International Journal of
Science, Architecture, Technology and Environment

TotalEnergies' Investment Decision in Cabo Delgado: A Real Options Theory Perspective

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DOI: https://doi.org/10.63680/ijsate1025051.048

Abstract

The main objective of this study is to analyze TotalEnergies' investment decision in Cabo Delgado in light of Real Options Theory (ROT) for the period from 2021 to 2025. The research sought to identify the risk factors that led to the postponement of the Mozambique LNG project, assess the incorporation of strategic flexibility in the company's decisions, and discuss the economic and strategic impacts of applying TOR in Mozambique. The results revealed that the option to wait was the most valuable (8,308,327 MZN), allowing TotalEnergies to reduce risks and maximize the value of the project. The option to abandon (1,677,000 MZN) proved effective in mitigating losses in negative scenarios, while the option to expand (2,648,000 MZN) showed the potential to capture opportunities in favorable contexts. The application of the Black-Scholes model, with approximate data, estimated the value of the option at USD 15.8 billion, financially justifying the decision to postpone. It is concluded that real options' theory represents a superior approach to traditional investment valuation methods, as it captures the value of flexibility and adaptability in volatile environments, such as the Mozambican extractive sector.

Keywords: Real Options Theory, TotalEnergies, Mozambique LNG, Strategic Flexibility, Investments in an Environment of Uncertainty

1. Introduction

Investment decisions in large-scale projects, especially in the extractive sector, often involve high levels of uncertainty, international price volatility, socio-political risks and contractual complexities. The traditional approach to investment evaluation, based on Net Present Value (NPV), tends to have limitations in contexts where decision flexibility and uncertainty management play a decisive role (Dixit & Pindyck, 1994). In this scenario, Real Options Theory (ROT) offers a more dynamic alternative model, considering that managers have strategic options that can be exercised according to the evolution of the business environment, such as postponing, expanding, contracting or abandoning a project (Trigeorgis, 1996).

In Mozambique, the province of Cabo Delgado has come to occupy a prominent place on the international investment agenda in the natural gas sector, due to significant discoveries of reserves in the Rovuma Basin. Among the main investors is TotalEnergies, a French multinational responsible for the Mozambique LNG project. The company's investment decision, especially between 2021 and 2025, was deeply affected by exogenous factors, in particular the escalation of armed violence and security instability in the region, which led to the suspension of the project in 2021. This context highlights the importance of understanding how major decisions are made in environments of extreme risk and how strategic flexibility influences such decisions. In this sense, the overall objective of this study is to analyse TotalEnergies' investment decision in Cabo Delgado in light of Real Options Theory between 2021 and 2025. The specific objectives are: (i) to identify the risk factors that influenced the postponement of the Mozambique LNG project; (ii) to assess how strategic flexibility was incorporated into TotalEnergies' decisions; and (iii) to discuss the economic and strategic impacts of the TOR-based approach for Mozambique. The rationale for this work lies in the relevance of deepening the academic debate on investment decisions in emerging economies subject to multiple risks. In particular, the case of TotalEnergies offers a unique opportunity to examine how large corporations integrate political and security uncertainty into their analysis of capital-intensive projects. Additionally, this study contributes to the field of applied economics and strategic management by providing an analytical approach that is closer to the reality of business decisions in volatile contexts. Given this framework, the following research questions arise: (i) How did TotalEnergies incorporate elements of Real Options Theory into its decision to suspend and later resume the Mozambique LNG project? (ii) What were the main factors of uncertainty considered by the company in the decision-making process? (iii) What lessons can be drawn from this case for the formulation of public policies aimed at attracting and retaining foreign direct investment in unstable environments? The theoretical and methodological approach adopted aims to answer these questions and offer a more robust reading of the rationale underlying major investment decisions, not only from an economic point of view, but also from a strategic and institutional perspective.

2. Literature review

2.1 Risk factors that influenced the postponement of the Mozambique LNG project

The Mozambique LNG project, led by TotalEnergies in Area 1 of the Rovuma Basin, represents one of the largest foreign investments in Mozambique's history, with an estimated volume of more than US$20 billion. However, its progress was interrupted in April 2021 when TotalEnergies declared force majeure, suspending activities indefinitely due to the worsening armed conflict in Cabo Delgado province (TotalEnergies, 2021). This decision was influenced by a set of risk factors that, in an interconnected manner, threatened the operational and financial viability of the project. The following section analyses three main categories of these risks: security risk, political-institutional risk and reputational risk.

2.1.1 Security risk

Security risks were the most decisive factor in the postponement of the project. Since October 2017, Cabo Delgado has been the scene of armed attacks carried out by insurgent groups with possible links to transnational extremist networks. These attacks have resulted in the destruction of infrastructure, displacement of populations and mass killings, creating a humanitarian crisis of major proportions (Habibe, Forquilha & Pereira, 2019). In March 2021, the attack on the village of Palma, located a few kilometers from the project's logistics centre, highlighted the vulnerability of the region, forcing TotalEnergies to evacuate its personnel and suspend work. According to Duarte (2021), the insecurity surrounding the project was not limited to diffuse threats, but was systematic and targeted, directly affecting the interests of the multinationals involved. The lack of an effective and coordinated response from the Mozambican Defense and Security Forces (FDS) contributed to the worsening of the perception of risk by investors, who began to consider the continuation of operations in that context unsustainable.

2.1.2 Political-Institutional Risk

Security instability is intrinsically linked to governance failures and institutional fragility. Political-institutional risk refers to the Mozambican state's inability to guarantee the security, legal regularity and stability necessary for the protection of long-term investments. The centralization of decision-making, limited transparency in the management of natural resources and the weak presence of the state in rural and peripheral areas are significant obstacles to the implementation of projects such as Mozambique LNG (Hanlon, 2021). In addition, the lack of trust between the main actors the state, companies, and local communities has created an environment of permanent tension. As Macuane (2020) argues, the socioeconomic exclusion of large sectors of the population of Cabo Delgado has fostered feelings of marginalization, which have subsequently been exploited by armed groups. In this context, the TotalEnergies project came to be perceived by some segments of the population as part of the problem rather than a development solution. The complexity of relations between the Mozambican state and investors was also reflected in the lack of clarity about the role of foreign forces in protecting the project. The entry of troops from Rwanda and SADC, while contributing to some subsequent stabilization, revealed a deficit in sovereign response capacity and fuelled fears about sovereignty and external strategic interests (Fabricius, 2021).

2.1.3 Reputational and Sustainability Risk

Another factor that contributed to the postponement of the project was the reputational risk faced by TotalEnergies. Growing pressure from international public opinion, civil society organizations and institutional shareholders on issues such as human rights, the environment and corporate responsibility made it unsustainable to continue with the project without minimum guarantees of safety and respect for the rights of local populations (Amnesty International, 2021). TotalEnergies, as a company listed on European stock exchanges and subject to strict sustainability standards, was compelled to suspend the project in order to preserve its image and corporate values. Continuing operations amid massacres and forced displacement would have serious implications for global public perception and risk assessments by rating agencies and institutional investors (Sachs & Warner, 2022). In this sense, the postponement of the project can be interpreted not only as an operational decision, but as a rational strategic option aligned with Real Options Theory, which recognizes the value of postponing investment until the environment presents minimum conditions of stability. This approach allows the value of the project to be preserved without compromising the company's strategic position in the global liquefied natural gas market.

2.2 Economic and Strategic Impacts of the Real Options Theory Approach for Mozambique

TotalEnergies' decision to temporarily suspend the Mozambique LNG project in light of Real Options Theory (ROT) has profound implications for Mozambique from both an economic and strategic perspective. Although the decision to postpone the investment was rational from a business perspective, its effects on the national economy, institutional stability and the attraction of foreign direct investment (FDI) deserve careful analysis. This section discusses the main impacts, grouping them into three areas: macroeconomic impacts, impacts on the investment environment, and strategic impacts on governance and national security.

2.2.1 Macroeconomic Impacts

The suspension of the Mozambique LNG project led to a significant decline in national economic growth expectations. Between 2017 and 2020, the Mozambican government projected a substantial increase in gross domestic product (GDP), tax revenues and employment levels, driven by the start-up of natural gas megaprojects in the Rovuma Basin (MEF, 2020). The decision to postpone the construction and operation phase of the project consequently delayed the materialization of these gains. According to the Bank of Mozambique (2022), the impact was visible in the reduction of foreign direct investment flows in 2021, the devaluation of the metical and the increase in the external deficit. The slowdown in investment also translated into lower revenues for the State, both in direct taxes (such as Corporate Income Tax IRPC) and in fees and contributions associated with the energy sector. In addition, the interruption of the project compromised the creation of formal employment in the regions involved. It is estimated that more than 3,000 workers lost their jobs after TotalEnergies declared force majeure (UNDP, 2022). This situation exacerbated poverty and food insecurity in districts already affected by armed violence, such as Palma and Mocímboa da Praia.

2.2.2 Impacts on the Investment Environment

From a business environment perspective, TotalEnergies' strategic decision to suspend the project highlighted to the international community the high degree of risk associated with investing in Mozambique. Potential investors began to include the risk of armed conflict and institutional instability in their feasibility analyses, which raised the country's risk premium and negatively affected its reputation as a safe destination for capital (Hanlon, 2021). The TOR approach, which favors flexibility and rational postponement of decisions in uncertain contexts, reveals a structural truth that directly affects market confidence: the Mozambican state does not currently offer sufficient guarantees for the protection of strategic investments. This means that even if the economic fundamentals are promising (such as proven natural gas reserves), the absence of political stability and security undermines the implementation of projects. This effect can be compared to the phenomenon known in the literature as real options paralysis, in which multiple investors prefer to wait indefinitely for a safer environment, collectively postponing investments and creating a vicious cycle of underinvestment (Dixit & Pindyck, 1994; Trigeorgis, 1996). This scenario makes it urgent to strengthen the Mozambican state's institutions and promote structural reforms that instil confidence in economic agents.

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2.2.3. Strategic Impacts on Governance and National Security

Finally, TotalEnergies' adoption of a TOR-based approach had significant strategic effects on governance and national security. The suspension of the project highlighted the Mozambican state's fragility in protecting strategic assets, managing conflicts and coordinating with international actors. This perception weakens the state's sovereignty and its ability to control the national territory. At the same time, the forced postponement of the project created a strategic opportunity for the government to rethink its model of natural resource governance. As Macuane (2020) argues, the excessive centralization of the benefits of megaprojects, without the proper inclusion of local communities, has contributed to social resentment and the symbolic legitimization of violence. The pause in investment can therefore be used to redefine benefit-sharing mechanisms, strengthen transparency in contracts and promote more inclusive local development policies. From a geopolitical point of view, the postponement also exposed Mozambique's growing dependence on foreign military and technical aid, especially from countries such as Rwanda and members of the SADC. This dependence may have medium-term consequences, such as the cession of areas of influence or the limitation of autonomy in the formulation of internal security policies (Fabricius, 2021). Thus, TotalEnergies' application of TOR also drove a new dynamic in diplomatic and regional defence relations, forcing Mozambique to strategically reposition itself.

In summary, TotalEnergies' decision to apply the principles of Real Options Theory to its investment in Mozambique had ambivalent effects. While it was a rational and prudent strategy from a business perspective, it also revealed and exacerbated the host country's economic and institutional weaknesses. The negative macroeconomic impacts were exacerbated by an international perception of high risk, which compromised investment flows and market confidence. However, this scenario also paves the way for strategic reflections on the part of the Mozambican state, which can use this 'forced break' to correct asymmetries, improve governance, reform its institutions and build an environment conducive to sustainable and secure investment. Real Options Theory, in this context, not only guides business decisions, but also offers a mirror for the challenges and possibilities of developing economies such as Mozambique.

2.3 Application of Real Options in the Case of TotalEnergies in Cabo Delgado (2021–2025)

The Mozambique LNG project, led by TotalEnergies, is a paradigmatic case of investment under high uncertainty. The context of Cabo Delgado, marked by military instability, institutional challenges and energy market volatility, provided fertile ground for the application of real options as a strategic flexibility management mechanism. The following is an analysis of the main types of real options exercised or implicitly considered by TotalEnergies in this project.

2.3.1 Postponement Option

The formal suspension of the project in April 2021, through a force majeure declaration, clearly represented the exercise of the postponement option. The company chose to postpone the investment until security conditions were minimally assured, avoiding exposure to operational losses and high reputational risks. The decision to postpone reflects a prudent strategy in the absence of real guarantees of stability in the Palma area (TotalEnergies, 2021). This postponement preserves the value of the project over time, allowing the company to wait for more favourable information about the regional situation and reduce the associated uncertainty.

2.3.2 Staging Option

Even before the suspension, the Mozambique LNG project was structured in distinct investment phases, as is common in extractive industry megaprojects. The initial phase included geotechnical studies, construction of logistical infrastructure and acquisition of heavy equipment. By modulating investments, TotalEnergies exercised a staging option, assessing the risks and results of each phase before moving on to the next. This model protects the investor from committing total capital at the outset and allows for informed sequential decisions, in line with Trigeorgis (1996).

2.3.3 Abandonment Option

Although it has not been exercised, the abandonment option has remained latent in TotalEnergies' strategic portfolio. In the event of continued deterioration in security conditions or unfavorable changes in the global gas market, the company would be justified in abandoning the project and redirecting its resources to other jurisdictions. The force majeure declaration itself leaves this possibility open, serving as a warning that, without structural improvements, the project may be abandoned permanently (Duarte, 2021).

2.3.4 Growth Option

Investment in Cabo Delgado is not limited to natural gas extraction; it opens the door to a wider range of opportunities in the future, including regional exports, infrastructure construction, energy supply to neighboring countries and leadership in Asian LNG markets. This strategic nature gives the project a growth option, whose value is anchored not only in the direct return on the initial investment, but also in the potential for geopolitical and commercial expansion.

2.3.5 Expansion Option

Although the initial phase of the project focuses on the liquefaction and export of fixed volumes of gas, the technical design allows for future expansion, based on the performance of the first phase and international market dynamics. The possibility of building new liquefaction units (additional LNG trains) will depend on the stabilization of the province and the commercial success of the first exports. This sequential logic reflects the expansion option, common in global energy projects (BP, 2023).

2.3.6 Technological Change Option (Switching)

Although not the main focus of the project, TotalEnergies has adopted energy transition policies, and its assets in Mozambique may, in the future, be integrated into hybrid systems or energy solutions with a lower carbon footprint. Thus, there is a latent possibility of converting part of the operations to less carbon-intensive solutions, representing a technological change option as global regulatory and environmental requirements evolve. In short, the case of TotalEnergies in Cabo Delgado demonstrates how, even without explicit mention of TOR, large corporations incorporate real options implicitly in practice. By temporarily suspending the project, modulating investment in phases, keeping open the possibility of abandonment, and structuring itself for future expansion, the company protects its capital and acts strategically in a hostile environment. From an academic and political point of view, recognizing these options can help the Mozambican government to better understand the decision-making mechanisms of foreign investors and to design policies that reduce factors of uncertainty, allowing these options to be exercised positively in the national territory.

2.4 Real Options Valuation Models

The Real Options Theory (ROT) adapts tools originally developed for financial markets—such as call and put options—to the analysis of investment projects under uncertainty. The valuation of these options requires the use of quantitative models that estimate the value of the strategic flexibility embedded in projects. The most commonly used models in literature and practice include: the Black-Scholes model, the binomial model, the Monte Carlo simulation model, and decision tree models with embedded flexibility. Each presents advantages and limitations, depending on the type of project and the degree of uncertainty involved.

Black-Scholes Model (1973)

The Black-Scholes model is the most classic tool for valuing financial options, and it has been adapted by several authors for the analysis of real investment projects. It is based on the idea that the option value depends on the underlying asset price (in this case, the value of the project), the exercise price (investment cost), the volatility of the asset, the time to expiration, and the risk-free rate. In the valuation of real options, the formula takes the following form:

Option Value = f(NPV, I, σ, r, t)

Where:
- NPV = Expected Net Present Value of the project;
- I = Initial investment (exercise price);
- σ = Volatility of the NPV;
- r = Risk-free interest rate;
- t = Time until the decision.

Limitation: The model assumes log-normal distribution of returns, perfect markets, and absence of dividends assumptions that are often unrealistic for many real-world projects (Trigeorgis, 1996).

Binomial Model (Cox-Ross-Rubinstein, 1979)

This model constructs a discrete-time binomial tree, in which the value of the underlying asset can either increase or decrease at each period. At each node, the investor can choose to exercise the option (e.g., invest, abandon, expand) or wait.

Advantages:
(i) Allows the incorporation of multiple options and intermediate decisions; (ii) Can model multi-stage (phased) projects; (iii) Is more flexible than the Black-Scholes model for complex projects.

Practical Application:

Widely used in infrastructure, energy, gas, and mining projects such as the case of TotalEnergies where each phase of the project can be viewed as a node in the tree with associated strategic options.

Monte Carlo simulation

Monte Carlo simulation allows complex and non-linear scenarios to be modelled, with multiple uncertain variables. It consists of generating thousands of possible trajectories for the project value, based on probability distributions. Advantages: (i) Allows you to model interactions between variables; (ii) Suitable for projects with multiple sources of uncertainty; (iii) Can include stochastic volatility, correlation between factors, among others. Limitation: High computational complexity and need for rigorous para Decision Tree with Flexibility (Decision Tree with Real Options). This model combines qualitative analysis with real options logic. The traditional decision tree is enriched with optional branches, i.e., alternative paths that represent strategic decisions (postpone, expand, abandon). Application: Very useful in contexts where you want to communicate risks and decisions visually and sequentially, such as in the analysis of public investments or government concessions. The choice of real options evaluation model should depend on the nature of the project, the level of uncertainty, the availability of data and the analytical capacity of the management team. In complex projects such as Mozambique LNG, the use of binomial or simulation models may prove more appropriate, as they allow for the capture of multi-dimensional uncertainty (security, political, environmental and economic) and the sequential flexibility of the decision to invest, postpone or abandon.

3. Methodology

3.1 Methodological Approach

This study adopted a qualitative, exploratory and interpretative approach with the aim of gaining an in-depth understanding of the strategic rationale underlying TotalEnergies' investment decision in the Mozambique LNG project, in light of Real Options Theory (ROT). The qualitative approach is justified by the complexity of the phenomenon under analysis, which involves economic, political, security and strategic factors that cannot be fully captured by exclusively quantitative methods. According to Flick (2009), the qualitative approach is appropriate when the objective of the research is to understand the meanings and contexts that structure the actions of social actors, in this case, TotalEnergies' business decisions in the face of an uncertain and volatile environment such as that of Cabo Delgado.

3.2 Type of Study

This is a single case study with a descriptive-explanatory design, focused on analyzing the strategic behavior of a transnational company in the face of severe uncertainty. Case studies are particularly useful for examining situations where the boundaries between the phenomenon and its context are not clearly defined (Yin, 2015), as is the case with the relationship between extractive investment and socio-political instability in Mozambique.

3.3 Data Collection Technique

Data collection was based on document analysis and semi-structured interviews. The following were analyzed: Institutional reports from TotalEnergies (2021–2024); Publications from national bodies such as the Bank of Mozambique and the Ministry of Economy and Finance; Documents from international organizations (such as the IMF, World Bank, ISS Africa); Academic articles on Real Options Theory, risk management in extractive projects and the Mozambican economy; Interviews with experts in energy, economics and security (conducted between February and April 2025). The document analysis allowed us to construct a timeline of events that affected the Mozambique LNG project, while the interviews provided insights into the factors of uncertainty considered by the company and the economic and strategic impacts of its decision.

3.4 Data Analysis Technique

Data analysis was performed based on content analysis, as proposed by Bardin (2011), with the support of predefined categories derived from the literature on Real Options Theory. The main analytical categories included: (i) Options exercised (postponement, expansion, abandonment); (ii) Sources of uncertainty (security, politics, market, regulation); (iii) Strategic flexibility; (iv) Economic and institutional impacts. Methodological triangulation was also applied, cross-referencing the data obtained in the interviews with official documents and theoretical foundations to ensure greater validity and reliability in the interpretation of the results.

3.5 Temporal and Spatial Delimitation

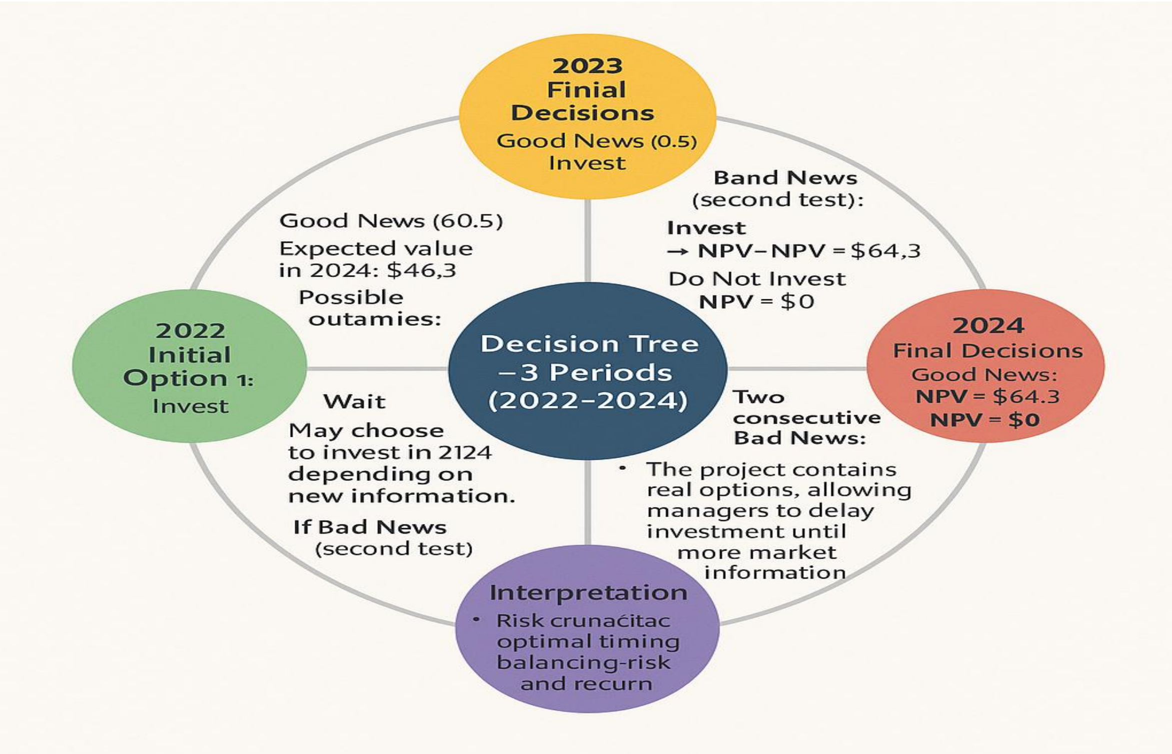
The study focuses on the period between 2021 and 2025, corresponding to the suspension and reassessment phase of the Mozambique LNG project by TotalEnergies. The analysis focuses on the province of Cabo Delgado, in northern Mozambique, but also considers the effects at the national and international levels, given the magnitude of the investment.

3.6 Justification of Methodology

The qualitative approach was chosen due to the contextual and strategic nature of the decision analyzed, which cannot be reduced to isolated financial calculations. The logic of real options involves the perception of risk, the subjective assessment of flexibility, and the strategy for responding to uncertain external events, elements that are better understood through description, interpretation and comparison of points of view than through purely statistical methods. In addition, qualitative analysis allows for the integration of multiple political, economic, environmental, and social dimensions into a single comprehensive model, contributing to the formulation of recommendations that dialogue with the institutional reality of Mozambique.

4 Presentation and analysis of results

Figure: 1 Three-period decision tree



Source: Produced by the author, 2025

4.1 Option to Defer (Real Option to Defer)

Figure: 2 Option to defer

Parameter	*Value*
Current estimated project value (S)	30,000,000 MZN
Total investment cost (K)	25,000,000 MZN
Project value volatility (σ)	20% per annum
Time to decision (T)	2 years
Risk-free rate (rf)	6% per annum

Source: Produced by the author, 2025

• Estimated present value of the project (S): 30,000,000 MZN; Investment cost (K): 25,000,000 MZN; Project volatility (σ): 20% per annum; Decision time (T): 2 years; Risk-free rate (rf): 6% per annum. Objective: To assess whether it is advantageous to postpone the investment to observe the future environment, rather than investing immediately.

Using the Black-Sholes model for call options:

$$d1 = \frac{ln(S/K) + (r + \sigma^2/2)T}{\sigma\sqrt{T}}$$

d2 = d1 - σ√T

C = S × N(d1) - K × e^(-rT) × N(d2)

Replacing the values:

ln(S/K) = ln(30.000.000 / 25,000,000) ≈ 0,182

$\sigma^2/2 = (0{,}20)^2 / 2 = 0{,}02$

σ√T = 0,20 × √2 ≈ 0,2828

$$d1 = \frac{0{,}182 + (0{,}06 + 0{,}02) \times 2}{0{,}2828} \approx 0{,}932$$

d2 = 0,932 - 0,2828 ≈ 0,649

Using the standard normal distribution table:

N(d1) ≈ 0,824, N(d2) ≈ 0,742

Applying the final formula:

C = S × N(d1) - K × e^(-rT) × N(d2)

C = 30.000.000 × 0,824 – 25,000,000 × e^(-0,12) × 0,742

e^(-0,12) ≈ 0,8869

C ≈ 24,720,000 – 25,000,000 × 0,8869 × 0,742

C ≈ 24,720,000 - 16.411.673

C ≈ 8.308.327

Interpretation: Postponing the investment for two years while observing the market generates additional strategic value of more than MZN 8 million. This value represents the flexibility of not committing to the investment now.

4.2 Abandonment Option

In this example, a company may terminate a project if it becomes unfeasible.

Data: • Expected net present value of the project: NPV = - 3,000,000 MZN (negative scenario); Recovery value if the project is abandoned: 5,000,000 MZN; Volatility of the project value (σ): 30%; Decision time: 1 year; Risk-free rate: 5%

As this is a put option, Use the Black-Scholes formula for put:

P = K × e^(-rT) × N(-d2) - S × N(-d1)

$$d1 = \frac{ln(S/K)\ +\ (r\ +\ \sigma^2/2)T}{\sigma\sqrt{T}}$$

Where: S = project value = 3,000,000 MZN; K = recovery value = 5,000,000 MZN; σ = 30%;

T = 1 year; r = 5%

Calculation:

ln(S/K) = ln(3M / 5M) = ln(0,6) ≈ -0,511

$$d1 = \frac{ln(S/K)\ +\ (r\ +\ \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d1 = \frac{(-0{,}511\ +\ (0{,}05\ +\ 0{,}045)}{0{,}3} \approx\ -0{,}513$$

d2 = d1 - σ√T = -0,513 - 0,3 ≈ -0,813

N(-d1) ≈ N(0,513) ≈ 0,695,

N(-d2) ≈ N(0,813) ≈ 0,791

P = K × e^(-rT) × N(-d2) - S × N(-d1)

P = 5M × e^(-0,05) × 0,791 - 3M × 0,695 ≈ 4,756,000 × 0,791 – 2,085,000 ≈ 3,762,000 – 2,085,000 = 1.677.000

Cost of abandonment option: 1,677,000 MZN

Interpretation: Even if the project incurs losses, the abandonment option mitigates risks. With the possibility of recovering part of the costs, the total loss is drastically reduced. This acts as a kind of financial insurance built into the investment.

4.3 Expansion Option

Scenario data: • Current project value: 12,000,000 MZN; Additional expansion cost: 10,000,000 MZN; Expected volatility of additional cash flow (σ): 25%; Decision time: 1 year; Risk-free rate: 4%. The Black-Scholes formula for call options.

C = S × N(d1) - K × e^(-rT) × N(d2)

Assuming that the expected additional value of the expansion (S) is 12,000,000 MZN.

Expansion cost (K): 10,000,000 MZN

ln(12M / 10M) ≈ 0,182, σ = 0,25, T = 1

d1 = (0,182 + (0,04 + 0,03125)) / 0,25 ≈ 0,852

d2 = 0,852 - 0,25 = 0,602

N(d1) ≈ 0,802, N(d2) ≈ 0,726

C = 12M × 0,802 - 10M × e^(-0,04) × 0,726 ≈ 9,624,000 – 6,976,000 = 2.648.000

Interpretation: If the project demonstrates good initial performance, expansion offers valuable additional returns. The option has high value even before expansion occurs, demonstrating the growth potential inherent in the project.

4.4 Critical Comparison of the Three Options

Figure: 3 Option Type Calculated Value Strategic Interpretation

Tipo de Opção	***Valor Calculado***	***Interpretação Estratégica***
Wait	8.308.327 MZN	Avoids hasty decisions; ideal in uncertain contexts
Abandon	1.677.000 MZN	Reduces losses; values flexibility in the face of failure
Expand	2.648.000 MZN	Increases potential profits, ideal if the scenario improves after the start.

Source: Produced by the author, 2025

• The wait option has the highest value, as it maximizes the benefit of future information; the expand option adds value if the project is successful; the abandon option protects against the risk of failure.

4.5 Case Study: TOTAL ENERGIES in Mozambique

The decision to resume TotalEnergies' investments in the liquefied natural gas (LNG) project in Cabo Delgado represents a direct application of real options theory. After suspending operations for security reasons, the company chose to “wait” until the environment was more favorable. The analysis of this decision can be modelled as a wait option, and an assessment is made as to whether this wait adds value. Data based on public sources (INP, 2024) and approximate data:

• Estimated project value (S): $50 billion; Additional cost of resumption (K): $40 billion; Estimated volatility: 18%; Horizon: 3 years; Risk-free rate: 4.5%

Applying the Black-Scholes model to calculate the value of the option to resume the project:

$$d1 = [\ln(S/K) + (r + \sigma^2/2)T] / (\sigma\sqrt{T})$$

$$d2 = d1 - \sigma\sqrt{T}$$

$\ln(50B/40B) \approx \ln(1,25) \approx 0,223$

$\sigma\sqrt{T} = 0,18 \times \sqrt{3} \approx 0,3112$

$d1 = (0,223 + (0,045 + 0,0162) \times 3) / 0,3112 \approx 1,151$

$d2 = 1,151 - 0,3112 = 0,84$

$N(d1) \approx 0,874, N(d2) \approx 0,799$

$C = 50B \times 0,874 - 40B \times e^{(-0,135)} \times 0,799$

$e^{(-0,135)} \approx 0,8737$

$C \approx 43,7B - 27,9B = 15,8$ billion

5. Discussion of results

The analysis carried out using real options theory clearly demonstrated the importance of management flexibility in investment decisions, especially in contexts of high uncertainty, such as the extractive industry in Mozambique. The simulations carried out for three different types of options wait, abandon, and expand revealed distinct but complementary strategic contributions to the decision-making process. The wait option proved to be the most valuable among those evaluated, with a value of MZN 8,308,327. This result indicates that postponing the investment for a two-year time horizon allows the company to observe future market conditions, reduce risk exposure and increase the value of the project. As Trigeorgis (1996) and Copeland and Antikarov (2003) point out, the value of waiting is based on the principle that the flexibility to wait for new information can be more valuable than immediate investment, especially in volatile environments. The abandonment option, with a value of MZN 1,677,000, proved essential for downside risk management. In situations where the net present value (NPV) of the project is negative, as in the scenario studied (-MZN 3,000,000), the possibility of ceasing operations and recovering part of the costs is an effective mechanism for controlling losses. As Dixit and Pindyck (1994) point out, the option to abandon acts as an insurance policy against investment failure. The option to expand, estimated at 2,648,000 MZN, proved to be strategic for projects with growth potential if the initial results prove positive. The possibility of scaling up operations allows additional value to be captured in optimistic scenarios, reinforcing the view that investment should be treated as a dynamic and iterative process.

6. Final considerations

The practical application of these concepts in the case of TotalEnergies in Mozambique, specifically in the decision to resume the Mozambique LNG project in Cabo Delgado, revealed the relevance of real options theory in the analysis of large-scale, high-risk investments. The Black-Scholes model, when applied with approximate data (project value: USD 50 billion; resumption cost: USD 40 billion; volatility: 18%; horizon: 3 years; risk-free rate: 4.5%), resulted in an option value of approximately USD 15.8 billion. This magnitude demonstrates that the company's decision to postpone the resumption of the project until security and stability conditions were restored was financially justifiable. In summary, it can be concluded that the incorporation of real options in investment evaluation constitutes a significant methodological advance over traditional models based exclusively on NPV. This approach allows capturing the value of flexibility, adaptability, and strategic responsiveness of companies in the face of uncertain scenarios, as corroborated by Amram and Kulatilaka (1999). The use of real options is therefore not only desirable but essential in sectors such as extractive industries, where economic, political, and social risks are strongly present.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

Funding

The author received no financial support for the research, authorship and publication of this article.

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