages encompassing the life cycle of technology. The economic rationale behind the "S" shape of the life-cycle curve is of paramount significance. Due to the inherent nature of technological advancements, it is common for the development of new technologies to exhibit uneven progress in terms of the incorporation of technical features within their products and processes. As a result, the initial phase of this evolution tends to demonstrate a relatively stagnant trajectory. Joseph Schumpeter, a distinguished scholar, astutely observed and meticulously documented the occurrence of nascent technologies enduring prolonged periods of inactivity in his seminal research, which was published in the year 1950. The observation made over half a century ago draws attention to the temporal elongation evident in the initial flat section of the P-P curve. Nevertheless, it is imperative to acknowledge that there exists a pivotal juncture, commonly referred to as the initial segment of the more pronounced central region of the P-P curve. When the novel technological advancement surpasses the pinnacle ratio of the preexisting technology, it attains the tipping point and subsequently experiences rapid market penetration.

Alternatively, as Schumpeter astutely observed, a substantial alteration in relative pricing due to an economic crisis can also trigger the tipping point (Schumpeter, 1950).

Significant economic advantages, in the form of increased earnings and employment opportunities, are derived as the nascent technology gradually establishes its dominance and facilitates enhancements in both product quality and operational procedures. However, over time, the ability to increase the P-P ratio begins to decline. The upper segment of the P-P curve exhibits a relatively lower slope, thereby indicating a flatter trajectory. At this juncture, the technological infrastructure is primed for substitution.

The evolution of technological platforms is an inherent consequence of the dynamic nature of research-based advancements. The progression of solid-state physics over the course of several decades has culminated in a state of knowledge that possesses the necessary depth and breadth to facilitate the advancement of semiconductor technologies. Significant "waves" or cycles with a duration of ten years or more exhibit a conspicuous and enduring "S" shape in terms of their economic impact. In the realm of semiconductor technology, solid-state physics, the foundational discipline of this field, has attained a stage of advancement that has facilitated the design and fabrication of devices surpassing the cutting-edge achievements in electronic research, particularly those involving vacuum tubes. Joseph Schumpeter is widely regarded as the progenitor of innovation economics, with his seminal contributions revolving around the conceptualization of the "process of creative destruction." Furthermore, the individual in question has formulated an extensive theoretical framework pertaining to the manifestation of economic fluctuations, wherein he astutely observed the intricate interdependence between shorter-term cycles and their broader counterparts. Furthermore, the author expounded upon the phenomenon known as the "long wave," meticulously delineating its sequential progression into four distinct phases, namely prosperity, recession, depression, and recovery. In accordance with Schumpeter's seminal contribution in 1950, the phenomenon of creative destruction commences in a gradual manner during the initial triadic phases of invention, specifically stages two and three. However, it is not until the advent of stage four that this process truly gains momentum, leading to substantial market penetration and noteworthy innovations.

The prosperity experienced in the aftermath of World War I can be attributed to the initial advancements in manufacturing, followed by the subsequent integration of information technology on a global macroeconomic scale. Nevertheless, it is imperative to acknowledge that the global economic crisis has been influenced by the endeavors of industrialized economies to maintain their standard of living by resorting to debt. This, in turn, has led to a transformation in relative prices and has been further compounded by the growth of Asian economies, as well as other emerging economies, albeit to a lesser degree. The contemporary developed regions, namely North America, Europe, and Japan, currently reside within the transitional phase between Schumpeter's second and third stages. The burgeoning global expenditure on research and development serves as a harbinger of the nascent genesis of the ultimate phase of rejuvenation, commonly referred to as stage four. The substantial investment will yield a multitude of novel technologies aimed at enhancing productivity, thereby driving the growth of high-tech services and advanced manufacturing. The forthcoming paradigm shift shall endeavor to rectify the prevailing discrepancy between economic expansion propelled by indebtedness and expansion predicated upon tangible assets, such as technological advancements (Schumpeter, 1939).

2. Valuation Methods of Technology investments

2.1 Definitions of the methods – NPV and Real Options

2.1.1 Net Present Value (NPV)

According to Arshad (2012), the concept of net present value (NPV) entails the aggregation of all forthcoming cash flows in order to determine their present value. In the realm of financial analysis, it is customary to apply a predetermined rate of discount to both incoming and outgoing cash flows during the process of cash flow computation. The computation entails the subtraction of cash outflows, also known as investment expenses, from cash inflows. In the realm of project management, the concept of net present value (NPV) is employed to assess the viability of a project when its anticipated returns surpass its initial investment, as posited by Archer and Ghasemzadeh (1999). The determination of a project's net present value, or NPV, involves the computation of the present value of all cash flows associated with the project, encompassing both inflows and outflows. The computation can be made by discounting the cash flows at a rate that aligns with the project's level of risk. The application of computational findings to the decision-making process is of utmost importance. As per the seminal work of Myers and Majluf (1984), investments exhibiting a favorable net present value (NPV) are commonly regarded as lucrative and warrant meticulous examination, while those displaying a negative NPV are prone to financial losses and may not be deemed suitable for pursuit. In instances where the net present value (NPV) equates to zero, an alternative interpretation becomes imperative. According to the assertions made by Mackevičius and Tomaševič (2010), it is posited that the presence of such an investment endeavor is typically not observed in practical contexts owing to its inherent incapacity to yield substantial results. The investor posits that even marginal modifications to the market conditions possess the potential to engender financial losses for the enterprise. Nevertheless, given the investor's lack of interest in alternative options that could potentially yield similar outcomes, it is imperative to consider pursuing the project only after mitigating the associated risks and exhaustively exploring all other potentially lucrative alternatives (Mackevičius, 2010). In the context of a business entity faced with multiple potential projects, it is customary to employ a systematic approach to evaluate and prioritize said projects based on their respective profitability. This process entails the establishment of a hierarchical order, commencing with the project exhibiting the highest level of profitability and subsequently descending towards those with comparatively lower levels of profitability. Furthermore, it is imperative to ensure that the utmost significant endeavors are accomplished prior to the exhaustion of the entire allocated financial resources, as elucidated by AlKulaib (2016).

Initially, it is evident that the concept of the time value of money is integrated within the framework of the net present value (NPV) methodology, as elucidated by Gallo (2014). The present valuation of the currency surpasses its anticipated future value. When corporations and stakeholders disregard the rate and exclusively focus on the present value, they expose themselves to the peril of overestimating forthcoming outcomes and incurring financial setbacks. The meticulous assessment of the temporal value of money is a fundamental element of the capital budgeting procedure. Secondly, as Levine (2005) astutely observes, it is imperative to incorporate the expenditures and advantages that transcend the project manager's initially envisaged timeframe for completion. The proclivity of project managers to accord higher priority to phases within their immediate purview, often to the detriment of subsequent phases, constitutes a significant apprehension within the domain of project management. According to Levine (2005), the utilization of the Net Present Value (NPV) methodology serves to mitigate this inherent risk and necessitates a comprehensive assessment of all relevant project outcomes. In addition, it is worth noting that the net present values (NPVs) of each discrete project can be aggregated to ascertain the collective net present value (NPV) of a portfolio of projects, as elucidated by Hopkinson's (2016) scholarly investigation. In a more concise manner, each estimation conforms to a standardized scale predicated upon the prevailing monetary worth. The aforementioned portfolio management tool possesses inherent value as it facilitates equitable comparisons between investors and/or projects, irrespective of their temporal or monetary cash flow arrangements (Hopkinson, 2016).

Moreover, it offers a foundational framework for the seamless amalgamation of numerous endeavors. The computation of the net present value (NPV) resulting from the amalgamation of two distinct projects, A and B, entails the summation of their respective NPVs. Thus, the methodology for assembling these constituents and subsequently conducting a comparative investigation is straightforward. In this case, it is deemed disadvantageous to engage in portfolio investment if the aggregate net present value (NPV) falls below that of the project's NPV. Moreover, as posited by Mackevičius and Tomaševič (2010), this particular attribute facilitates the comparative analysis of multiple alternatives within the confines of a given undertaking. The singular availability of a combination for an investor to select implies a high likelihood of the options being mutually exclusive. To ascertain the optimal combination among the available possibilities, it is imperative to undertake a comprehensive examination of the costs and benefits associated with each combination, employing the Net Present Value (NPV) methodology. Moreover, it is imperative to bear in mind that the Net Present Value (NPV) methodology can prove to be advantageous in scenarios where the rate of return fluctuates throughout the duration of a project, as suggested by Magni (2010). The NPV method offers a heightened level of precision as it possesses the capability to uniformly and automatically apply a singular rate, namely the cost of capital, to all investment proposals. Given the premise that incoming funds are reinvested at a rate equivalent to the market's cost of capital, an argument can be made in favor of the net present value (NPV) methodology as a more justifiable assumption, as supported by the research conducted by Magni in 2010. Moreover, the utilization of the Net Present Value (NPV) methodology serves as a valuable tool in fostering effective project management practices. According to Wetekamp (2011), it is imperative for project managers to duly consider any unanticipated alterations to the project timeline.

Moreover, it is imperative to take into account each of these constituent factors when evaluating the project's financial viability. The utilization of the net present value (NPV) approach within the realm of corporate governance enables the efficacious and fruitful administration of projects. The aforementioned statement posits that the utilization of said stimulant could potentially serve as a catalyst for project managers, prompting them to ground their assumptions in pragmatic scenarios. Furthermore, it functions as a jarring reminder that neither projects nor organizations can bear the burden of failure without dire consequences (Wetekamp, 2011). Hence, in order to attain comprehensive success, project managers must endeavor to produce precise estimations and execute a suitable strategy for risk management.

The formula for calculating NPV is as follows:

$$NPV = \sum_{t=1}^{n} \frac{ACF_t}{(1+k)^t} - IO$$

Where:

- ACF is the Cash inflow and represents the expected cash received in each period.
- k is the discount rate, reflecting the opportunity cost of capital.
- t is the time period in which the cash flow occurs.
- IO is the initial outlay of cash (investment amount)
- n is project's/product's expected life

Source: Zhe Lu et al. 2006

The initial investment is the sum of money needed to start a specific enterprise or make an investment. Understanding this specific formula is critical because it makes it easier to assess if an investment provides a positive or negative return for the investor. A positive net present value (NPV) indicates that an investment has the potential to be profitable; on the other hand; a negative NPV suggests that the venture might not be viable.

2.1.2 Disadvantages of NPV

First off, there are a lot of estimates in the NPV technique. The NPV expression involves a number of processes, such as selecting an appropriate rate to use in the discounting process and determining all of the additional cash flows that arise from the project's start to finish, both "riskless" and risky (AlKulaib, et. al, 2016). It takes a lot of effort and time to estimate each of the formula's figures, and the most crucial one is quite unknown. Juhász (2011) highlights that the results of a decision made solely on the basis of the absolute value of net present value (NPV) can vary depending on the specific parameters of the interest rate used in the calculations.

Furthermore, the cultivation of critical thinking skills serves as a means to attain the aforementioned fifth advantage. The forecast could potentially exhibit a high degree of optimism. Given the imperative of engaging with the corporate finance team to deliberate upon the project's business backdrop, it is not uncommon for managers to harbor inflated expectations regarding the project's prospective triumph. Consequently, it is plausible that the examined cash flows may exhibit an excessive magnitude. Due to the substantial quantity of assumptions, it is plausible that this particular technique may exhibit a tendency towards an upward bias in its underlying assumptions.

Thirdly, Hui (2015) posits that the NPV criterion fails to account for potential project enhancements over time and the acquisition of new information, as it relies solely on the data available at the time of decision-making. The interrelation between the marketability, price, and technological history of the present product can be established by examining pertinent data such as cash flows and cost of capital. In relation to the practical implementation, the enhancement of the firm's value can be achieved through the implementation of initiatives that possess the flexibility and cost-effectiveness to be readily adapted in response to notable alterations in the aforementioned aspects. Contrary to the assertions made by Hui (2015), the conclusions derived from the analysis of Net Present Value (NPV) do not align with such claims.

It is imperative to bear in mind that when conducting a comparative analysis of projects that exhibit variations in scale, the utilization of the Net Present Value (NPV) metric may prove inadequate within the framework of project evaluation. The significance of perceiving the Net Present Value (NPV) as an absolute aggregate, as opposed to a percentage, is underscored by Le (2021). According to Yescombe (2007), the heightened net present value can be attributed solely to the greater magnitude of the initial investment. Primarily due to its superior internal rate of return, Investment A exhibits a more favorable performance in comparison to Investment B. In contrast to the returns generated by Investment A, the additional allocation of $1000 towards Investment B yields a significantly diminished rate of return.

2.1.3. Real Options

The initial proponents of applying option valuation techniques to investment decision-making were economists McDonald and Siegel (1985) and Brennan and Schwarts (1985). Myers (1977) coined the phrase "real options" and proffered the notion of regarding investment opportunities as growth options in a preceding period. Subsequent to that juncture, a substantial corpus of scholarly investigations pertaining to real options and their manifold applications within the realm of the economy has been disseminated.

Subsequently, we engage in a discourse pertaining to the realm of financial possibilities, diligently endeavoring to ascertain a comprehensive understanding of the essence and characteristics of authentic options. The bedrock of real options is constituted by the various financial alternatives available. The two predominant types of financial options are call and put options (Alcaraz García & Heikkilä, 2003). A call option confers upon the purchaser the privilege, albeit not the compulsion, to acquire an asset, such as shares, at a predetermined price during a specified timeframe. The counterparty is obligated to furnish the asset in return for the predetermined amount, referred to as the exercise price, upon the option holder's exercise of the option. It is an indisputable fact that the possessor ought to engage in physical exertion in the event that the value of the stock surpasses the predetermined exercise price at the time of maturity. Conversely, the possessor of a put option possesses the right to vend the underlying asset at a prearranged time and price. The individual assuming the role of the holder will exhibit the aforementioned behavior in the event that the exercise price of the put option surpasses the price of the underlying shares upon reaching maturity, as elucidated by Trigeorgis in 1993.

A distinction exists between the choices available within the American and European contexts. The distinction lies in the fact that European options possess the capacity for exercise solely at the precise moment of their expiration, whereas American options exhibit the ability to be exercised at any point leading up to the designated maturity date.

The concept of genuine options bears a striking resemblance to that of financial options in the context of decision-making in the realm of practical existence. Analogous to a strategic alternative, a real option refers to the capability to execute a specific task pertaining to business endeavors. In a judicious determination.The exercise price of an option refers to the monetary value that must be invested in order to initiate the requisite transaction, whereas the maturity term denotes the temporal duration within which the opportunity ceases to be valid. While a financial option incorporates the prevailing stock price and the inherent uncertainty in stock valuation within its computations, a real option, on the other hand, takes into account the present value of projected cash flows and the uncertainty associated with the underlying project. The act of engaging in financial options trading is commonly linked with the presence of minimal transaction costs. According to Villar (2003), it is commonly observed that real options are not commonly exchanged in financial markets.

Real options are highly appealing to corporate management due to their inherent ability to offer flexibility and aid in effectively navigating through the complexities of uncertain future scenarios. Various types of possibilities can be discerned from each other. According to Poerink Willem, 2013, the various options currently being deliberated can be categorized into three overarching groups: those pertaining to the magnitude of the project, those related to its timeline, and those associated with its implementation.

- Options to expand or contract

When the success of the project is uncertain, flexibility in the facility's size may be beneficial. When demand proves to be strong and acts as a call option, the company can exercise the option to increase production. This is why it is desirable to have an option to expand. For example, a business could construct more capacity than it anticipates needing, enabling it to quickly ramp up production in the event that demand increases. Because of the establishment costs, a project with this option to grow will initially cost more than one without, but when the benefits that would occur later on are taken into account, the investment will be worthwhile.

It is also feasible for the alternative to occur: a contraction. If the market doesn't develop as expected, the business can scale back its operations. If the need arises, it can reduce its output. There are, of course, initiatives that employ the opposite strategy, allowing for the dynamic switching between high and poor operational productivity (McDonald and Siegel, 1985).

- Option to defer

Due to the presence of this temporal opening, the managerial body possesses the ability to defer the execution of operational initiatives as opposed to promptly engaging in a financial commitment. Through the implementation of this particular strategic approach, organizational management possesses the ability to diligently monitor prevailing market conditions, thereby enabling them to make judicious and informed determinations regarding the potential exercise of the company's call option. The decision to postpone can be interpreted as a call option to acquire a coveted property or a prospective asset; it would be rational to exercise this option if the market valuation of the output that necessitates provision rises and the organization is capable of deriving financial gains from said property or resource (Tourinho, 1979).

- Option to abandon

Like its predecessor, this particular option relates to the project's timeline and duration. In this particular case, the management is free to end a project at any time and move forward with selling the related assets without having to fulfill any obligations to do so. There may be an attraction to a project if its liquidation value is greater than the present value of its remaining cash flows. The variant under consideration exhibits characteristics akin to a put option, whereby the exercise price is equivalent to the salvage value (Myers, and Majd, 1990).

- Option to temporarily shut down

The forerunners in the subject of real options, McDonald and Siegel (1985) and Brennan and Schwartz (1985), also examined this option. This option allows one to resume operations at a faster pace when opportunities present themselves after momentarily stopping or reducing them when they don't seem to be producing the desired results. Brennan and Schwartz (1985) gave the example of a gold mining company, showing that it makes sense to temporarily halt operations when the commodity's fluctuating spot price approaches the cost of extraction.

- Proprietary or shared

Shared options are those that are proprietary to multiple parties concurrently, as opposed to only one party. A proprietary option, on the other hand, refers to an investment opportunity with extremely high barriers to entry or a purchased license for a research and development investment. As an example, a shared real option could be the chance to introduce a new product or enter a new geographic market without being protected by the entry of close substitutes.

- Compound options

All of the aforementioned options can exist as simple options, which implies they can exist as options unto themselves. On the other hand, options can also result from other choices; a first investment is required to finance a subsequent investment. A so-called compound option arises from an ongoing project that requires capital contributions over two stages. Each sequential action is perceived as a prospective allocation of resources for subsequent phases. The contemplation pertains to an R&D endeavor aimed at developing a novel pharmaceutical product, wherein the preliminary expenditures associated with research and development may be perceived as a form of remuneration for the potential opportunity to engage in subsequent investments should favorable outcomes be achieved. In this context, the decision to allocate resources towards a pharmaceutical endeavor is contingent upon the projected financial returns expected to be generated during subsequent stages. In this sense, compound options are links in a network of related initiatives rather than standalone options. The latter requires the former as a requirement. There is a distinction between parallel and sequential alternatives. Sequential options are those that should be executed in order to create another option. Parallel refers to the possibility of options existing side by side yet still gaining value from one another.

This point of view offers a compelling framework for the strategy of a company. The buy-and-build strategy is a widely favored technique that is based on the aforementioned decision structure. This platform engenders a viable framework that can be utilized to procure financial resources for the purpose of facilitating subsequent investments in supplementary stadiums. The platform acquisition can be conceptualized as an underlying call option, wherein it presents a series of subsequent opportunities. The inaugural commencement of a diminutive enterprise may be conceptualized as a foundational structure, and the subsequent multifaceted decision entails expanding into a novel market. The act of maturing on the platform can be regarded as an inherent decision, as suggested by Trigeorgis (1993).

As previously articulated by Bowman and Hurry in 1993, it is imperative for a firm's strategy to incorporate genuine alternatives that manifest through a series of path-dependent activities. The aforementioned claim was substantiated through empirical evidence presented by Quig (1993), wherein it was posited that the inclusion of compound options could account for the observed market prices that surpassed the implied values derived from the traditional model. In contrast to conventional intuition, the real option framework has the potential to offer enhanced elucidation regarding the prospective strategic worth of an acquisition, given its existence.

2.1.4. Advantages of Real Options

Over time, there have been supporters and opponents of genuine option analysis. Flexibility already has an advantage: the ROV (Real Options Valuation) forces the decision-maker to consider the importance of management's flexibility. The fact that ROV fills in the gaps left by NPV is yet another important advantage of ROV. One major flaw with NPV is that because it ignores possibilities for expansion, it can turn away excellent enterprises. The application of ROV provides a safeguard against early termination because it includes a wide range of options in its pricing structure. Joseph (2007) made a public counterargument to this claim, stating that the ROV is not a factor in this discrepancy. It is easy to see how to decide when to stop or continue with real engineering tasks. Even when there is a great deal of uncertainty in the sector, projects with questionable marginal value shouldn't be pursued. At now, real option premiums are only able to provide value and influence decisions in situations where the net present value (NPV) is zero or below. Because there are real option premiums in this case, it is significant that the project's value will in fact exceed zero. It is crucial to recognize that the project will not, unless there are real options with absurdly high option prices, reach a decisive marginal value. Since sincere engineering project managers steer clear of side projects, true options are irrelevant in these kinds of situations (Joseph, 2007).

2.1.5. Disadvantages of Real Options

The primary weaknesses of ROV that are emphasized by its adversaries are enumerated as follows. Initially, it is imperative to acknowledge that the existing framework exhibits certain limitations in its ability to comprehensively address the diverse array of investment decisions. As per the scholarly work of Adner and Levinthal (2004), the utilization of the real options framework in the context of path-dependent activities is deemed suitable primarily for investments that are well-defined, such as foreign production facilities and innovation licenses. However, its applicability becomes less favorable when dealing with less predictable opportunities, such as high-technological markets, due to the inherent challenges associated with its implementation.

Furthermore, the implementation of the mathematically ROV technique may present challenges. Knaus and Murphy (2008), for instance, have expressed concerns regarding individuals' aptitude to effectively employ the real option approach in complex real-world scenarios. Because they can't even put it into practice in a straightforward, controlled, delineated, and incentive-filled environment. Borison (2005) showed that implementation can be challenging by presenting several approaches to use the ROV and pointing out that the results vary greatly depending on the method selected. He demonstrated how the estimated project values from the various employed approaches vary significantly. Managers use genuine option thinking, but they don't always get the specifics right. The aforementioned perspective was substantiated through empirical evidence by Howell and Jägle (1997), wherein they presented findings indicating that managers with greater age and experience tend to overestimate the presence of authentic options in comparison to their younger and less experienced counterparts. In light of the unfavorable assessments, Miller and Shapira (2004) posited that numerous managers are presently employing the ROV or a derivative thereof, albeit unknowingly or without explicitly acknowledging it as the "real option technique." In relation to the aforementioned assertion, Yavas and Sirmans (2005) conducted an empirical investigation wherein they presented participants with a tangible scenario involving a clear-cut choice dilemma. It has been determined that the investors in question prematurely executed their investment strategies, thereby neglecting to accurately ascertain the genuine value of the underlying option. In conclusion, it can be posited that leveraging the recommended behavior derived from the ROV framework may yield advantageous outcomes in terms of profit optimization, particularly when individuals' inherent behavioral tendencies diverge from the aforementioned ROV-prescribed conduct.

2.2. Technology investments as real options

Numerous investments in the realm of technology exhibit the characteristics associated with options. The inherent presence of real options within a technology investment holds significant value, as it empowers management to engage in logical and value-enhancing endeavors that possess the potential to positively influence the operational characteristics of said investment, particularly in relation to timing, scale, and scope. In order for options to possess value, it is imperative that they are meticulously strategized and tailored to suit each investment in accordance with its unique and ever-changing circumstances (Benaroch, 2002).

An exemplification of this concept can be observed in the case of investments made in data warehouses, wherein value is gradually generated by virtue of the enhanced capacity to expeditiously develop novel applications. In a similar vein, the implementation of an open architecture facilitates the expansion of sourcing alternatives. An initial step in implementing the real options approach involves delineating the categories of options commonly encountered in technology investments. This enables decision-makers to promptly comprehend the magnitude and comparative significance of the diverse options at hand. The team responsible for implementation can subsequently ascertain the extent of comprehensive analysis necessary to thoroughly explicate the suggested alternatives (Steffens & Douglas, 2007).

Illustrative examples from the realm of information technology and high-tech sectors are presented. Typically, business enterprises allocate their investments towards two distinct categories of technological alternatives: growth options, also known as strategic options, and operating flexibility options, also referred to as operating options.

The growth options entail the strategic alignment of technology investment scale with the pace of business expansion. Let us contemplate a hypothetical enterprise whose overarching corporate strategy necessitates a proactive and assertive pursuit of market expansion initiatives across diverse regions within the Asian continent. From the perspective of IT investment, a triumphant expansion will yield a substantial augmentation in the volume of transactions traversing the supply chain management system. Nevertheless, there exists a degree of ambiguity surrounding the precise timing and magnitude of market triumph (Lee, 2011). In this particular scenario, the utilization of a real options analysis would serve as a valuable tool for decision-makers to meticulously contemplate the optimal timing for the expansion of IT capacity. The attainment of this objective is accomplished through the establishment of a connection between the worth of information technology investments and the various potential consequences for business operations. Additionally, it involves the identification of pivotal business factors that serve as indicators for determining the appropriate timing for initiating the subsequent phase of growth. The aforementioned growth options typically arise from investments that are directed towards the development of fundamental technologies and/or the acquisition of expertise in promising technologies that have the potential to serve as catalysts for future organizational capabilities (Smit & Trigeorgis, 2007).

Flexibility options encompass a range of operational strategies that are frequently observed in technology investments, resulting in tangible and quantifiable returns. Nevertheless, it is imperative to meticulously strategize and tailor these operational alternatives in accordance with the unique characteristics and requirements of each investment. The operational strategy of flexibility enables an organization to efficiently and expeditiously adapt its product features or service offerings in response to dynamic market conditions. Investment in flexible manufacturing systems exemplifies a paradigmatic instance wherein it engenders opportunities for product and production flexibility, thereby facilitating the alteration of product mix and production throughput at subsequent junctures (Smit et al., 2004).

Within the realm of the utility sector, when an electricity generating entity embarks upon the endeavor of investing in a novel power plant, a pivotal decision must be made regarding the selection of plant designs, specifically between those that solely utilize oil as a fuel source or those that incorporate both oil and coal in their operational framework. The option of a dual-fuel plant provides the advantageous capability to seamlessly transition between different fuel sources in response to favorable fluctuations in fuel prices. Within the realm of information technology, novel software development tools have emerged, facilitating the widespread customization of both information and services pertaining to the e-commerce domain. The act of investing in these software packages entails the procurement of an option that facilitates the potential for expeditious and efficient development of novel enterprises, made possible by the utilization of this innovative software platform. The presence of operational options is not an inherent characteristic of technology investments per se; rather, it necessitates meticulous planning and tailored design to align with the unique attributes of each investment (Huisman, 2013).

2.2.1. Investments embedded with options: case examples

The achievement of business development can be attributed to either the impetus of technological advancements or the identification of lucrative market opportunities. The elucidation of the illustrative nature of adopting a real options mindset in the context of entering an emerging market with potential for upside gains highlights the significance of managerial flexibility.

Illustrative of a scenario involving market entry into the Chinese markets, the adoption of a real option mindset is exemplified. The real option perspective holds significant relevance and inherent value when contemplating market entry into the vast and expansive Chinese market. Foreign enterprises, whether they are entirely owned by foreign entities or engage in equity joint ventures, have the capacity and indeed demonstrate profitability through their investments in the Chinese market. This success can be attributed to their ability to recognize and embrace the significance of managerial adaptability, as well as their aptitude for swiftly assimilating valuable insights. In the realm of business competition, it is noteworthy to acknowledge that forward-thinking rivals possess the capacity to exert considerable sway in the formulation of regulatory frameworks and the cultivation of novel prospects within nascent markets. The subsequent insights gleaned align with the tenets of the real options mindset, which emphasizes the significance of managerial adaptability in swiftly responding to evolving market dynamics and consumer demands. Additionally, it underscores the value of leveraging shifting market conditions to implement astute strategies through a sequence of prudent and calculated actions aimed at enhancing profitability (Yan, 1998).

The Volkswagen case: Following the establishment of its assembly plants in Shanghai, China, Volkswagen promptly adapted its assumptions and operating paradigms, ultimately attaining success in a burgeoning offshore market. Volkswagen has implemented a scalable growth strategy. The primary objective at the outset was to prioritize the commercial sector, with a strong emphasis on establishing a robust distribution network and a proactive sales team. The establishment of this growth platform facilitated the amplification of volume through its network of distributors, ultimately attaining a state of critical mass (Yeo & Qiu, 2003). Subsequently, the entity proceeded to exercise an operational option in order to effectively address the escalating need for taxi services. This was achieved through the astute utilization of the burgeoning taxi fleet market, wherein the entity capitalized on the opportunity to vend its domestically manufactured automobiles to various taxi enterprises situated in Shanghai. The company achieved economies of scale and subsequently reduced prices. Conversely, Peugeot, despite being an early participant in the burgeoning Chinese market, exhibited inflexibility in its market strategy, resulting in financial losses. Sustainable long-term positions are inherently constructed through a sequence of efficacious short-term maneuvers by strategically deploying a range of options, particularly in the context of a volatile and dynamic market. The initiation of a virtual cycle for achieving success can be catalyzed by a sequence of incremental accomplishments facilitated by tangible opportunities (Funk, 2003).

2.3. Real options versus financial options

The concept of real options within the framework of option thinking is predicated upon the fundamental principles that underlie financial options. To possess a genuine option entails the capacity to deliberate over a given duration and make a decision in favor of or in opposition to a particular matter, without imposing any prior commitments upon one self. Real options possess inherent value due to their ability to encompass flexibility and latent potentials. Nevertheless, it is important to acknowledge that while real options bear resemblance to financial options, it is imperative to recognize that they are not identical in nature. The primary distinction between financial options, such as stock options, and real options lies in the fact that real options pertain exclusively to tangible assets. A genuine asset is commonly characterized by its tangibility, exemplified by entities such as factories, machinery, and the like. Conversely, a financial asset typically encompasses intangible entities such as stocks, bonds, currency, and similar instruments (Kumar, 1997).In the realm of real investment, certain financial options solutions possess potential utility when appropriately adapted through the lens of financial analogies. The yield derived from an investment, akin to the yield obtained from a stock, encompasses both the appreciation of capital and the distribution of dividends. Over the course of an extended period, the anticipated rate of return derived from a tangible investment is equivalent to the aggregate of the projected growth rate and the convenience yield associated with the fundamental commodity. Nevertheless, it is imperative to acknowledge that the direct transposition of the financial options theory onto the realm of real options is not a straightforward endeavor, primarily due to the presence of significant disparities in the fundamental perspectives embraced by these two domains (Kumar, 1997).

Initially, it is important to note that financial options generally exhibit a transient nature, with a lifespan of less than one year until their expiration. Conversely, tangible selections often exhibit an extended duration of existence and lack a predetermined termination point. Furthermore, it is imperative to bear in mind that financial options exhibit a profound interdependence with the underlying securities, which are actively traded across diverse marketplaces. It is imperative to bear in mind that assets encompassed within trade procedures cannot feasibly be assigned a negative valuation. It is imperative to bear in mind that the underlying asset under consideration within the realm of real options may assume the form of a notional asset, thereby signifying its lack of active trading. Therefore, it is crucial to acknowledge that the absence of trading activity does not impose any limitations on the probability of the asset's price exhibiting a negative value. The absence of an ascertainable market price for the underlying asset in real options is commonly elucidated by the fundamental premise that real options do not derive from publicly traded assets.

Thirdly, it is worth noting that financial options tend to exhibit a certain degree of simplicity, as they typically entail a singular option with a solitary exercise price. Nevertheless, it is imperative to acknowledge that the exercise price of real options exhibits temporal variability and, in some instances, may even manifest as a stochastic process. It is not uncommon for there to exist multiple distinct alternatives associated with a given underlying asset on a regular basis. As an illustration, the engagement in research and development (R&D) engenders the potentiality to embrace a technology whose benefits remain uncertain. In the event that research and development proves to be fruitful, a subsequent opportunity arises to broaden the scope of the product line. As the product undergoes obsolescence, one may consider the possibility of abandonment. The inclusion of the value associated with the subsequent expansion and abandonment of options is a key component of the research and development (R&D) option, as highlighted by Kulatilaka and Perotti in their seminal work in 1998.

The influence of the market position of the company holding the option extends to both the option value and the optimal time to exercise. In the event of imperfect competition, it may be deemed optimal to expeditiously exercise options in order to proactively anticipate competitive reactions and fully capitalize on forthcoming growth prospects. When the strategic advantage is robust, heightened uncertainty serves as a catalyst for fostering investment in growth options. In practical application, strategic deliberations may necessitate an initial allocation of resources, even as a delay in doing so would mitigate overall project risk. Consequently, the optimal decision must effectively reconcile these two factors(Dixit, 1992).

2.4. Determining the value for the customer NPV

In the world of personal finance and consumer decision-making, Net Present Value (NPV) plays a crucial role in helping customers evaluate and determine the value of various products, projects, and investments.

2.4.1. Project or Product Evaluation

When confronted with the task of allocating their funds towards a project or product purchase, consumers often express a desire to evaluate the prospective long-term financial advantages and disadvantages associated with such a decision. Through the utilization of quantitative analysis, specifically by computing the present value of the anticipated cash inflows and outflows linked to each alternative, the Net Present Value (NPV) emerges as an invaluable instrument that facilitates individuals in making informed and rational choices. For illustrative purposes, let us contemplate a prospective consumer who is contemplating the acquisition of an automobile. By employing the Net Present Value (NPV) methodology, one can effectively incorporate not only the initial expenditure associated with the acquisition of the automobile but also the anticipated forthcoming cash inflows. These prospective forthcoming financial streams may encompass (Ryals, 2008):

- Fuel Savings: The Net Present Value (NPV) methodology enables customers to quantitatively assess the potential cost savings associated with fuel expenditures throughout the entire lifespan of the vehicle. One may consider incorporating projected fuel costs, their approximated distance traveled, and the vehicular fuel efficiency into their analysis.

- Maintenance Costs: Customers can also use NPV to evaluate the expected maintenance costs of the vehicle, such as regular servicing and repairs. These costs can be projected over time, considering factors like the age of the vehicle and its maintenance history.

- Resale Value: An extra component in determining the net present value (NPV) of the vehicle is the expected residual value at the end of its useful life. Consumers are able to calculate this value by considering a variety of factors, such as the specific make and model of the car, its current condition, and the prevailing trends in the market.

Through the integration of these components into a Net Present Value (NPV) analysis, the buyer is able to assess the comprehensive financial consequences linked to the acquisition of the car, including not only the original purchase price but also the projected savings and expenses over the car's whole life. When deciding how much the purchase is worth investing over an extended period of time, the thorough analysis helps people make well-informed selections (Keat, & Young, 2006).

2.4.2. Risk Assessment

The evaluation of risk is an imperative facet in the determination of customer value. Customers express a desire to comprehend the intricate relationship between external factors, namely fluctuations in interest rates, inflationary pressures, and market dynamics, and the consequential effects on the valuation of their investments or acquisitions. The Net Present Value (NPV) idea offers a flexible framework that makes assessing and analyzing risk variables easier. Consumers can evaluate how responsive their investments or purchases are to various risk variables by using the Net Present Value (NPV) metric. When it comes to risk assessment, using Net Present Value (NPV) is a very useful method. As a financial statistic, net present value (NPV) helps assess a project's or investment's potential profitability by taking the time value of money into account. NPV makes the following possible by discounting future cash flows to their present value (Pfeifer et al., 2005):

- Varying Discount Rates: Customers are able to adjust the discount rate that is used in their net present value (NPV) calculation to take different levels of risk into consideration. Customers can see how the net present value (NPV) changes under different conditions by using high discount rates to represent scenarios with higher risk and low discount rates for scenarios with lower risk.
- Scenario Analysis: Using NPV computations under various assumptions, customers can participate in scenario analysis. With this specific approach, clients can explore a wide range of possible outcomes and understand how different risk factors could impact the decision's total worth.

When a consumer is thinking about making a long-term investment in the stock market, Net Present Value (NPV) becomes an important instrument for evaluating the potential returns. To do this, the discount rate is adjusted to account for the varying levels of market volatility. This makes it possible for people to evaluate the possible effects of market swings on the value of their investment and decide how much risk they are ready to take on (Ryals, 2008)

2.4.3. Decision-Making Process

The net present value (NPV) is an invaluable instrument that aids individuals in the intricate process of decision-making. When faced with a multitude of investment or purchase alternatives, customers frequently find themselves in the position of having to engage in a process of comparative analysis and evaluation in order to ascertain which option presents the most advantageous value proposition in terms of monetary considerations. Utilizing the Net Present Value (NPV) methodology, customers are able to engage in a series of sequential steps within their decision-making process (Stahl et al., 2003):

- Identify Alternatives: Customers begin by identifying the various alternatives available to them. These alternatives could include different investment opportunities, products, or services.

- Calculate NPVs: Customers engage in the process of computing the net present value (NPV) for each available alternative, wherein they duly consider the present value of anticipated cash inflows, the initial investment outlay, and any pertinent risk elements.

- Comparison: Customers engage in the comparative analysis of net present values (NPVs) pertaining to various alternatives. Through a comprehensive analysis of these values, one can effectively evaluate and ascertain which option is poised to yield the most advantageous financial outcome.

- Informed Decision: Equipped with the NPV analysis, individuals are empowered to make judicious choices predicated upon their fiscal objectives, proclivity for risk, and personal inclinations.

Consider, by way of illustration, a hypothetical scenario in which a prospective consumer seeks to procure a novel heating, ventilation, and air conditioning (HVAC) apparatus for their residential dwelling. The individual in question has procured quotations from multiple vendors, each presenting divergent figures pertaining to equipment expenditures, levels of energy efficiency, and projected energy conservation. Through the process of computing the net present value (NPV) for each alternative, the consumer can ascertain the HVAC system that exhibits the highest degree of cost efficiency throughout its anticipated lifespan, taking into accounts both the initial investment and the prospective long-term energy conservation. This aids individuals in formulating a judicious determination that is congruent with their financial constraints and aspirations for energy conservation (Stahl et al., 2003).

A versatile and essential tool used by shrewd people to evaluate the inherent value of different projects, goods, and financial businesses is the net present value (NPV). The application of this particular methodology makes it easier to evaluate projects and goods by quantifying the discounted cash flows over a predefined time horizon that include both expenses and cost reductions. When assessing risk, the Net Present Value (NPV) plays a crucial role in helping clients understand how their actions are affected by various risk variables. Additionally, it is a very helpful tool for accelerating the decision-making process by allowing users to compare and contrast different options with ease. As a result, this empowers people to make informed decisions that align with their financial goals and personal preferences. With the Net Present Value (NPV) metric integrated into their decision-making frameworks, people can enhance their financial literacy and, consequently, make more confident and strategically smart decisions (Pfeifer et al., 2005).

2.5. The Customer's Perspective on NPV

2.5.1. Time Value of Money

The comprehension of the time value of money is an essential principle that individuals must acquire in order to proficiently utilize the net present value (NPV) framework in their decision-making processes. Fundamentally, it underscores the notion that the present worth of a dollar obtained or conserved surpasses the equivalent sum in subsequent periods, owing to the influence of inflation, opportunity cost, and indeterminacy. The comprehension of this principle exerts an influence on the manner in which customers evaluate the prospective advantages and drawbacks linked to a product or investment (Naim, 2006).

When customers engage in the process of evaluating various mortgage options, they aptly acknowledge that a diminished interest rate yields reduced monthly payments, thereby alleviating their financial obligations. Through the process of comparing the net present values (NPVs) associated with different mortgage options, individuals are able to discern the profound implications of interest rates on their overall financial obligations over an extended period of time.

Customers who are in the process of planning for their retirement possess a comprehensive understanding of the paramount importance of initiating saving and investing endeavors at an early stage. It is widely recognized that individuals who invest at an earlier stage stand to benefit from the potential growth of their capital over time, owing to the phenomenon known as compounding. Through the utilization of computational techniques, individuals have the capacity to ascertain the Net Present Value (NPV) of their retirement contributions. This analytical approach enables customers to gain a profound understanding of the intricate interplay between the temporal aspect of money and its consequential impact on the growth and development of their retirement nest egg. By integrating the concept of the time value of money into their decision-making process, individuals are able to make more judicious choices that are in accordance with their financial objectives, thereby reducing the likelihood of underestimating or overestimating the future benefits and costs associated with various products and investments (Bodie et al., 2013).

2.5.2. Customer's NPV Calculations

Individual consumers have the ability to employ the Net Present Value (NPV) framework in order to assess their personal financial circumstances, thereby enabling the deliberate and well-informed decision-making process. When contemplating an investment, such as the installation of a solar panel system on one's residential property, individuals are presented with the prospect of evaluating the net present value (NPV) of said system through the utilization of a tailored analysis. This methodology operates in the subsequent fashion:

- Initial Investment: Customers start by determining the upfront cost of the solar panel system, including equipment and installation.

- Cash Flows: Cash flows are projected by customers to encompass the anticipated lifespan of the system. These cash flows comprise of the anticipated energy savings resulting from reduced electricity bills, as well as potential government incentives that may be obtained for utilizing renewable energy sources.

- Discount Rate: The onus is on customers to select an appropriate discount rate by taking into account a range of factors, including opportunity cost of capital, individual risk tolerance, and other relevant concerns.

- Calculation: People can participate in the process of calculating the net present value (NPV) of the solar panel system by using the given values in conjunction with the NPV formula. While a negative net present value (NPV) could indicate that the investment is not economically viable, a positive NPV indicates that the venture is financially reasonable (Naim, 2006).

Through the diligent application of NPV calculations, individuals are empowered to make judicious determinations regarding the viability of investing in solar panel systems. This analytical approach enables customers to holistically evaluate the potential advantages, encompassing both the environmental merits and the consequential financial ramifications. This particular approach facilitates the empowerment of customers in their ability to assess the economic feasibility of investments that are in alignment with their personal values and long-term objectives.(Marais & Saleh, 2009).

2.5.3. Emotional and Non-Monetary Factors

The Net Present Value (NPV) concept primarily centers on financial considerations. However, it is imperative to acknowledge that customers frequently take into account non-financial and emotional variables in their assessment of value. Subjective factors possess the inherent capacity to exert a substantial influence on individuals' cognitive processes involved in decision-making.

In the process of making decisions, customers often place a high degree of importance on the perceived quality and reliability of the product or service under consideration. A product or service that possesses a distinguished reputation for excellence may garner greater appeal among customers, notwithstanding a marginal increase in cost. In addition, it is imperative to acknowledge that brand loyalty and reputation wield significant influence over the decision-making processes of customers. Consumers have demonstrated a propensity to allocate additional financial resources towards the acquisition of goods and services originating from reputable brands or those that align with their personal values (Arifin & Mulyati, 2021).

Consumers exhibiting a pronounced environmental consciousness may assign significant importance to commodities or services that yield a favorable influence on the natural environment. This may encompass the utilization of environmentally conscious products or the implementation of sustainable methodologies, notwithstanding their potentially elevated upfront expenses. The level of convenience and user-friendliness exhibited by a product or service can exert a substantial influence on the decision-making process of customers. Customers may exhibit a higher propensity to allocate additional financial resources towards the attainment of convenience, which can manifest in various forms such as expedited shipping, interfaces that are intuitive and easy to navigate, or customer service that is devoid of any complications or inconveniences.

While aligning these emotional and non-monetary factors with net present value (NPV) estimates can be a challenging task, it is nevertheless necessary to arrive at comprehensive conclusions that accurately capture customer values and preferences. Clients are required to participate in an extensive evaluation that covers not just the monetary consequences of their decisions but also their emotional contentment and compatibility with their personal ideals.

When selecting between two smartphones, it is possible that a customer will exhibit a preference for the one with the larger net present value (NPV) because of its advantageous features, like lower long-term expenses and increased resale value.

Nevertheless, in the event that the alternative smartphone presents a distinctive attribute that corresponds to the customer's personal inclinations or possesses a robust brand image, the customer may exhibit a willingness to allocate a slightly higher monetary value for these intangible advantages(Bodie et al., 2013).

2.6. Implications for Businesses

Business enterprises that take into account the net present value (NPV) from the standpoint of the customer have a propensity to embrace a customer-centric orientation. This approach encompasses not solely the provision of products or services exhibiting favorable net present values (NPVs), but also the proactive facilitation of customer comprehension and computation of the NPV associated with their prospective acquisitions. The establishment of trust and loyalty among customers can be facilitated by businesses that are perceived to genuinely prioritize the financial well-being of their clientele (Brijlal, 2008).

Organizations have the capacity to employ the Net Present Value (NPV) as a fundamental framework for formulating their pricing strategies. In the realm of business, it is worth noting that companies possess the capacity to offer pricing models that emphasize the prospect of achieving cost savings over a prolonged duration when compared to their counterparts within the market. Through proficient communication, businesses can effectively convey the potential positive net present value (NPV) associated with their offerings. This enables them to captivate customers who place significant emphasis on cost considerations, consequently establishing a notable competitive edge over their rivals (Arifin & Mulyati, 2021).

Enterprises possess the capacity to adopt a proactive stance in mitigating the risk factors that are inherently associated with their respective offerings, be it products or services. This encompasses the provision of customers with comprehensive and lucid information pertaining to warranty, maintenance, and prospective future expenditures. By facilitating the evaluation and mitigation of these risks, enterprises have the potential to enhance customer satisfaction and foster a sense of trust.

Moreover, enterprises possess the capability to provide financing alternatives that are in accordance with the cash flow preferences of their clientele. As an illustration, a purveyor of automobiles may offer a financial arrangement featuring reduced monthly installments albeit accompanied by a marginally elevated aggregate expenditure, thereby enabling patrons to proficiently administer their fiscal allocations. This particular methodology has the potential to enhance the desirability of products that exhibit favorable net present values (Gallo, 2014).

2.6.1. Real-World Examples

Amidst the pursuit of a more sustainable trajectory, a considerable number of consumers are contemplating the allocation of resources towards investments in renewable energy alternatives, such as solar panels or wind turbines. The application of the Net Present Value (NPV) framework is a highly valuable tool for evaluating investments, as it enables individuals to quantitatively determine the long-term financial implications associated with these specific decisions. Within the framework of a homeowner who is engaged in a thoughtful examination of the prospective adoption of a solar panel system within their property, the application of Net Present Value (NPV) can be utilized as a method to assess the financial viability of this specific venture (Rocha et al., 2012).The initial step for the consumer entails assessing the initial investment associated with procuring and implementing solar panels, encompassing the expenses related to equipment acquisition, labor costs, and the acquisition of any requisite permits. Subsequently, the customer proceeds to assess and approximate the anticipated cash inflows and outflows throughout the envisaged duration of the system's existence. This encompasses the potential benefits of energy conservation resulting in decreased electricity expenditures, as well as the possibility of availing oneself of governmental incentives or tax credits associated with the adoption of renewable energy sources. The consumer judiciously determines an appropriate discount rate, typically contingent upon their personal risk tolerance or the opportunity cost of capital. The aforementioned rate takes into consideration the temporal worth of fiscal assets, as elucidated by Wernz et al. (2013).

The individual possesses the capability to proficiently calculate the Net Present Value (NPV) of the solar panel system by employing the provided numerical values within the NPV equation. The demonstration of an investment's financial justification is manifested through a positive net present value (NPV) when considering the inclusion of projected cost savings and incentives. Conversely, a negative net present value (NPV) may indicate a deficiency in the investment's economic feasibility.

Consumers may perceive a solar panel system as financially enticing if it exhibits a favorable net present value (NPV), indicating that the system's enduring benefits, such as reduced energy expenses and incentives, surpass the initial investment. Conversely, individuals who neglect to incorporate these aforementioned factors may perceive the investment as unduly expensive, thus disregarding noteworthy prospects for cost mitigation and environmental benefits (Wu et al., 2012).

Moreover, the contemplation of acquiring residential real estate versus opting for tenancy represents a significant fiscal choice that individuals often encounter. When facilitating individuals in the assessment of these alternatives, the Net Present Value (NPV) assumes a position of paramount significance, taking into account a plethora of financial considerations:

- Mortgage Interest Rates: Customers possess the capacity to utilize the Net Present Value (NPV) metric for the purpose of assessing the all-encompassing costs linked to homeownership, while duly considering the prevailing interest rates that are applicable to their mortgage. The decrease in interest rates has the potential to result in the achievement of more favorable net present values (NPVs), consequently making homeownership economically advantageous.

- Property Appreciation: Customers are afforded the opportunity to deliberate upon the potential appreciation in the value of their property over a specified duration. The potential impact of property appreciation on the net present value (NPV) of homeownership can be perceived as a favorable element, given its ability to generate long-term financial advantages.

- Maintenance Costs: The act of possessing a residential property requires the ongoing dedication of monetary funds in order to sustain and preserve its condition. Customers have the ability to estimate these costs and incorporate them into their net present value (NPV) calculations to assess the actual expenditure linked to home ownership.

- Tax Benefits: The act of owning a residential property is frequently accompanied by a range of tax advantages, most notably encompassing the ability to deduct mortgage interest expenses. Customers have the ability to quantitatively evaluate the impact of these tax benefits on the net present value (NPV) of their respective decisions (Board, 2015).

Through comprehensive analysis that compares the net present value (NPV) of homeownership vs renting, people may make an informed choice that suits their individual financial objectives and preferences. When homeownership's net present value (NPV) is positive, it indicates that purchasing a home is a financially favorable decision over a longer period of time. This analysis considers a wide range of variables, including the drop in mortgage interest rates, the possibility of property value growth, and the positive effects of tax benefits. On the other hand, people might choose to rent if the net present value (NPV) of doing so showed a better result, realizing the benefits of flexibility and lower upfront costs (Board, 2015).

Another example concerns the calculation of Net Present Value (NPV) in relation to the purchase of an Electric Vehicle (EV). Through active participation in this analysis, people can determine the degree to which the potential long-term savings from reduced fuel and maintenance costs, combined with government incentives, result in a positive net present value (NPV) (Slowik et al., 2019). A positive net present value (NPV) could indicate that an Electric Vehicle (EV) exhibits advantageous financial characteristics over a prolonged duration, making it a wise choice for the buyer. But it's important to note that buyers who only focus on the initial purchase price—not giving enough thought to the potential savings and incentives down the road—may fail to recognize the significant financial benefits that come with owning an electric vehicle (EV). In situations such as evaluating the long-term value of renewable energy investments, weighing the pros and cons of buying versus renting, or analyzing the financial impact of switching to electric cars, Net Present Value (NPV) provides a methodical framework for thinking through these choices. Consumers who apply the Net Present Value (NPV) concept to their decision-making process show that they are more prepared to choose options that meet both their financial goals and their personal preferences. Value optimization over a long time horizon is ensured by this method (Melicher & Norton, 2013).

3. Combining NPV and ROA

A strategic approach to financial decision-making that offers a more complete picture of the possible profitability and efficiency of an investment is the combination of Net Present Value (NPV) and Real Options Approach (ROA). Businesses use net present value (NPV) and Real Options Approach (ROA) as key financial measures to evaluate the performance and viability of initiatives.

3.1. Studies on Concepts and applications of ROA

The strategic approach to be employed in this particular scenario necessitates a comprehensive and systematic examination of the subject matter. The field of academic inquiry known as real options has been the subject of persistent and unwavering scholarly investigation since the 1980s. The revelation of the lack of strategic adaptability within the discounted cash flow (DCF) assessment was elucidated by Hayers and Garvin (1982), who concurrently advocated for the development of a novel methodology (Lee, 2011). According to Myers (1984), the discounted cash flow (DCF) technique is associated with four significant limitations. The limitations in question pertain to the DCF methodology's inherent incapacity to establish a connection between present investments and prospective future returns. Myers further expounded upon the notion of bridging the divide between corporate strategy and financial theory, drawing a parallel to the metric of Real Options Approach (ROA). The individual in question can be credited as the pioneer who established a connection between forthcoming investment alternatives and call options. Furthermore, he is renowned for introducing the term "real options" as a means to articulate the interplay between strategic decision-making and financial resourcing.

Harrison and Perdue (2006) observed the utilization of financial prognostications, such as the discounted cash flow (DCF) methodology, within the framework of the ceteris paribus assumption. Harrison and Perdue (2006) underscored the paramount importance of marketing endeavors in ascertaining the value of a project, a facet that is often overlooked within the realm of the financial industry. The researchers also conducted an analysis on the importance of marketing in assessing the investment viability of a given project.

Several scholars have proposed the notion of Real Options Approach (ROA) integrated with options in projects, which has the potential to significantly impact the feasibility of said projects. The model proposed by McDonald and Siegel (1986) elucidates the evaluation of the option to defer, specifically, the act of waiting. Trigeorgis and Mason (1993) expounded upon the advantages of employing the decision tree analysis, a bona fide option pricing model, within the realm of concrete investments. The approach proposed by Myers and Majd (1990) for the computation of abandonment value is grounded in option pricing theory, as further expounded upon by Wu et al. (2007). Dixit and Pindyck (1994) elucidated the imperative nature of employing a financial option pricing model for the purpose of investment valuations. According to Coperland and Atrikaerov (2003), binomial option pricing models are deemed more appropriate for application in the realm of corporate finance when compared to the Black-Scholes Model. The real options methodology has been employed by numerous scholars across diverse disciplines, encompassing mining, corporate real estate, research and development, manufacturing, intangible assets (Bouteiller, 2003), and technology assessment (Ashuri and Baabak, 2010).

3.2. Studies on ROA Approach for Valuing Infrastructure Investment

Within the realm of infrastructure, scholars have proposed the utilization of Real Options Approach (ROA) as a viable alternative to the traditional Net Present Value (NPV) methodology for evaluating infrastructure investments. This novel approach involves the application of either the binomial model or the Black-Scholes model. In the study conducted by Rose (1998), a comprehensive examination and evaluation were undertaken to assess two distinct alternatives pertaining to a toll road. These alternatives were identified as the "concession 10 period" option and the deferral of the concession fee. It was duly recognized that these options possess the potential to contribute significantly to the accurate estimation of the project's value. A thorough real option pricing methodology that skillfully incorporates the inherent uncertainties related to the project's net cash flow and construction costs was put forth by Ho and Liu (2002). According to Lee (2011), their approach serves as a basic framework for assessing the financial viability of PPP projects.

Ford (2002) effectively captured design and infrastructure investment changes with a binomial option pricing model. The results of the study indicate that implementing this specific option has the potential to significantly increase managerial flexibility. Vandoros and Pantouvakis (2007) conducted a comparison analysis between the net present value (NPV) method and the real options methodology. To explore the possible enhancements that real options analysis could offer in the financial evaluation of an infrastructure project, the researchers used a fictitious project as a case study. When it comes to evaluating the value of infrastructure projects, one important area of research is the examination of government assurances. From a financial standpoint, these guarantees are seen as choices and represent a special feature of infrastructure investments that set them apart from other investment vehicles. Santi (2003) carried out a study that employed a real options approach to analyze and evaluate a suggested methodology for the planning and development of government subsidies. A 2006 assessment of the Minimum Revenue Guarantee (MRG) and its accompanying abandonment option was carried out by Hang and Chou. The MRG value and the option value of abandonment have been found to correlate reciprocally by the researchers. The empirical data suggests that there is an inverse relationship between the option value of abandonment and an increase in the MRG (marginal revenue growth) metric, which results in a decrease in the latter. Conversely, Hang and Chou's (2006) study shows that a decrease in the marginal rate of growth (MRG) is linked to a comparable increase in the option value of abandoning.

Takashima, Yagi, and Takamori (2010) conducted a thorough analysis of the complex relationships that arise between a government agency and a private company in the context of a public-private partnership in their groundbreaking work. With the use of a real options framework, the researchers examined the timing of investment decisions while simultaneously considering the extent of risk allocation and cost distribution during project implementation. According to Takashima, Yagi, and Takamori (2010), the private firm tends to exercise the investment option earlier when the government provides a sizable guarantee and the private firm's cost sharing rate is relatively low. This is in contrast to a situation where the policy prioritizes the maximization of project value. Brandao and Saraiva (2008) looked into a real option framework for the minimum traffic guarantee (MTG) on a toll road that connects the Amazon River in Brazil with the Midwest region of Brazil. After conducting a study, Brandao and Saraiva (2008) came to the conclusion that option pricing techniques can be a useful tool for representing the implementation of public-private partnerships (PPP) that incorporate guarantees and constraints on government expenditure. The previously outlined method provides a workable alternative for encouraging private participation in public infrastructure projects that are by their very nature highly risky.

A number of researchers have become experts in complex quantitative approaches for using real alternatives in real-world applications. These methods cover a range of approaches, including fuzzy modeling and Monte Carlo simulation. In their groundbreaking study, Yang and Dai (2006) employed the real option framework to investigate the process of making concession-related decisions. The researchers carefully considered all of the options available to them, including the possibility of changing the concession price, the possibility of farming the nearby area, and the viability of increasing the project's total capacity. To get the best answers, the researchers used an algorithm based on the concepts of the Monte Carlo simulation. Liu and Cheah (2009) believe that in order to achieve a more optimal balance between risk and benefit, it is imperative to integrate the inherent value of alternatives within projects in an efficient manner. To achieve this goal, the researchers conducted a comprehensive analysis of the Real Options Approach (ROA), assessing the Malaysia-Singapore Second Crossing project's valuation through the use of advanced Monte Carlo simulation tools. According to Liu and Cheah (2009), there is significant potential for using Real Options Approach (ROA) as a method of evaluating a wide range of options. Qin et al. (2009) introduced the fuzzy real option financial evaluation model for the BOT (build-operate-transfer) infrastructure project. The researchers have concluded that the option value associated with the project increased as a result of the presence of uncertain variables. The significant increase in value has been instrumental in prompting investors to reassess the whole valuation of the build-operate-transfer (BOT) infrastructure project, while appropriately taking into account the perspective of alternatives.

3.3. Characteristic comparison with NPV

Within the realm of the electricity market, the assessment of investment opportunities necessitates the consideration of a multitude of uncertainties, typically spanning a protracted temporal horizon. The conventional net present value (NPV) methodology is insufficient in effectively encompassing the investor's capacity to modify subsequent decisions in light of unforeseen market dynamics. In contrast, the Real Options Approach (ROA) acknowledges the potential for additional value derived from future market uncertainties and the inherent flexibility of projects. This makes it particularly well-suited for the development of the electricity market (K. Jo Min & Wang, 2002).

3.4. Case study

In the case study presented by Zhe Lu et al. 2006, we showcase an evaluation of a power plant investment project by employing the NPV (Net Present Value) and ROA (Real Options Approach) methodologies. The present cohort possesses a license for the construction of a power plant, encompassing a pair of Combined Cycle Gas Turbine (CCGT) generators, each boasting a capacity of 300MW. The proposed design entails the construction of the plant in two distinct segments. The initial segment is projected to be completed within a span of three years, following which the generation phase will commence promptly, boasting a capacity of 300MW. The commencement of the second segment construction will ensue subsequent to the culmination of the first segment, and the subsequent expansion endeavor is projected to reach its conclusion within a span of two years. The investment costs for each segment amount to $650 per kilowatt (kW) and $416 per kilowatt (kW) respectively. This is due to the fact that the second segment will be constructed utilizing the existing plant acquired in the first segment, which already possesses the necessary access to all required resources. It is anticipated that the generators will possess an economical lifespan of 30 years. In the context of this project, the evaluation shall be undertaken with the underlying premise of employing two distinct capital financing frameworks:

- full equity financing
- combining both equity and debt together.

3.4.1. NPV calculation

1) Cash flow simulation

The initiation of construction is anticipated to occur in 2005, with the completion of the initial segment projected for 2007, followed by the commencement of electricity generation in 2008. Subsequently, the initiation of the second segment will coincide with the first unit's commencement of electricity generation, and the second unit is expected to commence electricity generation in 2010. The consideration of the salvage value of the power plant is omitted in the calculation.

The annual production can be determined by multiplying the utilization factor with the generation capacity. It is important to note that the total periods considered should align with the expected economical life of the generators. The predominant factor contributing to the annual cost as delineated in the table primarily emanates from the expenditure incurred on fuel. The annual revenue can be determined by multiplying the annual production with the prevailing electricity prices. Subtracting the annual cost from the annual revenue yields the annual cash inflows, which serve as the foundation for calculating tax charges. The net annual cash inflows represent the ultimate income for investors, derived from the deduction of taxes from the annual cash inflows (Copeland et al., 2000).

2) NPV analysis based on equity financed capital

The process of ascertaining the necessary rate of return within the established structure of utilizing equity-financed capital for investment objectives is achieved through the application of the Capital Asset Pricing Model (CAPM), resulting in a calculated value of 9.70% in this specific case. By employing the suitable discount rate, one can ascertain the net present value (NPV) of this particular undertaking over various temporal intervals, encompassing 10, 15, 25, and 30 years, thereby encompassing the entirety of the project's duration. Within the framework of the generators' all-encompassing economic lifecycle strategy, the analysis of net present value (NPV) uncovers an unfavorable outcome.

Year	Initial investment	NPV (equity financed)
2005	-$195,000,000	-$20,197,916
2008	-$124,800,000	
2014		-$166,426,154
2019		-$105,622,963
2024		-$67,349,898
2029		-$43,258,606
2034		-$28,094,146

Table 1 NPV (EQUITY FINANCED)

Source: Zhe Lu et al. 2006

3) NPV analysis based on equity-debt financed capital

In the context of employing a combination of equity and debt financing to make investments, the determination of the requisite rate of return is accomplished through the computation of the WACC, which, in this particular instance, amounts to 8.26%. The simulated cash flow has been subjected to discounting using the specified rate, resulting in the computation of the respective net present value (NPV) for the plant investment over the course of 10, 15, 25, and 30 years, encompassing the entire duration of the project. The project is expected to have a positive outcome.

Year	Initial investment	NPV (equity-debt financed)
2005	-$195,000,000	$24,744,949
2008	-$124,800,000	
2014		-$159,880,550
2019		-$88,790,950
2024		-$40,986,761
2029		-$8,840,842
2034		$12,775,676

Table 2 NPV (EQUITY-DEBT FINANCED)

Source: Zhe Lu et al. 2006

The primary source of revenue for the power plant stems from the sale of electricity. The sale of electricity is subject to the direct influence of two significant factors: an internal factor known as the utilization factor, and an external factor pertaining to electricity prices.

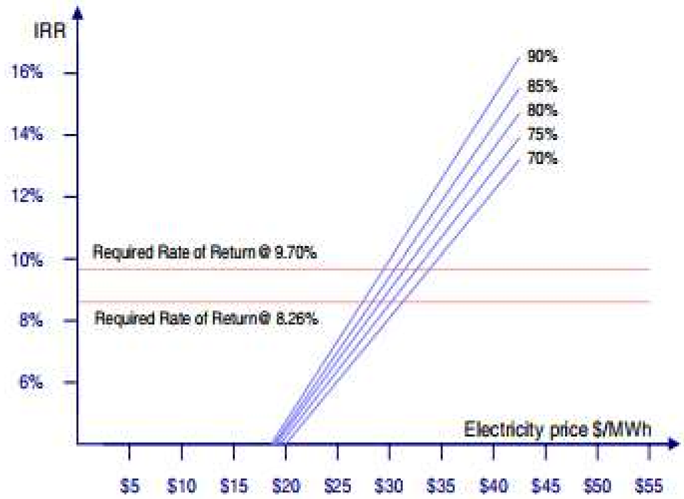

Figure 1 – Internal Rate of Return (IRR) and Electricity Price for various Utilization Factors

Source: Zhe Lu et al. 2006

Figure 1 exhibits the Internal Rate of Return (IRR) in relation to the anticipated prices of electrical energy across different levels of utilization factors. Based on the premise that the plant will function at a utilization factor of 70% and with an assumed electricity market price of $35/MWh, it is evident that this project will solely meet the investors' required return if the capital is financed through a combination of equity and debt. Notwithstanding, it is imperative for the investors to duly contemplate the prevailing market uncertainty pertaining to the potential decline in both the electricity price and the utilization factor, as compared to the projected levels. The acceptance criteria, grounded in the framework of net present value (NPV), stipulate that a venture ought to be sanctioned if the projected NPV surpasses or equals zero, as per the scholarly investigation conducted by Damodaran in 2012. The presence of adequate loan and equity financial resources is an essential requirement for the successful execution of a project. It is of utmost importance to emphasize, henceforth, that the net present value (NPV) is expected to demonstrate a positive trajectory throughout the forthcoming years of its economic lifespan. Undoubtedly, it is postulated that this anticipated advantageous transition will transpire roughly eight years preceding the culmination of unit 2 and six years preceding the culmination of generator 1. It is imperative to acknowledge that, notwithstanding the amalgamation of loan and equity capital, the net present value (NPV) over a span of 34 years presents itself as rather unassuming in light of the initial investment of $25 million, particularly when juxtaposed with the substantial sum of $320 million.

Based on the aforementioned research, it is conceivable that investors may experience a sense of disillusionment with regards to the trajectory of this specific project's progression.

3.4.2. Option evaluation

1) Overview of this project

In the context of this project, it is imperative to delineate the investment process into two distinct stages. It is crucial to note that the commencement of the second stage shall only transpire subsequent to the successful operationalization of the initial generation unit. From a real options standpoint, the second segment can be viewed as an option contingent upon the initial stage of construction, whereby the investing entity retains the right to expand the power plant. The investor possesses the entitlement, albeit without compulsion, to execute the option, primarily contingent upon the evolvement of market conditions (Black & Scholes, 1973). In the present case illustration, it is observed that the projected electricity price is anticipated to remain constant at $35 per megawatt-hour (MWh). Consequently, the determinant for initiating additional generation expansion is established as the alteration in reserve levels.

2) Reserve level as investment trigger

The electricity price is assumed to be stable in the whole project life, and the investment decision will be made based on the reserve level change.

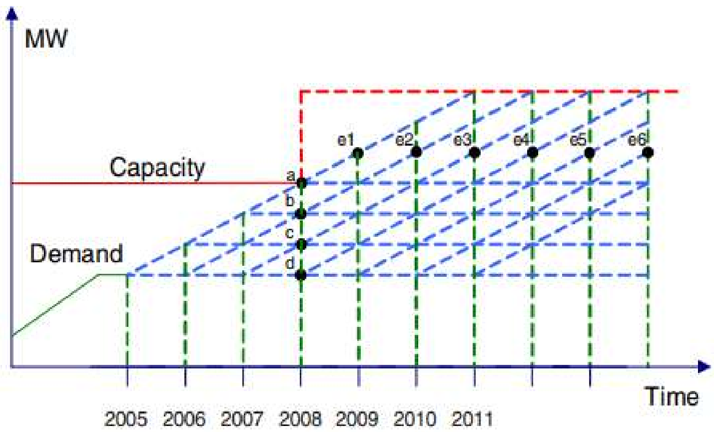

Figure 2 Reserve trigger levels

Source: Zhe Lu et al.

Based on the graphical representation, it can be inferred that the reserve level will experience an upward trajectory subsequent to the activation of generation unit 1 in the year 2008. The projected trajectory of demand growth commences in 2005, wherein there is a 50% likelihood of ascending to a higher level, while the remaining 50% probability entails the maintenance of the current level. According to the consecutive high growth scenario, the capacity reserve level is projected to be reached in the year 2008. Upon the commencement of production for generation unit 1, the reserve level will undergo a significant shift towards a higher magnitude. The newly established investment trigger level is defined as the threshold characterized by nodes e. The rationale behind establishing this threshold level is rooted in the observation that once the demand reaches node e, the reserve capacity will be depleted within a span of two years. This temporal frame aligns with the necessary lead time required for the expansion of the plant through the addition of an additional generation unit. Each individual node within the investment trigger level is intrinsically linked to a corresponding probability. Commencing the simulation at the present moment in 2005, we are able to ascertain the likelihood of the demand attaining the trigger level from the year 2009 onwards.

3) The evaluation

In order to conduct a comprehensive assessment of this project, with particular emphasis on its expansion component, it is imperative to consider the inherent worth of the dynamic expansion option. This worth can be quantified as the disparity between the net income that shall be generated by the second generation unit and the corresponding investment cost. In the realm of traditional appraisal techniques, such the Black-Scholes model and the binomial tree approach, it is important to recognize that the evaluation of option value is influenced, in part, by the inherent volatility of the price of the underlying asset. Because energy prices will not fluctuate over the facility's lifetime, cash flows and the probabilities that go along with them must be integrated into the project in order to fully evaluate it. According to Inc et al. (2010), the idea being discussed may be known as the anticipated value of the enterprise. After conducting a Net Present Value (NPV) analysis, it has been concluded that the generator is expected to last for a total of thirty years. Moreover, it is imperative to recognize that the discount factor utilized in the assessment is the combined rate of return resulting from the amalgamation of debt and equity financing, now standing at 8.26%. Finally, it is necessary to recognize that the construction phase of the enlargement project is expected to take place over the course of two years.

4) ROA recommendation

The real option approach is employed to assess the second segment as a potential expansion option for generation. This assessment is then combined with the net present value (NPV) evaluation of the first segment. The culmination of these evaluations yields the final assessment of value for the power plant project.

NPV (segment 1) + Option Value (segment 2)		
	NPV	Option Value
Equity-debt financed	-$23,351,653	$60,761,577
Sum	$37,409,924	

Table 3 ROA Recommendations

Source: Zhe Lu et al. 2006

As evidenced by the data presented in the Table 3, the option values clearly indicate the project's attractiveness, thereby providing the investor with a compelling rationale to proceed with the project based on this comprehensive evaluation.

Based on the aforementioned analysis, it is evident that the Real Options Approach (ROA) exhibits a noteworthy positive value in relation to the entirety of the project. The significant value of the Real Options Approach (ROA) stems from the potential savings resulting from immediate investment. This value is indicative of the management's ability to exercise flexibility in utilizing expansion options, or alternatively, it can be interpreted as a reflection of their response to future uncertainties.

3.4.3. Results comparison

The present analysis encompasses a comprehensive examination of two prominent investment evaluation techniques, namely Net Present Value (NPV) and Real Options Approach (ROA). The purpose of this discourse is to put forth a novel investment evaluation approach that caters to the requirements of the contemporary generation. The Real Options Approach (ROA) methodology posits that a company possessing the potential to make an investment is effectively retaining a "option," akin to a financial call option. In order to assess the investment, the Real Options Approach (ROA) metric will take into account the potential actions that an investor may undertake in response to changes in the market environment. The inherent market uncertainties and the adaptability of management can be conceptualized as factors that contribute to the enhancement of value within the project. Given the aforementioned assertion, one could posit that the utilization of the Real Options Approach (ROA) metric presents a more suitable approach for assessing performance within the power market when juxtaposed with the computations of Net Present Value (NPV). The primary factor contributing to this phenomenon can be attributed to the intrinsically intricate nature of accurately evaluating the dynamic characteristics of the culture and practices prevalent in the utilities and power markets. As per the findings of Remer et al. (1993), the case study employs a combination of Net Present Value (NPV) and Real Options Approach (ROA) as evaluative metrics for a specific project. The utilization of the Net Present Value (NPV) methodology yields a negative outcome, thereby indicating a diminished likelihood of the project under consideration augmenting the investors' aggregate net worth. In terms of comparative analysis, it is worth noting that the Real Options Approach (ROA) metric demonstrates a significantly favorable outcome. The elucidation of this phenomenon can be attributed to the incorporation of the supplementary value that investors derive from the implementation of adaptable management methodologies and the anticipation of forthcoming strategic initiatives.

The current proposition concerning option-based valuation tackles the inherent uncertainties linked to the investment, while also considering the estimated value derived from management flexibility. The aforementioned approach can be regarded as a strategic tool employed to evaluate the prospective profitability of an investment opportunity. Furthermore, it is of utmost importance to take into account the impact of market prices on investments in electricity generation, a crucial aspect that has unfortunately been neglected in this analysis. From a financial perspective, it is evident that the price signal demonstrates a greater level of responsiveness in comparison to the reserve shortage signal. It is imperative to acknowledge that, from a practical standpoint, these two indicators possess an inherent correlation with each other. Nevertheless, it is apparent that through the utilization of electricity price as a catalyst for investment, one can potentially replicate the inherent volatility observed in market prices. The subsequent impact of this phenomenon influences the fluctuation of revenue income, ultimately enhancing the value of options and enabling the utilization of binomial trees for computational purposes (Lee, 2011).

Conclusion

The current study explores the realm of Technology Lifecycle Management (TLM) and scrutinizes the integration of Net Present Value (NPV) and Real Options Approach (ROA) as decision-making instruments. This research elucidates noteworthy discoveries and ramifications that bear pertinence for enterprises as they traverse the perpetually shifting landscape of technology investments.

The inquiry was instigated through the establishment of a comprehensive elucidation of Technology Lifecycle Management (TLM) and the subsequent elaboration on the discrete stages inherent in the technological life cycle. The present undertaking sought to establish a foundational understanding of the subject matter. The next discussion went on to explore the complexities of the valuation techniques used in the field of technology investments, focusing on the concepts of Net Present Value (NPV) and Real Options. This study conducted an extensive analysis that included a close examination of the definitions of the ideas being studied, as well as a thorough assessment of the benefits and drawbacks associated with their actual use.

An important finding from the analysis of Net Present Value (NPV) and Real Options is that the traditional NPV framework might not be sufficient to fully understand the volatile nature of technology markets and the inherent uncertainties they involve. Like financial call options, real options also exhibit a higher level of skill in evaluating technology investments due to their capacity to incorporate both market volatility and the possibility of managerial flexibility.

The mentioned case study of Zhe Lu et al., 2006 provides additional support for the usefulness of embracing the real options perspective by integrating the use of Net Present Value (NPV) and Real Options Approach (ROA) in the context of a technological investment. Analysis of the results shows that net present value (NPV) is not sufficient to capture all possible value, which highlights the need for a more flexible and sophisticated approach when assessing technology investments. The case study demonstrated not only how to use Net Present Value (NPV) and Real Options Approach (ROA) pragmatically, but also how they complement each other to provide a thorough evaluation of technological investments.

The ramifications for enterprises are substantial, emphasizing how critical it is to adopt a strategy framework that successfully integrates the use of Net Present Value (NPV) and Real Options Approach (ROA). Empirical examples highlight the importance of this methodology in efficiently managing the uncertainties associated with technological investments. The above described examples are representative cases that demonstrate how this specific strategy can improve decision-making procedures and, in turn, contribute significantly to the overall success of businesses.

The combination of Net Present Value (NPV) and Real Options Approach (ROA) serves as a tactical tool for assessing the potential return on investments made in technology. The previously indicated methodology offers a comprehensive perspective that appropriately considers the complexities and uncertainties inherent in the rapidly advancing field of technology.

This study provides a significant contribution to the ongoing scholarly discourse regarding the effectiveness of decision-making in the realm of technology and its lifecycle management (TLM). By elucidating this subject matter, it establishes the groundwork for the formulation of increasingly knowledgeable and flexible methodologies within an era distinguished by perpetual technological progress.

Bibliography

1. Arshad, Net present value is better than internal rate of return. Interdisciplinary journal of contemporary research in business, vol. 4(8), 2012, pp. 211-219.

2. A. Gallo, A refresher on net present value. Harvard Business Review, 2014, https://hbr.org/2014/11/arefresher-on-net-present-value

3. Abemathy W, Utterback J. A dynamic model of productand process innovation. Omega Int J Manag Sci.1975 ;3:639-56

4. Adner, R., Levinthal, A (2004), "What is Not a Real Option: Considering Boundaries for the Application of Real Options to Business Strategy", The Academy of Managament Review, Vol. 29, No. 1, p. 74-85

5. Allen, F., Bhattacharya, S., Rajan, R., & Schoar, A. (2008). The Contributions of Stewart Myers to the Theory and Practice of Corporate Finance*. *Journal of Applied Corporate Finance*, *20*(4), 8–19. https://doi.org/10.1111/j.1745-6622.2008.00200.x

6. Arifin, Z., & Mulyati, S. (2021, May 31). *Investment Strategy in Sharia Mutual Funds: Case Study on the Indonesian Capital Market*. Www.atlantis-Press.com; Atlantis Press. https://doi.org/10.2991/assehr.k.210531.056

7. Arriaga, M., Canizares, C. A., & Kazerani, M. (2013). Renewable Energy Alternatives for Remote Communities in Northern Ontario, Canada. *IEEE Transactions on Sustainable Energy*, *4*(3), 661–670. https://doi.org/10.1109/tste.2012.2234154

8. Ashuri, Kashani, and Lu. Financial Valuation of Risk and Revenue Sharing Options in Build-Operate-Transfer (BOT) Highway Projects, Engineering Project Organizations Conference working paper. 2010.

9. Aswath, D. (2004). Tools and Techniques for Determining the Value of Any Asset. Translated from English–Moscow: Alpina Business Books.

10. Atefeh Mousavi, Hossein Zare, Aydin Asadian, and Mehdi Mohammadzadeh, 2022, Factors Affecting the Product Life Cycle of Generic Medicines , DOI: https://doi.org/10.5812/ijpr-127039

11. Bauwens, T., Gotchev, B., & Holstenkamp, L. (2016). What drives the development of community energy in Europe? The case of wind power cooperatives. *Energy Research & Social Science*, *13*, 136–147. https://doi.org/10.1016/j.erss.2015.12.016

12. Benaroch, M. (2002). Managing Information Technology Investment Risk: A Real Options Perspective. *Journal of Management Information Systems*, *19*(2), 43–84. https://doi.org/10.1080/07421222.2002.11045726

13. Bengtsson, J. (2001). Manufacturing flexibility and real options: A review. *International Journal of Production Economics*, *74*(1-3), 213–224. https://doi.org/10.1016/s0925-5273(01)00128-1

14. Black, F., & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, *81*(3), 637–654. https://doi.org/10.1086/260062

15. Board, C. F. P. (2015). CFP Board Financial Planning Competency Handbook. In *Google Books*. John Wiley & Sons. https://books.google.com/books?hl=el&lr=&id=Yi_dCQAAQBAJ&oi=fnd&pg=PA73&dq=Personal+Financial+Planning.+Cengage+Learning.++This+book+explores+how+individuals+can+apply+financial+planning+concepts

16. Bodie, Z., Kane, A., & Marcus, A. (2013). EBOOK: Essentials of Investments: Global Edition. In *Google Books*. McGraw Hill. https://books.google.com/books?hl=el&lr=&id=1MovEAAAQBAJ&oi=fnd&pg=PP1&dq=Bodie

17. Borison, A. (2005), " Real Options Analysis: Where are the Emperors' Clothes?", Journal of Applied Corporate Finance, Vol. 17, No. 2, p. 17- 31

18. Bouteiller, C. (2003). Points de vue sur les sciences de gestion. *Www.torrossa.com*, 1–304. https://www.torrossa.com/gs/resourceProxy?an=5123488&publisher=FZ2990#page=243

19. Bowman, E.H. and Hurry, D. (1993), "Strategy through the option lens: an intergrated view of resource investmens and the incremental-choice process", The academy of management review, Vol. 18, No. 4, p. 760-782

20. Brandao, and Saravia. "The Option Value of Goverment Guarantees in Infrastructure Projects." Construction Management and Economics Vol. 26. 2008. pp. 1171-1180.

21. Brennan, M.J. and Schwarts, E.S. (1985), "A new approach to evaluating natural resource investments", Midland Corporate Finance Journal, No. 3, p. 37-47

22. Brijlal, P. (2008, August 21). *The Use of Capital Budgeting Techniques in Businesses: A Perspective from the Western Cape*. Papers.ssrn.com. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1259636

23. C.A. Magni, Average internal rate of return and investment decisions: a new perspective. The Engineering Economist, vol. 55(2), 2010, pp. 150- 180. DOI: https://doi.org/10.1080/00137911003791856

24. Carlisle, N., Van Geet, O., & Pless, S. (2009, November 1). *Definition of a "Zero Net Energy" Community*. Www.osti.gov. https://www.osti.gov/servlets/purl/969716

25. Copeland, and Antikarov. Real Option: A Practitioner's Guide. Ross Publishing. 2003.

26. Copeland, T. E., Koller, T., & Murrin, J. (2000). Valuation : measuring and managing the value of companies. *(No Title)*. https://cir.nii.ac.jp/crid/1130282272419504000

27. Crespo, J. (2011). How Emergence Conditions of Technological Clusters Affect Their Viability? Theoretical Perspectives on Cluster Life Cycles. *European Planning Studies*, *19*(12), 2025–2046. https://doi.org/10.1080/09654313.2011.633824

28. Damodaran, A. (2012). Investment Valuation: Tools and Techniques for Determining the Value of Any Asset. In *Google Books*. John Wiley & Sons. https://books.google.com/books?hl=el&lr=&id=E8-30Pga-nkC&oi=fnd&pg=PA1&dq=Investment+Valuation:+Tools+and+Techniques+for+Determining+the+Value+of+any+Asset.+John+Wiley+%26+Sons&ots=9CR8rjrycQ&sig=VGtOdkLAzEH8M-RV9KIo1erNdTw

29. Dixit, A. (1992). Investment and Hysteresis. *Journal of Economic Perspectives*, *6*(1), 107–132. https://doi.org/10.1257/jep.6.1.107

30. Dixit, A. K., Pindyck, R. S., & Pindyck, R. (1994). Investment under uncertainty princeton univ. Press, Princeton, New Jersey.

31. Dixit, and Pindiyck. Investment Under Uncertainty. Princeton University Press. 1994.

32. E.R. Yescombe, Chapter 4 - Cash Flow and Investment Analysis. In Public-Private Partnerships, Elsevier Ltd, 2007, pp. 49-57, ISBN 9780750680547, DOI: https://doi.org/10.1016/B978-075068054-7.50028-9.

33. Funk, O. (2003). *Foreign Direct Investment to the Czech Republic. Comparing the Case of Škoda Automobilová and Volkswagen With Bargaining for Budějovický Budvar by Anheuser-Busch*. Etd.ohiolink.edu. https://rave.ohiolink.edu/etdc/view?acc_num=miami1060098170

34. Gallo, A. (2014). A Refresher on Net Present Value. In *Harvard Business Review*. http://www.cogencygroup.ca/uploads/5/4/8/7/54873895/harvard_business_review-a_refresher_on_net_present_value_november_19_2014.pdf

35. H.A. Levine, Project portfolio management: a practical guide to selecting projects, managing portfolios, and maximizing benefits. John Wiley & Sons, 2005.

36. Harrison, and Perdue. "Where Does Marketing Fit into the Capital Budgeting Equations." Academy of Marketing Studies Journal. Vol.10. 2006

37. Hartwell, J. C., Upadhyay, Y., & Sourani, A. (2019). Influential factors of life cycle management in education PFI projects. *Built Environment Project and Asset Management*, *9*(2), 302–314. https://doi.org/10.1108/bepam-02-2018-0043

38. Haupt, R., Kloyer, M., & Lange, M. (2007). Patent indicators for the technology life cycle development. *Research Policy*, *36*(3), 387–398. https://doi.org/10.1016/j.respol.2006.12.004

39. Howell, S.D. and Jägle A.J. (1997), "Laboratory evidence on how managers intuitively value real growth options", Journal of Business Finance & Accounting, Vol 24. No. 8., p. 915-935

40. Huang, Y., & Chou, S. (2006). Valuation of the minimum revenue guarantee and the option to abandon in BOT infrastructure projects. *Construction Management and Economics*, *24*(4), 379–389. https://doi.org/10.1080/01446190500434997

41. Huenteler, J., Schmidt, T. S., Ossenbrink, J., & Hoffmann, V. H. (2016). Technology life-cycles in the energy sector — Technological characteristics and the role of deployment for innovation. *Technological Forecasting and Social Change*, *104*, 102–121. https://doi.org/10.1016/j.techfore.2015.09.022

42. Huisman, K. J. M. (2013). Technology Investment: A Game Theoretic Real Options Approach. In *Google Books*. Springer Science & Business Media. https://books.google.com/books?hl=el&lr=&id=OyflBwAAQBAJ&oi=fnd&pg=PA1&dq=Technology+investments+as+real+options&ots=jei0UFDVKu&sig=xcmQJvblY3Xdq6QIIw20LNCui78

43. Hüseyin Doğan, Henshaw, M., & Esmond Neil Urwin. (2009). A "Soft" Approach to TLM Requirements Capture to Support Through-Life Management. *Springer EBooks*, 458–469. https://doi.org/10.1007/978-3-642-10488-6_44

44. J. Mackevičius, V. Tomaševič, Evaluation of investment projects in case of conflict between the internal rate of return and the net present value methods. Ekonomika, vol. 89(4), 2010, pp. 116-130. DOI: 10.15388/Ekon.2010.0.962

45. J. Mackevičius, V. Tomaševič, Evaluation of investment projects in case of conflict between the internal rate of return and the net present value methods. Ekonomika, vol. 89(4), 2010, pp. 116-130. DOI: 10.15388/Ekon.2010.0.962

46. Joseph, C. (2007), "Real options and real engineering projects", Engineering Management Journal, Vol. 19, No.4, p. 11

47. K. Jo Min, & Wang, C.-H. (2002). *Generation planning for inter-related generation units: a real options approach*. https://doi.org/10.1109/pess.2000.867343

48. Karunathilake, H., Hewage, K., Mérida, W., & Sadiq, R. (2019). Renewable energy selection for net-zero energy communities: Life cycle based decision making under uncertainty. *Renewable Energy*, *130*, 558–573. https://doi.org/10.1016/j.renene.2018.06.086

49. Keat, P., & Young, P. (2006). Managerial economics, economic tools for today's decision making.

50. Knaus, S.D., Murphy, R.O. (2008), "Real options in the laboratory: An experimental study of sequential investment decisions"

51. K.T. Yeo, Fasheng Qiu (2002), The value of management flexibility - a real option approach to investment evaluation, Division of Systems and Engineering Management, School of Mechanical and Production Engineering, doi:10.1016/S0263-7863(02)00025-X

52. Kulatilaka, N., & Perotti, E. C. (1998). Strategic Growth Options. *Management Science*, *44*(8), 1021–1031. https://doi.org/10.1287/mnsc.44.8.1021

53. Kumar, R. (1997). DSS Value and Time-Constrained Decision Making. *AMCIS 1997 Proceedings*. https://aisel.aisnet.org/amcis1997/101/

54. L. Juhász, Net present value versus internal rate of return. Economics & Sociology, vol. 4(1), 2011, pp. 46-53.

55. Lee, H. (2011). *A Real option approach to valuating infrastructure investments*. Archives.kdischool.ac.kr. http://archives.kdischool.ac.kr/handle/11125/30344

56. Lee, S.-C. (2011). Using real option analysis for highly uncertain technology investments: The case of wind energy technology. *Renewable and Sustainable Energy Reviews*, *15*(9), 4443–4450. https://doi.org/10.1016/j.rser.2011.07.107

57. Liu, J., & Cheah, C. Y. J. (2009). Real option application in PPP/PFI project negotiation. *Construction Management and Economics*, *27*(4), 331–342. https://doi.org/10.1080/01446190902807071

58. Paul Lodder (2022). Managemnt and Different Stages of Technology Life Cycle. DOI: 10.35248/2311-3278.22.10.203

59. M. Hopkinson, The case for project net present value (NPV) and NPV risk models. 2016, pp. 61-67.

60. Marais, K. B., & Saleh, J. H. (2009). Beyond its cost, the value of maintenance: An analytical framework for capturing its net present value. *Reliability Engineering & System Safety*, *94*(2), 644–657. https://doi.org/10.1016/j.ress.2008.07.004

61. McDonald, R. and Siegel, D. (1985), "The value of waiting to invest", Quarterly Journal of Economics No. 101, p. 707-728

62. McDonald, R., & Siegel, D. (1986). The Value of Waiting to Invest. *The Quarterly Journal of Economics*, *101*(4), 707. https://doi.org/10.2307/1884175

63. Melicher, R. W., & Norton, E. A. (2013). Introduction to Finance: Markets, Investments, and Financial Management. In *Google Books*. John Wiley & Sons. https://books.google.com/books?hl=el&lr=&id=Jv7WAgAAQBAJ&oi=fnd&pg=PR3&dq=Financial+Markets+and+Institutions.+Cengage+Learning.++The+book+covers+financial+markets+and+investment+decisions

64. Miller, K. and Shapira, Z., (2004), "An Empirical Test of Heuristics and Biases Affecting Real Option Valuation", Strategic Management Journal, Vol. 25, No. 3, p. 269-284

65. Myers, S. (1977), "Determinants of corporate borrowing", Journal Financial Economics, No. 5, p. 147-175

66. Myers, S. and Majd, S. (1990), "Abandonment value and project life", Advances in Futures and Options Research, p. 1-21

67. N.P. Archer, F. Ghasemzadeh, An integrated framework for project portfolio selection. International Journal of Project Management, vol. 17(4), 1999, pp. 207-216. DOI: https://doi.org/10.1016/S0263-7863(98)00032-5

68. Naim, M. M. (2006). The impact of the net present value on the assessment of the dynamic performance of e-commerce enabled supply chains. *International Journal of Production Economics*, *104*(2), 382–393. https://doi.org/10.1016/j.ijpe.2004.11.015

69. Pajchrowski, G., Noskowiak, A., Lewandowska, A., & Strykowski, W. (2014). Materials composition or energy characteristic – What is more important in environmental life cycle of buildings? *Building and Environment*, *72*, 15–27. https://doi.org/10.1016/j.buildenv.2013.10.012

70. Peter Slowik, Dale Hall, Nic Lutsey, Michael Nicholas, Sandra Wappelhorst , 2019, FUNDING THE TRANSITION TO ALL ZERO-EMISSION VEHICLES

71. Pfeifer, P. E., Haskins, M. E., & Conroy, R. M. (2005). Customer Lifetime Value, Customer Profitability, and the Treatment of Acquisition Spending. *Journal of Managerial Issues*, *17*(1), 11–25. https://www.jstor.org/stable/40604472

72. Poerink Willem, 2013, Real Options and the Bias of Commitment Escalation, Department of Applied Economics, University of Rotterdam

73. Qin, Z., Yun, P., & Hu, M. (2009). Investment Decisions In The BOT Transport Infrastructure Applying Fuzzy Real Option. *Logistics*. https://doi.org/10.1061/40996(330)231

74. Quig, L. (1993), "Empirical testing of real option-pricing models. Journal of Finance

75. Remer, D. S., Stokdyk, S. B., & Van Driel, M. (1993). Survey of project evaluation techniques currently used in industry. *International Journal of Production Economics*, *32*(1), 103–115. https://doi.org/10.1016/0925-5273(93)90013-b

76. Rocha, H., Maurício César Delamaro, & Maria, L. (2012). NEW PRODUCT DEVELOPMENT RISK MANAGEMENT AND DECISION-MAKING: THE USE OF REAL OPTIONS. *WORLD SCIENTIFIC EBooks*, 311–320. https://doi.org/10.1142/9789814452052_0026

77. Ryals, L. (2008). Determining the indirect value of a customer. *Journal of Marketing Management*, *24*(7-8), 847–864. https://doi.org/10.1362/026725708x345542

78. S. Le, The Applications of NPV in Different Types of Markets. In 2021 3rd International Conference on Economic Management and Cultural Industry (ICEMCI 2021), Atlantis Press. 2021, pp. 1054-1059.

79. S.C. Myers, N.S. Majluf, Corporate financing and investment decisions when firms have information that investors do not have. Journal of Financial Economics, vol. 13, issue 2, 1984, pp.187-221, ISSN 0304-405X. DOI: https://doi.org/10.1016/0304-405X(84)90023-0.

80. Schumpeter J. Business cycles: a theoretical, historical, and statistical analysis of the capitalist process, vol. 2.New York: McGraw-Hill; 1939

81. Schumpeter J. Capitalism, socialism, and democracy.3rd ed. New York: Harper & Row; 1950

82. Smit, H. T. J., & Trigeorgis, L. (2007). Strategic Options and Games in Analysing Dynamic Technology Investments. *Long Range Planning*, *40*(1), 84–114. https://doi.org/10.1016/j.lrp.2007.02.005

83. Smit, H., Kester, C., Mcgrath, R., Myers, S., Perotti, E., & Salinger, M. (2004). *QUANTIFYING THE STRATEGIC OPTION VALUE OF TECHNOLOGY INVESTMENTS*. https://www.realoptions.org/papers2004/SmitTrigeorgisAMR.pdf

84. Stahl, H. K., Matzler, K., & Hinterhuber, H. H. (2003). Linking customer lifetime value with shareholder value. *Industrial Marketing Management*, *32*(4), 267–279. https://doi.org/10.1016/s0019-8501(02)00188-8

85. Steffens, P. R., & Douglas, E. J. (2007). Valuing technology investments: use real options thinking but forget real options valuation. *International Journal of Technoentrepreneurship*, *1*(1), 58. https://doi.org/10.1504/ijte.2007.013270

86. Takashima, R., Yagi, K., & Takamori, H. (2010). Government guarantees and risk sharing in public–private partnerships. *Review of Financial Economics*, *19*(2), 78–83. https://doi.org/10.1016/j.rfe.2009.10.001

87. Tarik Driouchi, & Leseure, M. (2005). *Planning under uncertainty: assessing the robustness of technology real options*. https://doi.org/10.1109/picmet.2005.1509702

88. Taylor, M., & Taylor, A. (2012). The technology life cycle: Conceptualization and managerial implications. *International Journal of Production Economics*, *140*(1), 541–553. https://doi.org/10.1016/j.ijpe.2012.07.006

89. Tourinho, O.A.F (1979), “The option value of reserves of natural resources”, Technical report, University of California, Berkeley.

90. Trigeorgis, L. (1993), “Real Options and the interactions with financial flexibility”, Financial Management assocation, Autumn edition

91. Trigeorgis, L. (1993). Real Options and Interactions with Financial Flexibility. *Financial Management*, *22*(3), 202. https://doi.org/10.2307/3665939

92. Vandoros, and Pantouvakis. "Using Real Options in Evaluating PPP/PFI Projects." .2007. pp. 594-603.

93. W. Wetekamp, Net Present Value (NPV) as a tool supporting effective project management. In Proceedings of the 6th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems, IEEE Press, 2011, vol. 2, pp. 898-900. DOI: 10.1109/IDAACS.2011.6072902

94. Wernz, C., Gehrke, I., & Ball, D. R. (2013). Managerial decision-making in hospitals with real options analysis. *Information Systems and E-Business Management*, *13*(4), 673–691. https://doi.org/10.1007/s10257-013-0230-3

95. Wu, L.-C., Li, S.-H., Ong, C.-S., & Pan, C. (2012). Options in technology investment games: The real world TFT-LCD industry case. *Technological Forecasting and Social Change*, *79*(7), 1241–1253. https://doi.org/10.1016/j.techfore.2012.03.008

96. Wu, M.-C., Yen, S. H., & Lou, K.-R. (2007). Pricing real abandonment options on several R&D investment projects. *Soft Computing*, *11*(12), 1123–1129. https://doi.org/10.1007/s00500-007-0162-2

97. X. Hui, Using the Net Present Value Rule to Make Value-Creating Investment Decisions. In Proceedings of the International Conference on Chemical, Material and Food Engineering, Atlantis Press, 2015, pp. 644-647.

98. Y.A. AlKulaib, S.A. Al-Jassar, K. Al-Saad, Theory and practice in capital budgeting: evidence from Kuwait. Journal of Applied Business Research (JABR), vol. 32(4), 2016, pp. 1273-1286. DOI: https://doi.org/10.19030/jabr.v32i4.9736

99. Y.A. AlKulaib, S.A. Al-Jassar, K. Al-Saad, Theory and practice in capital budgeting: evidence from Kuwait. Journal of Applied Business Research (JABR), vol. 32(4), 2016, pp. 1273-1286. DOI: https://doi.org/10.19030/jabr.v32i4.9736

100. Yan, R. (1998). Short-term results: The litmus test for success in China. Harvard Business Review, 76(5), 61-70.

101. Yang, W., & Dai, D. (2006). Concession Decision Model of BOT Projects Based on a Real Options Approach. https://doi.org/10.1109/icmse.2006.313928

102. Yavas, A. and Sirmans, C. (2005), "Real Options: Experimental Evidence.", The Journal of Real Estate Finance and Economics, Vol. 31, No. 1, p. 27-52

103. Yeo, K. T., & Qiu, F. (2003). The value of management flexibility—a real option approach to investment evaluation. *International Journal of Project Management*, *21*(4), 243–250. https://doi.org/10.1016/s0263-7863(02)00025-x

104. *Zhe Lu, Ariel Liebman and Zhao Yang Dong, Member, IEEE,* Power Generation Investment Opportunities Evaluation: A Comparison between Net Present Value and Real Options Approach

Author’sStatement:

I hereby expressly declare that, according to the article 8 of Law 1559/1986, this dissertation is solely the product of my personal work, does not infringe any intellectual property, personality and personal data rights of third parties, does not contain works/contributions from third parties for which the permission of the authors/beneficiaries is required, is not the product of partial or total plagiarism, and that the sources used are limited to the literature references alone and meet the rules of scientific citations.