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Real Options Valuation: The Case of Pedestrian Paths in Madeira Island

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Master in Finance

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Resumo

O turismo de natureza desenvolvido em percursos pedestres está em crescimento. Porém, a fruição desregrada dos trilhos pode levar a consequências económicas e ambientais irreversíveis, pelo que a atração de visitantes implica a implementação de práticas sustentáveis, investimento em infraestruturas turísticas e cobertura dos custos de conservação local. A taxação turística é um instrumento eficaz, mas a aceitação da sua implementação depende das preferências dos turistas, cada vez mais conscientes dos problemas ambientais, e do conhecimento sobre o destino da aplicação da taxa. O presente estudo visa avaliar a viabilidade dos percursos pedestres da ilha da Madeira, através do método de opções reais, considerando o número de utilizadores como fonte de incerteza. Numa primeira avaliação assumimos uma *Minimum Revenue Guarantee* e, mais tarde, um contrato *collar*, finito ou perpétuo, estabelecidos entre governo e promotores. Temos como objetivo perceber as repercussões na decisão do investidor com a limitação do subsídio, associada a uma quantidade máxima de utilizadores, e com a alteração da duração do contrato. É de salientar que os dois tipos de contratos procuram a minimização do risco para o investidor, mas o segundo destaca-se por considerar a questão da sustentabilidade dos percursos pedestres. Com base nos resultados obtidos, se o objetivo dos decisores políticos for incentivar o investimento imediato nos projetos da Levada das 25 Fontes e da Levada do Risco, então deverão oferecer um contrato *collar* aos promotores, no qual o incentivo é tanto maior quanto maior for a duração do contrato.

Palavras-Chave: Opções Reais; Turismo; Percursos Pedestres; Incerteza; Minimum Revenue Guarantee; Collar Contract.

Sistema de Classificação JEL: Q28, Z33

Abstract

Nature-based tourism developed on pedestrian paths is a growing tourism sector. However, its unregulated use can lead to irreversible consequences in economic and environmental terms, meaning that attracting visitors implies sustainable practices, investment in tourist infrastructures, and covering the costs of local conservation. Tourist taxation is considered an effective instrument, but the acceptance of its implementation depends on the preferences and the tourists' acknowledgement of its application, who are more aware of environmental problems. This study aims to assess the feasibility of the pedestrian paths projects in Madeira Island through the real options approach, considering the number of users per route as the main source of uncertainty for the project. In the first phase of the evaluation, we assume that there is a Minimum Revenue Guarantee and, later on, a collar contract, finite or perpetually established between the government and potential promoters. We intend to understand the repercussions on the investor's decision with the limitation of the subsidy, associated with a maximum number of users, and with the changes in the duration of the contract. Both contracts aim to minimize investors' risk, but the second one stands out by putting the issue of sustainability of pedestrian paths into the analysis. Based on the results, from the policymakers' point of view, if the objective is to encourage immediate investment in the *Levada das 25 Fontes* and *Levada do Risco* projects, then they should offer a collar contract to the promoters, in which the incentive is greater the greater the contract duration.

Keywords: Real Options; Tourism; Pedestrian Paths; Uncertainty; Minimum Revenue Guarantee; Collar Contract.

JEL Classification System: Q28, Z33

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Glossary of Acronyms

BSM – Black-Scholes-Merton Model

DCF – Discounted Cash Flow

DREM – *Direção Regional de Estatística da Madeira*

FIT – Feed-In Tariff

GBM – Geometric Brownian Motion

GDP – Gross Domestic Product

IFCN – *Instituto das Florestas e Conservação da Natureza, IP-RAM*

INE – *Instituto Nacional de Estatística*

MRG – Minimum Revenue Guarantee

MTG – Minimum Traffic Guarantee

NPV – Net Present Value

OECD – Organization for Economic Co-operation and Development

SP – Smooth Pasting Condition

SRARNAC – *Secretaria Regional de Ambiente, Recursos Naturais e Alterações Climáticas*

VM – Value-Matching Condition

UNESCO – United Nations Educational, Scientific and Cultural Organization

THR – *Turismo Hotelería y Recreación, S.A.*

Glossary of Symbols

- c_0 – Time-0 price of a European-style call option
- K_1 – Investment in fixed capital (initial investment cost)
- K_2 – Maintenance and security costs (annual marginal cost)
- p_0 – Time-0 price of a European-style put option
- Q^* – Investment trigger
- S_0 – Spot price
- $C(Q)$ – Value of the option to invest in a project with a collar
- H – Number of users ceiling (quantity cap)
- I – Total investment cost
- K – Strike price
- L – Number of users floor (quantity floor)
- $M(Q)$ – Value of the option to invest in a project with a MRG
- P – Tariff value (price)
- q – Dividend yield
- Q – Number of users per pedestrian path
- r – Riskless interest rate
- $S(Q, T)$ – Forward-start perpetual collar
- $V(Q, T)$ – Value of the project until T
- $V(Q)$ – Value of the project
- μ – Deterministic drift
- Π – Profit of the project
- σ – Volatility
- T – Time to maturity

1. Introduction

The value of Madeira Island's pedestrian paths makes it an election destination for those looking for tourist activities linked to nature. However, their use involves risks both for users and for the ecosystem itself. The unregulated and abusive use of pedestrian paths causes erosion and destruction. Therefore, it accumulates unnecessary risks that jeopardize the quality of the paths and the safety of users, which can lead to irreversible consequences in terms of attracting visitors. For this, Madeira Island cannot only rely on the beauty of its natural legacy, but has to assure clear and rigorous procedures and regulations that guarantee the offer of a product and service of quality, in which the conditions of safety, comfort and experience suitable for the practice of hiking, supported by the integrity of ecosystems, are fundamental.

The present study was motivated by the public discussion that preceded the recent publication of the new Legal Regime for Pedestrian Paths in Madeira Island (Regional Legislative Decree n. 24/2022/M), which aims to establish guidelines and assign powers to the intervening entities to guarantee sustainable development of nature activities. Given the relevance of the topic in the current public discussion, not only at the political level, but also involving all potential investors, this can contribute to future models and make the difference between the success and failure of investments in situations with similar conditions.

For the use of pedestrian paths to occur under the conditions described above and to be economically viable, it must generate revenues that, despite being limited by the maximum load per path that allows a balance between user enjoyment and sustainable conservation, are capable of covering the expenses inherent to the maintenance of the trails.

Our goal is to investigate, through the real options approach, the feasibility of investing in pedestrian paths in Madeira Island, considering the uncertainties of the number of users interested in this product and others arising from its natural limitations. In this way, this case study could serve as a basis for potential investors' decision-making in investment projects like this.

In addition, we seek to help investors and policymakers define an efficient payment modality and the tariff value that users are willing to pay. Furthermore, our main purpose is to help policymakers to make political decisions by identifying the amount to be supported, in this case by the Regional Government of Madeira, when the minimum number of users that make the investment viable is not verified and considering that they need to take into account the maximum load that guarantees the sustainability of pedestrian paths and the natural heritage of the place. In

addition, this case study will help define the duration of the Minimum Revenue Guarantee (MRG). Finally, this thesis will also be useful for the users of the pedestrian paths, since it will help them understand why they have to pay a tourist tariff to enjoy the trails.

In spite of increasing demand for nature-based tourism, to the best of our knowledge, there are no papers about real options evaluation in nature-based tourism projects, namely in the pedestrian paths. Our second contribution to the literature is the adaptation of the analytical formulas normally used to evaluate, under the Geometric Brownian Motion (GBM) assumption, Feed-in Tariff (FIT) and collar contracts from a perspective of quantity uncertainty, instead of price, and the connection of this methodology to environmental sustainability.

That said, our main research question is whether or not it is worth investing in pedestrian paths in Madeira Island. However, to get a more consistent answer, we raise other questions: Why should the real options method be used in detriment of traditional valuation methods? What is the uncertainty associated with pedestrian paths? What is the quantity floor (L) that guarantees the viability of the investment? And what is the quantity cap (H) that guarantees the sustainability of pedestrian paths? Do the levels defined for L and H influence the promoters' investment decision? If yes, to what extent? And if the Regional Government is only willing to guarantee an L for a certain period of time, does that influence the promoters' decision-making? Under what conditions would the promoter be willing to invest? Is it useful to exercise the option to invest in this project?

In addition, we are interested in knowing if users are willing to pay for this tourism product, if so, how much? What effects can the application of tourist tariffs have on the viability of the investment?

In order to achieve the aforementioned goals, our study uses data provided by the Regional Government of Madeira and by some Municipal Councils about maintenance costs per path kilometer and associated infrastructures. Additional data was provided by the University of Madeira about the carrying capacity.

Bearing in mind that the tourist tariff is fixed, we assume that the main variable that influences the promoter's decision-making is the number of users per pedestrian path (Q). Thus, considering that this variable is the main source of uncertainty and presents a given random behavior, we assume, for simplification, that it follows a GBM process. Furthermore, assuming that Regional Government of Madeira is able to guarantee the amount related to the minimum number of users per pedestrian path that makes the investment viable we will basically deal with a MRG, but in

terms of users' quantity. However, due to sustainability issues, it is also necessary to limit pedestrian paths, and therefore the subsidy, to the maximum number of users, so, in this case, we will have to deal with a collar contract, but again in terms of users' quantity.

Depending on whether the Regional Government of Madeira establishes a minimum guarantee for a finite period of time or perpetually, we will deal, respectively, with finite maturity contracts or perpetual contracts. However, regardless of their duration, these contracts are linked to investment options: an option for developers to recover part of their losses in the case of the MRG policy and, additionally, an option for the government to be compensated in the case of the Collar scheme. For this reason, traditional evaluation methods should not be used as they fail to capture flexibilities and uncertainties, not forgetting that we are evaluating projects associated with natural resources endowed with uncertainty.

Based on the results obtained for the assumed parameters, if the government's objective is to make promoters to invest immediately in the *Levada das 25 Fontes* and *Levada do Risco* projects, it must guarantee a minimum number equal to 125,588 and 108,099 annual users, respectively. Furthermore, based on the study, from the point of view of accelerating investment, it is preferable for policymakers to offer a Collar scheme to the detriment of the MRG policy. As we increase the cap, the Collar trigger converges to the MRG trigger. Additionally, the incentive to invest is accelerated the lower the cap, up to a certain level, and the longer the contract duration.

According to the study carried out, the behavior of the value of the option linked to MRG differs from that associated with the Collar contract, in relation to the duration of the contract. In the first, as the duration increases, the value added to the project increases and, in the second, the opposite was observed. Even so, in both cases the value of the option increases as the volume floor increases and is more evident in the option associated with the MRG policy, even though it is more sensitive to risk.

Finally, increasing the tourist tax to be paid by users is a measure that can be adopted by the government to encourage promoters to invest in projects, since the investment trigger decreases as the price increases. Even so, this price increase must be well justified to users and must be converted into an improvement in the conditions of the routes.

2. Review of Literature

In this section, in order to understand and update what is currently known about the topic of this thesis, we present an overview of the results that have been discussed in the literature.

With the aim of obtaining answers to the research questions raised above, it makes sense that this part addresses the themes of nature-based tourism, namely in trails and paths, its taxation, and its sustainable development. In a second phase, given the uncertainties associated with nature-based tourism projects and taking into account the carrying capacity limit necessary for the quality of natural resources not to be compromised, real options methods capable of financially evaluating this type of investment will be analyzed.

2.1 Tourism, Tourist Taxation, and Sustainability

Nature-based tourism, one of the fastest growing tourism sectors, is gaining recognition and great proportions around the world to the point of transforming many lands and protected areas into important tourist destinations (Raya et al., 2018; Winter et al., 2019).

According to Raya et al. (2018), in recent years, there has been a remarkable increase in the demand for trails and paths in natural areas, as it corresponds to an inexpensive way to do some physical activity and learn about local nature while enjoying it. Furthermore, the same authors also add that it has a great potential to cheaply attract tourists to nature-based destinations, and it is a potential driver of local economic well-being by generating income and employment, in an easy and low-polluting way, benefiting the local community and the tourists themselves (Adedoyin et al., 2023; Raya et al., 2018).

However, attracting visitors cheaply does not mean that there are no costs. Cárdenas-García et al. (2022) and Raya et al. (2018) defend that the use of pedestrian paths requires investment, maintenance and, eventually, some promotion costs to be considered attractive from a tourist point of view.

Moreover, we cannot forget that nature-based destinations are also subject to the negative consequences of tourist activity, since part of the economic benefits of tourism are achieved at the expense of environmental and sociocultural balance (Drius et al., 2019; Mota et al., 2021) such as overexploitation and deterioration of the environment that often leads to depletion or scarcity of natural resources jeopardizing the lives of local communities and also those who depend on tourism for their livelihood (Adedoyin et al., 2023). So, there is another set of costs that must be covered in these investments, which correspond to environmental and cultural conservation, as well as

maintenance, with the aim of guaranteeing an adequate and satisfactory experience for users (Cárdenas-García et al., 2022).

To deal with the aforementioned expenses, one of the most used instruments and, normally, adopted by governments, is the direct or indirect taxation of tourists (Adedoyin et al., 2023). According to Organization for Economic Co-operation and Development (OECD) (2014, as quoted in Durán-Román et al., 2021), tourism taxation corresponds to all types of taxes levied on tourism that seek not only to develop economy, but also to finance environmental protection, local promotion and investments in infrastructure that aim to improve the product (Durán-Román et al., 2021). In addition, this tool is considered effectively capable of minimizing the negative impacts resulting from tourism, maintaining its competitiveness and sustainability (Cárdenas-García et al., 2022; Durán-Román et al., 2021).

However, as much as tourism creates employment and contributes to economic development, its sustainability is a worldwide challenge (Niñerola et al., 2019). In the words of Butler (1999), tourism is a "double-edged sword" that, if not sustainable, can jeopardize the development of tourist destinations. That said, the notion of sustainable tourism is extremely relevant (Niñerola et al., 2019), and its practices have never been so important (Winter et al., 2019).

The World Tourism Organization (as quoted in Niñerola et al., 2019) defines sustainable tourism as one that meets the needs of visitors, the industry, the environment and the local community, taking into account the economic, social and environmental impacts on present and future generations. In addition, the concept of sustainable development in tourism requires the efficient management of resources to satisfy the needs of all participants; that is, an experience full of positive feelings for the tourist must be guaranteed while ensuring the well-being of the host community and the preservation of natural resources (Cárdenas-García et al., 2022; Durán-Román et al., 2021; Pulido-Fernández and López-Sánchez, 2016).

To develop sustainable tourism activities, we must also consider that tourist destinations have limits and the number of users and their behavior can overwhelm ecosystems and influence their resilience (Corbau et al., 2019; Mota et al., 2021; Wall, 2020). In this way, despite the difficulty of addressing this problem, tourist areas must have their carrying capacity defined, which corresponds to the maximum number of users that can be accepted in that place at a given time without compromising the quality of resources and the visitor's experience (Corbau et al., 2019; Komarudin et al., 2022; Mota et al., 2021; Wall, 2020).

This concept is a “multi-dimensional compromise” (Bertocchi et al., 2020, p. 3) that, despite not presenting a universal calculation methodology, must consider a variety of factors that are normally difficult to measure, namely social, physical, infrastructural, environmental and economic aspects (Mota et al., 2021). More specifically, it must take into account human needs and values, perception, satisfaction and experience of visitors, existing physical space and respective area used and time spent per person, grade of erodibility, difficulty of accessing the site and respective infrastructures, weather conditions and consequent safety conditions and risk of accidents (Mota et al., 2021).

Nevertheless, for sustainable development in tourism to be achieved, it is necessary to take effective policies, such as the tourist taxation mentioned above. However, the implementation of tourism taxation without considering the preferences of tourists and without informing them of the need, the respective benefits, and the destination of the additional costs can result in poor acceptance of the measure (Cárdenas-García et al., 2022), leading them to opt for alternative destinations, impacting negatively the flow of tourists (Durán-Román et al., 2021), which, consequently, reverses the main objective of the taxes, the increase of income. In other words, when the increase in tourist taxation does not correspond to the increase in government expenditure on tourism, we can expect a harm in the industry (Adedoyin et al., 2023).

Even so, we have to keep in mind that there have been significant changes in the profile of the typical tourist (Durán-Román et al., 2021). Despite being more demanding, tourists are increasingly aware of the impacts of tourist activity as they look for more authentic products, such as tourism in natural, clean and safe spaces (Pulido-Fernández and López-Sánchez, 2016), in order to live unforgettable and ecologically responsible experiences (Brandão et al., 2019; Winter et al., 2019). Hence, as evidenced in the results obtained by Tsvetanova and Seetaram (2018) and already previously mentioned by Pulido-Fernández and López-Sánchez (2016), visitors who are more aware of environmental problems and who are looking for unique memories in nature are willing to pay more for more sustainable tourist destinations. According to Cárdenas-García et al. (2022), this translates, for example, into an average expenditure of €1.02 from their daily budget for hiking and mountain climbing.

We can highlight nature-based tourism as an environmentally sustainable tourism sector, as long as it maintains a proper balance with the negative effects of receiving visitors (Raya et al., 2018), which is normally practiced by individuals with environmentally responsible behaviors (Kil

et al., 2014), but to be considered sustainable tourism, as we saw earlier, it is not enough that it is only environmentally sustainable, it also must be socio-culturally acceptable and economically viable (Niñerola et al., 2019).

2.2 Real Options

According to Brennan and Schwartz (1985), the evaluation of investments in natural resources is particularly complicated due to the high level of uncertainty that they entail, not only in terms of prices, but also because of the possibility of resource depletion. For this reason, the authors claim that the real options approach is effective when evaluating investments in natural resources.

The term of real options bears the signature of Myers (1977) and corresponds to the right and not the obligation, held by investors, to make a capital investment decision (Guo et al., 2020; Ng et al., 2004). The expression "real" comes from the fact that these valuation techniques are associated with investments in real assets and not in financial ones (Guo et al., 2020). Unlike traditional methods, such as the Net Present Value (NPV), the real options approach does not ignore the types of uncertainty associated with real assets and managerial flexibilities that are used in practice in investments (Barbosa et al., 2018; Guo et al., 2020).

The NPV method, normally used in the corporate world, calculates the value of the project as the difference between the present value of the project's cash inflows and outflows. This means it fails to capture the uncertainties and flexibilities mentioned above, which implies that it systematically undervalues investments (Barbosa et al., 2018; Guo et al., 2020). In addition, following the rule that all projects with positive NPV should be undertaken and assuming that only "now-or-never" decisions are allowed, it may result in inadequate choices (Barbosa et al., 2018; Guo et al., 2020).

As we know, managers can study the market and change or adapt their investment strategy to take advantage of good news or avoid bad ones and wait for more favorable market conditions (Barbosa et al., 2018). For this reason, the real options method emerged in the literature to overcome the limitations pointed out by traditional valuation methodologies based on Discounted Cash Flow (DCF) methods, and it is a good basis for evaluating nature-based tourism projects, as managerial flexibilities and uncertainties are incorporated into the analysis (Guo et al., 2020). However, because nature-based tourism is dependent on the availability and access to natural resources, its demand is not constant. Consequently, there is a risk that the project will not always be able to generate sufficient cash flow to cover the investment costs and still generate revenue;

this is called revenue risk (Rakić and Radenović, 2014; Shan et al., 2010). That said, and considering that private investors are averse to revenue risk, according to the authors above, it is extremely important to mitigate it, given that the involvement of promoters depends largely on the financial viability of the project. According to Brandao and Saraiva (2008) and Takashima et al. (2010), one of the solutions involves sharing the risk of the project between the promoter and the government, through a Public-Private Partnership in which the public entity provides some support.

2.2.1 Minimum Revenue Guarantees

The support mentioned above can take different forms (Takashima et al., 2010) including government guarantees, usually known as Minimum Traffic Guarantees (MTG) or MRG. In these schemes, the government and investors define the underlying asset, the users' quantity or the equivalent revenue, respectively, and establish the minimum amount (known as floor) to be guaranteed by the government (Brandao and Saraiva, 2008; Rakić and Radenović, 2014; Shan et al., 2010).

A floor is usually an interest rate, and it is similar to a put option, which protects its holder against a drop in revenues (Shackleton and Wojakowski, 2007). This put option secures the minimum value, as the investor has the possibility to sell the underlying asset at the price floor instead of the market price, which means that the option is exercised when the price floor is greater than the market price (Barbosa et al., 2018; Shan et al., 2010).

That being said, in this type of contract, investors have the option to claim from the government the amount corresponding to the reduction in demand or revenue in case the project's performance is worse than expected, recovering losses up to the pre-established guarantee level. So, the investor is protected against the negative risk; that is, if the market price is lower than the minimum value the promoter receives the value established in the contract; otherwise, he receives the market price (Barbosa et al., 2018).

According to Rakić and Radenović (2014) and Shan et al. (2010) this strategy is extremely important in projects with high levels of uncertainty and essential to boost their financial viability. An example of MRG, widely used by policymakers to encourage investments in renewable energies, is the FIT Contract with a minimum price regime (Couture and Gagnon, 2010), analyzed by Barbosa et al. (2018), that can take two different forms: a safer one, the market-independent FIT, in which the investor's income is independent of the market price of the asset, and a more encouraging one but with greater risk, the market-dependent FIT, through which the premium value

is added over the market price (Barbosa et al., 2020; Couture and Gagnon, 2010; Schallenberg-Rodriguez and Haas, 2012).

However, according to Barbosa et al. (2018), it should be noted that the protection mentioned before can easily be jeopardized if the price floor defined by the policymakers is too low, since investors hardly received the guarantee, or too high, destroying the incentive. In this way, the main challenge of this FIT contract's scheme is the definition of the price floor.

Another concern to have in this type of contract is the choice of its duration: they can have a finite or perpetual maturity. Based on the study of Barbosa et al. (2018), the perpetual guarantees are neither attractive nor economically viable because they can only encourage investments with levels below the floor when the value of the guarantee is greater than the investment cost and there is no risk. On the other hand, in guarantees with finite maturity investors are willing to invest even if the guaranteed revenue is lower than the investment cost. This is apparently an unexpected result since the perpetual guarantee does not cease if the investment does not occur. Furthermore, as the floor and duration increase, there is an anticipation of the investment decision. In both cases, investors postpone the decision in a situation where market conditions are more volatile (Barbosa et al., 2018).

However, although these guarantees reduce the risk for investors, they also bring increased responsibilities for public entities through possible future obligations (Brandao and Saraiva, 2008). Thus, it should be noted that the indiscriminate granting of government support can have significant impacts on societies and, therefore, it is extremely important that there is a balance when defining the level of guarantee. This should be within a range in which it is capable of making the projects economically viable, without overloading the government and without jeopardizing society (Brandao and Saraiva, 2008).

2.2.2 Collar Contracts

Nevertheless, the government's exposure to risk can be limited by setting a maximum ceiling, also known as a cap, after which disbursements cease (Brandao and Saraiva, 2008). Like a floor, a cap is normally an interest rate, but which in turn is similar to a call option as it protects its buyer from rising costs (Shackleton and Wojakowski, 2007), preventing producers from earning excessively and consumers from making excessive payments. Thus, in terms of interest rates, the cap guarantees that costs do not exceed a certain level since the option allows its holder to acquire the underlying asset at the cap price instead of the market price, which means that this option is

exercised when the cap price is lower than the market price (Adkins and Paxson, 2017; Ng et al., 2004; Shan et al., 2010).

However, in the context of an active project and from an investor's point of view, the cap is not beneficial. In this case, where revenues are considered instead of costs, this limit obliges the investor never to receive a price higher than the cap value, it is similar to a short position in a call option, there is a sacrifice of the appreciation potential. It is the other entity in the contract, usually the government, that takes the long position in the call and receives the difference between the cap and the amount that exceeds it (Adkins and Paxson, 2017).

The model that combines a floor and a cap is called a collar contract, and it is a combination of put and call options with different strikes that restrict a certain variable, such as price, volume or revenue, to a limited range (Adkins and Paxson, 2017; Shackleton and Wojakowski, 2007; Shan et al., 2010). So, in this type of guarantee, the investor, despite being protected if the market price falls below the agreed minimum amount, is limited by the ceiling; that is, he never receives an amount greater than the cap. There is a sacrifice of potentially high revenues that are normally captured by the government to fund the floor (Adkins and Paxson, 2017; Shan et al., 2010), which means that the role of the ceiling is to make the government guarantee as costless as possible and “inhibits the spread of any allegations of being over-generous” (Adkins and Paxson, 2017, p. 28).

According to Shan et al. (2010), the collar contract stands out for its flexibility resulting from the existence of two strike prices, since the government can set them higher or lower, depending on the level of risk it is willing to take. Another characteristic that distinguishes it is its effectiveness in risk management, since it has the ability to redistribute downside losses and upside profits to meet stakeholders' needs (Shan et al., 2010).

Furthermore, Adkins and Paxson (2017) and Barbosa et al. (2020) claim that this type of contract results in earlier investment decision-making because, in addition to guaranteed minimum revenues, part of the investment costs can be recovered through higher profits. Barbosa et al. (2020) also suggest that a collar contract is a better policy as it reduces costs; in other words, it avoids excessive earnings for producers or excessive payments for consumers. In addition, it is suitable for projects in the growth phase, with moderate cash flows and subject to volatile revenues throughout their lifetime (Shan et al., 2010).

Like MRG, collars present some challenges, namely in negotiating floors, caps, and the duration of the contract, which can also be finite or perpetual. Through the study of Adkins et al.

(2019), most collar contracts offered by governments have finite maturity and are not perpetual. Despite offering substantially less protection for the government in a situation of low market prices, the finite subsidies are less sensitive to volatility and changes in the price cap and can encourage an earlier investment decision even when floor and ceiling values are low.

To conclude this section, in addition to being the most suitable for the assessment of natural resources, given the uncertainties previously mentioned, it must be emphasized that the MRG and the collar contracts considered in the present study, due to their similarities with options, must be valued using an option pricing method such as the real options approach (Adkins et al., 2019; Brandao and Saraiva, 2008). In MRGs, these characteristics come from the fact that there is an option for investors to recover part of their losses from the government if the project performs poorly (Brandao and Saraiva, 2008). In the case of collar contracts, it is because of "the guarantee on the downside and bonus compensation for the government on the upside are expressible as real options, the sunk cost is partly irretrievable, deferral flexibility is present, and uncertainty prevails" (Adkins and Paxson, 2017, p. 3).

3. Methodology

Starting by following Dixit and Pindyck (1994) solution for a plain perpetual investment opportunity, we need to consider a monopolistic firm with the option to invest in a project whose value depends on a single source of uncertainty. In this study, we consider that the main source of uncertainty for the project is the number of users per pedestrian path (Q) that, for modeling and simplification purposes, we assume that this stochastic variable follows the GBM process, an assumption from the Black-Scholes-Merton Model (BSM) (Black and Scholes, 1973; Merton, 1973).

In 1973, Black and Scholes (1973) released the first arbitrage-free valuation method for European-style options on dividend-free stocks. In the same year, Merton (1973) extended the model to dividend-paying stocks and added stochastic interest rates. However, determining the value of future dividends and knowing the dates of the respective payments in long-term options is extremely difficult. The alternative involves introducing a continuous dividend yield forecast, which corresponds to the “portion of the rate of return on the underlying share that only arises from the payment of dividends” (Dias, 2022), that results in the BSM model.

According to the BSM model, the time-0 price of a European-style call option on an underlying asset with a spot price S , strike price K and with expiry date at time T (≥ 0) is represented by $c_0(S, K, T)$ and is equal to (Black and Scholes, 1973; Merton, 1973):

$$c_0(S, K, T) = S e^{-qT} N(d_1) - K e^{-rT} N(d_2), \quad (1)$$

where

$$d_1(S, K) = \frac{\ln \frac{S}{K} + (r - q + 0.5\sigma^2)T}{\sigma\sqrt{T}} \quad (2)$$

and

$$d_2(S, K) = \frac{\ln \frac{S}{K} + (r - q - 0.5\sigma^2)T}{\sigma\sqrt{T}}, \quad (3)$$

with $N(x)$ being the standard normal distribution, T the option's time to maturity, σ the annualized volatility of the underlying asset, r the continuously compounded short-term risk-free interest rate, and q being the continuously compounded dividend yield of the underlying asset.

Similarly, the price of a European-style put option with the same characteristics ($p_0(S, K, T)$), is equal to:

$$p_0(S, K, T) = K e^{-rT} N(-d_2) - S e^{-qT} N(-d_1). \quad (4)$$

However, this assumption implies that the variable under study is never negative, its volatility is constant and that it has independent fluctuations from those of other periods (Brandao and Saraiva, 2008; Ng et al., 2004). Since Q fits all these requirements it can then be represented as:

$$dQ = (r - q)Qdt + \sigma QdW_t^{\mathbb{Q}}, \quad (5)$$

where $(r - q)$ and σ are the risk-neutral drift and the volatility of the number of users, respectively. Additionally, $r \geq 0$ stands for the risk-free rate and $q \geq 0$ is the dividend yield. Furthermore, $dW_t^{\mathbb{Q}}$ corresponds to the standard Gauss-Wiener process under $\mathbb{Q}$. This equation demonstrates that, in the small interval dt , the percentage change in quantity $\frac{dQ}{Q}$ follows a normal distribution with mean $(r - q)dt$ and instantaneous variance $\sigma^2 dt$.

Assuming neither taxes nor operating costs are considered and that an investment cost I is required for the project, the value of the project after investment is represented by:

$$V(Q) = \frac{Q}{q}P, \quad (6)$$

where without loss of generality we set P equal to 1.

3.1 The Investment Opportunity with a MRG

In this section we assume that the government offers to promoters a MRG, where if the number of users of the pedestrian path is lower than L , the investor receives the amount that corresponds to the quantity floor; otherwise, he receives the value corresponding to the number of registered users.

Considering the minimum guarantee, the profit flow of the project with a MRG is given by $\Pi(Q, L, K_2) = \max(Q, L) \times P - K_2$, with P being interpreted as the tariff value and K_2 as the maintenance and security costs.

3.1.1 Investments with Perpetual MRG

We start by assuming that the MRG lasts for the entire lifetime of the project. Bearing in mind that $V_{Mp}(Q)$ is the value of the project, after applying the Itô's Lemma (Dixit and Pindyck, 1994) and the arguments from Barbosa et al. (2018) that precede it, we get that:

$$V_{Mp}(Q) = \begin{cases} A_1 Q^{\beta_1} + \frac{L - K_2}{r} & \text{for } Q < L \\ A_2 Q^{\beta_2} + \frac{Q}{q} - \frac{K_2}{r} & \text{for } Q \geq L \end{cases} \quad (7)$$

with

$$A_1 = \frac{L^{1-\beta_1}}{\beta_1 - \beta_2} \left(\frac{\beta_2}{r} - \frac{\beta_2 - 1}{q} \right), \quad (8)$$

and

$$A_2 = \frac{L^{1-\beta_2}}{\beta_1 - \beta_2} \left(\frac{\beta_1}{r} - \frac{\beta_1 - 1}{q} \right). \quad (9)$$

In addition, β_1 and β_2 are the solutions to the following quadratic equation:

$$\frac{1}{2} \sigma^2 \beta (\beta - 1) + \beta (r - q) - r = 0. \quad (10)$$

So,

$$\beta_1 = \frac{1}{2} - \frac{r-q}{\sigma^2} + \sqrt{\left(\frac{r-q}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2r}{\sigma^2}} > 1, \quad (11)$$

and

$$\beta_2 = \frac{1}{2} - \frac{r-q}{\sigma^2} - \sqrt{\left(\frac{r-q}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2r}{\sigma^2}} < 0. \quad (12)$$

Assuming now that an investor has a perpetual option to invest for a sunk cost K_1 , it is possible to determine the value of the option to invest, $M_p(Q)$, and the optimal trigger, Q_{Mp}^* .

Then, following the same steps as before, but without considering the perpetual profit flow, and after using the value-matching (VM) and the smooth pasting (SP) conditions, we can calculate the investment trigger, Q_{Mp}^* , by numerically solving the following non-linear equation:

$$(\beta_1 - \beta_2) A_2 Q_{Mp}^{*\beta_2} + (\beta_1 - 1) \frac{Q_{Mp}^*}{q} - \beta_1 \left(K_1 + \frac{K_2}{r} \right) = 0, \quad (13)$$

where K_1 corresponds to the investment in fixed capital.

However, this is only possible when $Q_{Mp}^* \geq L$, since VM and SP conditions are not met in Eq. (7) when $Q < L$. In this way, through Eq. (14), we can determine, I_{Mp}^* , the level of investment for which the trigger (Q_{Mp}^*) is equal to the price floor (L). If $I_{Mp}^* < K_1 + \frac{K_2}{r}$, it means that $Q_{Mp}^* \geq L$, so it is possible to use Eq. (13) to obtain Q_{Mp}^* .

$$I_{Mp}^* = \frac{L}{r}. \quad (14)$$

In addition, we can discover, the floor value from which the investment occurs immediately and generates a risk-free profit, L_{Mp}^* . An interesting point that can be obtained by the simplified following equation:

$$L_{Mp}^* = rK_1 + K_2. \quad (15)$$

Notice that the values of the trigger are only valid when $\frac{L}{r} - K_1 - \frac{K_2}{r} \leq 0 \Leftrightarrow \frac{L-K_2}{r} - K_1 \leq 0$, because $Q_{Mp}^* \geq L$. For this reason, we have to consider that investment will occur for $Q < L$, when $\frac{L}{r} > K_1 + \frac{K_2}{r}$, where it immediately generates a risk-free positive NPV for every Q . After that, we can find the value of the option to invest, $M_p(Q)$, that is given by:

$$M_p(Q) = \begin{cases} (V_{Mp}(Q_{Mp}^*) - K_1) \left(\frac{Q}{Q_{Mp}^*}\right)^{\beta_1} & \text{for } Q < Q_{Mp}^* \\ V_{Mp}(Q) - K_1 & \text{for } Q \geq Q_{Mp}^* \end{cases} \quad (16)$$

3.1.2 Investments with Finite-lived MRG

Assuming that the MRG has now a finite duration of T years, the value of the project until T , $V_{Mf}(Q, T)$, is given by:

$$V_{Mf}(Q, T) = \begin{cases} A_1 Q^{\beta_1} N(d_{\beta_1}) + \frac{L}{r} (1 - e^{-rT} (1 - N(d_0))) \\ - A_2 Q^{\beta_2} N(d_{\beta_2}) - \frac{Q}{q} e^{-qT} N(d_1) - \frac{K_2}{r} (1 - e^{-rT}) & \text{for } Q < L \\ - A_1 Q^{\beta_1} (1 - N(d_{\beta_1})) - \frac{L}{r} e^{-rT} (1 - N(d_0)) \\ + A_2 Q^{\beta_2} (1 - N(d_{\beta_2})) \\ + \frac{Q}{q} (1 - e^{-qT} N(d_1)) - \frac{K_2}{r} (1 - e^{-rT}) & \text{for } Q \geq L \end{cases}, \quad (17)$$

with

$$d_{\beta}(Q, L) = \frac{\ln \frac{Q}{L} + (r - q + (\beta - \frac{1}{2})\sigma^2)T}{\sigma\sqrt{T}}, \quad (18)$$

where $\beta \in \{0, 1, \beta_1, \beta_2\}$.

After T , the promoter continues to receive revenues from the users' taxation, which corresponds to a cash flow with a present value equal to $\frac{Q}{q} e^{-qT}$. So, the value of the project that includes the MRG period and thereafter, $V_{Mf}(Q)$, is equal to:

$$V_{Mf}(Q) = V_{Mf}(Q, T) + \frac{Q}{q} e^{-qT} - \frac{K_2}{r} e^{-rT}. \quad (19)$$

Following the same steps as in the perpetual MRG section, we obtain the following equations, that must be numerically solved, to find optimal exercise threshold, Q_{Mf}^* :

$$-(\beta_1 - \beta_2) A_2 Q_{Mf}^{*\beta_2} N(d_{\beta_2}) - (\beta_1 - 1) \frac{Q_{Mf}^*}{q} e^{-qT} (N(d_1) - 1) + \beta_1 \left(\frac{L}{r} (1 - e^{-rT} (1 - N(d_0))) - (K_1 + \frac{K_2}{r}) \right) = 0 \text{ for } Q_{Mf}^* < L, \quad (20)$$

$$\begin{aligned}
& (\beta_1 - \beta_2)A_2 Q_{Mf}^{*\beta_2} \left(1 - N(d_{\beta_2})\right) + (\beta_1 - 1) \left(\frac{Q_{Mf}^*}{q} (1 - e^{-qT} N(d_1)) + \frac{Q_{Mf}^*}{q} e^{-qT} \right) - \\
& \beta_1 \left(\frac{L}{r} e^{-rT} (1 - N(d_0)) + (K_1 + \frac{K_2}{r}) \right) = 0 \text{ for } Q_{Mf}^* \geq L.
\end{aligned} \tag{21}$$

However, in order to know which of the above equations to use, it is necessary to calculate the investment level, I_{Mf}^* , for when $Q_{Mf}^* = L$. To do so, we substitute L for Q_{Mf}^* in Eq. (21) and, after rearranging, we solved it for $I = K_1 + \frac{K_2}{r}$, which yields the following equation:

$$\begin{aligned}
I_{Mf}^* = & \left(\left(\frac{\beta_1}{r} - \frac{\beta_1 - 1}{q} \right) \left(1 - N \left(d_{\beta_2}(Q_{Mf}^* = L) \right) \right) + \frac{(\beta_1 - 1)}{q} \left(1 - e^{-qT} N \left(d_1(Q_{Mf}^* = L) \right) + \right. \right. \\
& \left. \left. e^{-qT} \right) - \frac{\beta_1 e^{-rT}}{r} \left(1 - N \left(d_0(Q_{Mf}^* = L) \right) \right) \right) \frac{L}{\beta_1}.
\end{aligned} \tag{22}$$

In this case, as we are dealing with the finite case, if $I_{Mf}^* < K_1 + \frac{K_2}{r}$ it means that $Q_{Mf}^* \geq L$, which implies that we have to use Eq. (21), otherwise we use Eq. (20).

In addition, we can also discover, L_{Mf}^* , that is the floor value from which the investment occurs immediately and generates a risk-free profit, by numerically solving the following non-linear equation:

$$\begin{aligned}
& \left(\left(\frac{\beta_1}{r} - \frac{\beta_1 - 1}{q} \right) \left(1 - N \left(d_{\beta_2}(Q_{Mf}^* = L) \right) \right) + \frac{(\beta_1 - 1)}{q} \left(1 - e^{-qT} N \left(d_1(Q_{Mf}^* = L) \right) + e^{-qT} \right) - \right. \\
& \left. \frac{\beta_1 e^{-rT}}{r} \left(1 - N \left(d_0(Q_{Mf}^* = L) \right) \right) \right) L_{Mf}^* - \beta_1 \left(K_1 + \frac{K_2}{r} \right) = 0.
\end{aligned} \tag{23}$$

Then, we can obtain the value of the option to invest, $M_f(Q)$:

$$M_f(Q) = \begin{cases} (V_{Mf}(Q_{Mf}^*) - K_1) \left(\frac{Q}{Q_{Mf}^*} \right)^{\beta_1} & \text{for } Q < Q_{Mf}^* \\ V_{Mf}(Q) - K_1 & \text{for } Q \geq Q_{Mf}^* \end{cases} \tag{24}$$

3.2 The Investment Opportunity with a Collar

Now, considering that the government is offering the promoter a collar contract, where additionally to the public entity guaranteeing the value corresponding to the minimum number of users of the pedestrian route, it defines a quantity cap to the variable in order to limit the load capacity.

Bearing in mind the model mentioned above, where the number of route users is limited by a floor and a ceiling, the profit of the project is given by $\Pi(Q, L, H, K_2) = \min \{ \max(Q, L), H \} \times P - K_2$.

3.2.1 Investments with Perpetual Collar

$V_{cp}(Q)$ denotes the value of an active project whose output quantity Q varies between L and H during an indefinite period. Taking into account what was mentioned in the MRG section and based on the work from Adkins et al. (2019) and Barbosa et al. (2020), we get the solution for $V_{cp}(Q)$:

$$V_{cp}(Q) = \begin{cases} A_{11}Q^{\beta_1} + \frac{L-K_2}{r} \text{ for } Q < L \\ A_{21}Q^{\beta_1} + A_{22}Q^{\beta_2} + \frac{Q}{q} - \frac{K_2}{r} \text{ for } L \leq Q < H, \\ A_{32}Q^{\beta_2} + \frac{H-K_2}{r} \text{ for } Q \geq H \end{cases} \quad (25)$$

with

$$A_{11} = \frac{(H^{1-\beta_1} - L^{1-\beta_1})}{\beta_1 - \beta_2} \left(\frac{\beta_2 - 1}{q} - \frac{\beta_2}{r} \right), \quad (26)$$

$$A_{21} = \frac{H^{1-\beta_1}}{\beta_1 - \beta_2} \left(\frac{\beta_2 - 1}{q} - \frac{\beta_2}{r} \right), \quad (27)$$

$$A_{22} = -\frac{L^{1-\beta_2}}{\beta_1 - \beta_2} \left(\frac{\beta_1 - 1}{q} - \frac{\beta_1}{r} \right), \quad (28)$$

and

$$A_{32} = \frac{(H^{1-\beta_2} - L^{1-\beta_2})}{\beta_1 - \beta_2} \left(\frac{\beta_1 - 1}{q} - \frac{\beta_1}{r} \right). \quad (29)$$

Now, assuming that an investor has a perpetual option to invest for a sunk cost K_1 , it is possible to determine the value of the option to invest, $C_p(Q)$, and the optimal investment trigger, Q_{cp}^* . Considering the domain from Eq. (25) and after using VM and SP conditions, the investment trigger, Q_{cp}^* is given by:

$$Q_{cp}^* = \left(\frac{\beta_1}{(\beta_1 - \beta_2)A_{32}} \left((K_1 + \frac{K_2}{r}) - \frac{H}{r} \right) \right)^{\frac{1}{\beta_2}} > H, \text{ for } I \geq I_p^H, \quad (30)$$

where K_1 corresponds to the investment in fixed capital, and

$$I_p^H = \frac{H^{\beta_2}}{\beta_1} (H^{1-\beta_2} - L^{1-\beta_2}) \left(\frac{\beta_1 - 1}{q} - \frac{\beta_1}{r} \right) + \frac{H}{r}. \quad (31)$$

For the remaining cases Q_{cp}^* can be found by solving numerically the following non-linear equation:

$$(\beta_1 - \beta_2)A_{22}Q_{cp}^{*\beta_2} + (\beta_1 - 1)\frac{Q_{cp}^*}{q} - \beta_1(K_1 + \frac{K_2}{r}) = 0, \text{ for } I_p^0 = \frac{L}{r} < K_1 + \frac{K_2}{r} < I_p^H. \quad (32)$$

The option to invest in it, $C_p(Q)$, is given by:

$$C_p(Q) = \begin{cases} (V_{Cp}(Q_{Cp}^*) - K_1) \left(\frac{Q}{Q_{Cp}^*}\right)^{\beta_1} & \text{for } Q < Q_{Cp}^* \\ V_{Cp}(Q) - K_1 & \text{for } Q \geq Q_{Cp}^* \end{cases} \quad (33)$$

3.2.2 Investments with Finite-lived Collar

Assuming a finite-lived collar, the value of the active project, $V_{Cf}(Q)$, is given by:

$$V_{Cf}(Q) = V_{Cp}(Q) - S(Q, T) + \frac{Q}{q} e^{-qT} - \frac{K_2}{r} e^{-rT}, \quad (34)$$

where $S(Q, T)$ represents the present value of a collar that starts in the future moment T , which is designated as a forward-start perpetual collar and can be calculated by:

$$\begin{aligned} S(Q, T) = & A_{11} Q^{\beta_1} N(-d_{\beta_1}(Q, L)) + \frac{L}{r} e^{-rT} N(-d_0(Q, L)) \\ & + A_{21} Q^{\beta_1} \left(N(d_{\beta_1}(Q, L)) - N(d_{\beta_1}(Q, H)) \right) \\ & + A_{22} Q^{\beta_2} \left(N(d_{\beta_2}(Q, L)) - N(d_{\beta_2}(Q, H)) \right) \\ & + \frac{Q}{q} e^{-qT} \left(N(d_1(Q, L)) - N(d_1(Q, H)) \right) \\ & + A_{32} Q^{\beta_2} N(d_{\beta_2}(Q, H)) + \frac{H}{r} e^{-rT} N(d_0(Q, H)), \end{aligned} \quad (35)$$

with

$$d_{\beta}(Q, x) = \frac{\ln \frac{Q}{x} + (r - q + (\beta - \frac{1}{2})\sigma^2)T}{\sigma\sqrt{T}}, \quad (36)$$

where $\beta \in \{0, 1, \beta_1, \beta_2\}$, $x \in \{L, H\}$.

After carrying out all the aforementioned procedures again, the investment trigger, Q_{Cf}^* , depending on the value of $I = K_1 + \frac{K_2}{r}$, is given by solving numerically the respective equation of the ones below:

$$Z(Q_{Cf}^*) + \begin{cases} (\beta_1 - 1) \frac{Q_{Cf}^*}{q} e^{-qT} + \beta_1 \left(\frac{L}{r} - (K_1 + \frac{K_2}{r}) \right) = 0 & \text{for } I_f^0 < I < I_f^L \\ (\beta_1 - \beta_2) A_{22} Q_{Cf}^{*\beta_2} + (\beta_1 - 1) \left(\frac{Q_{Cf}^*}{q} + \frac{Q_{Cf}^*}{q} e^{-qT} \right) - \beta_1 \left(K_1 + \frac{K_2}{r} \right) = 0 & \text{for } I_f^L \leq I < I_f^H \\ (\beta_1 - \beta_2) A_{32} Q_{Cf}^{*\beta_2} + (\beta_1 - 1) \frac{Q_{Cf}^*}{q} e^{-qT} + \beta_1 \left(\frac{H}{r} - (K_1 + \frac{K_2}{r}) \right) = 0 & \text{for } I \geq I_f^H \end{cases}, \quad (37)$$

where

$$Z(Q) = -(\beta_1 - \beta_2) \left[A_{22} Q^{\beta_2} \left(N(d_{\beta_2}(Q, L)) - N(d_{\beta_2}(Q, H)) \right) + A_{32} Q^{\beta_2} N(d_{\beta_2}(Q, H)) \right] - (\beta_1 - 1) \frac{Q}{q} e^{-qT} \left(N(d_1(Q, L)) - N(d_1(Q, H)) \right) - \quad (38)$$

$$\beta_1 \left[\frac{L}{r} e^{-rT} N(-d_0(Q, L)) + \frac{H}{r} e^{-rT} N(d_0(Q, H)) \right],$$

$$I_f^0 = \frac{L}{r} (1 - e^{-rT}), \quad (39)$$

$$I_f^L = \frac{1}{\beta_1} \left(Z(L) + (\beta_1 - 1) \frac{L}{q} e^{-qT} + \beta_1 \frac{L}{r} \right), \quad (40)$$

and

$$I_f^H = \frac{1}{\beta_1} \left(Z(H) + (\beta_1 - \beta_2) A_{32} H^{\beta_2} + (\beta_1 - 1) \frac{H}{q} e^{-qT} + \beta_1 \frac{H}{r} \right). \quad (41)$$

The option to invest in a project with a finite-lived collar, $C_f(Q)$, is represented by:

$$C_f(Q) = \begin{cases} (V_{cf}(Q_{cf}^*) - K_1) \left(\frac{Q}{Q_{cf}^*} \right)^{\beta_1} & \text{for } Q < Q_{cf}^* \\ V_{cf}(Q) - K_1 & \text{for } Q \geq Q_{cf}^* \end{cases}. \quad (42)$$

4. Case Study

For a better understanding of the present study, it is important to describe the environment in which it is inserted and to present the origin of the problem that led to it.

Thus, in this section, before dealing with the available data, we present a brief characterization of the Autonomous Region of Madeira, the importance of the tourism sector in its economy, and the functioning of the existing pedestrian paths in its main islands. Further on, the need to restrict the use of routes for reasons of sustainability and the consequences that this has on the economic viability of the project are highlighted.

4.1 Brief Characterization of Madeira Island's Tourism Sector

The Madeira Archipelago, discovered by Portuguese navigators in 1419, is constituted by the habitable islands of Madeira and Porto Santo and the groups of uninhabitable islands of Desertas and Selvagens. They occupy an area of 801.5 km^2 and are located in the North Atlantic, around 900 km southwest of mainland Portugal and approximately 630 km west of the Moroccan coast (Almeida, 2016; *Instituto das Florestas e Conservação da Natureza*, IP-RAM (IFCN), 2016; Machado, 2012; Oliveira and Pereira, 2008).

In turn, the privileged geographic location of Madeira Island, also known as the “pearl of the Atlantic”, promotes a climate with subtropical characteristics, with a moderate level of humidity and mild maritime and atmospheric temperatures throughout the year (Machado, 2012; Oliveira and Pereira, 2008). In addition, its volcanic origin gives not only its mountainous and irregular relief that draws stunning and aesthetic landscapes, but also a more fertile soil that, combined with the formation of microclimates, allows the development of species of flora and fauna unique in the world (Machado, 2012; Oliveira and Pereira, 2008; Prudente et al., 2020).

These factors, combined with security, contribute to Madeira Island being one of the most traditional and oldest tourist destinations in the world, which has allowed it to be awarded several distinctions from European and World institutions and, between 2015 and 2022, consecutively receive the World Travel Awards in the Leading Island Destination category (Prudente et al., 2020; World Travel Awards, 2022).

As a result, tourism stands out from other economic sectors and corresponds to the main promoter of regional economic development which, according to *Direção Regional de Estatística da Madeira* (DREM) (2022), in 2019, represented around 28.8% of the Gross Domestic Product (GDP) of the Autonomous Region of Madeira. Compared to 2015, with a weight of 26.6% in the

Regional GDP (DREM, 2022), this increase over the years can be explained by the transformation of the tourist profile.

Nowadays, as mentioned in the literature review section, tourists are increasingly looking for more authentic products, giving greater importance to nature and the possibility of spending moments surrounded by it, which corresponds to a differentiating element provided by Madeira Island (Oliveira and Pereira, 2008).

The offer goes beyond the typical sun or beach option (Prudente et al., 2020). Visitors can choose from several activities such as trekking, climbing, canyoning, canoeing, bird watching, paragliding and hang gliding (Oliveira and Pereira, 2008).

However, it is worth highlighting the walks along the pedestrian paths which, according to Soares and Nunes (2019) studies, are the leisure activity that most arouse the interest of tourists, because in addition to being a physical activity, it is multisensory, since it allows visitors to appreciate fauna, flora and landscapes, and is inseparable from the socio-cultural and historical heritage of the island. More specifically, users of the pedestrian paths on Madeira Island are, in a greater percentage, Portuguese, French, German, and Spanish individuals, which coincides with the statistics on the countries that most contribute to the growth of the tourism sector in the region (Prudente et al., 2020). They are mostly active young people with higher levels of education and higher job positions, able to easily access updated information and recommendations provided on official websites (Oliveira and Pereira, 2008; Prudente et al., 2020; Soares and Nunes, 2019). In addition, they are increasingly aware of environmental problems and attracted by nature, which they consider aesthetically pleasing and ideal to be explored carefully (Oliveira and Pereira, 2008; Prudente et al., 2020; Soares and Nunes, 2019).

Pedestrian paths cover more than 3,000 *km* of the island and can be of three different types. The trails or paths which, according to the Regional Legislative Decree n. 24/2022/M (2022) are paths inserted in the forest, in natural surroundings or in rural areas, circular or linear, where hiking activities can be carried out. With a more holistic character, Madeira Island has land routes in urban, rural and forestry contexts, built before the establishment of the Portuguese Republic, designated by royal paths, which aggregate the historical, ethnographic, cultural, architectural and natural heritage of the Autonomous Region of Madeira (Regional Legislative Decree n. 24/2022/M, 2022). Finally, the famous *levadas* which, according to the Regional Legislative Decree n. 24/2022/M (2022), correspond to narrow channels or aqueducts, human-built infrastructures over

several kilometers, for the flow of water from its origins to its intermediate or final uses, and often flanked by a trail where hiking activity can be developed.

4.2 Problem Description

According to the studies carried out by Oliveira and Pereira (2008) and Soares and Nunes (2019), activities in nature are responsible for providing the most memorable and unforgettable experience on the island and are reason enough to return to this destination.

Nevertheless, the enjoyment of pedestrian paths in an unregulated and abusive way causes their destruction, accumulating unnecessary risks and negative effects that have been increasingly evident with the overload and human pressure verified, which jeopardizes the quality of the own routes and the safety of its users (Mota et al., 2021). Thus, “tourism’s growth is limited by natural, environmental, and social constraints” (Mota et al., 2021, p.2), so it is necessary to establish levels of sustainability for the different pedestrian paths on Madeira Island.

We cannot continue to rely almost exclusively on the intrinsic value of natural resources to attract visitors, it is not enough to have abundant and attractive natural resources, it is essential to create the conditions so that the trails can preserve the values that have always justified their contemplation (*Turismo Hotelería y Recreación, S.A. (THR)*, 2006).

In this way, the Government of the Autonomous Region of Madeira published on December 19, 2022, a new legal regime for pedestrian routes with the aim of reconciling sports activities and the protection and sustainability of the Region's nature, in order to avoid irreversible consequences in terms of attracting tourists. With the intention of making the natural heritage more profitable, this regime attributes powers to the intervening entities, which can now be public or private promoters, and consists of a set of guidelines and rules that make it possible to establish a balance between the use and conservation of new paths or already existing ones, in order to guarantee their quality, the conservation of nature and the safety of users (Regional Legislative Decree n. 24/2022/M, 2022).

More specifically, the routes will have to be duly classified, and their use will have to be supported by regulations that include rules of conduct and use of practitioners, inspection processes, maintenance, recovery and improvement plans, safety conditions and universal rules for signage (Regional Legislative Decree n. 24/2022/M, 2022).

The regulations and norms of conduct and safety have not yet been approved and published by the government through official documents, but some rules and recommendations can be found at

the *Instituto das Florestas e Conservação da Natureza, IP-RAM* (IFCN) website. In the Autonomous Region of Madeira, pedestrian paths are freely accessible and free of charge, although, in accordance with the Decree, cash donations can be given, but it is the sole responsibility of the user for any damage that occurs during their enjoyment. In this way, the Government of the Autonomous Region of Madeira recommends around 30 pedestrian paths and, through the IFCN (n.d.), advises its practitioners to bring a company or inform their acquaintances about their intentions to go on a hike, collect information about the chosen route and take all the necessary equipment to avoid risks and guarantee that it is done safely. In addition, users must remain within the trail and avoid noise and attitudes that disturb the environment.

Even so, for the use of pedestrian paths to occur under the conditions described above and to be economically viable, they must generate revenue capable of covering expenses inherent in maintaining the trails in good conditions of use. However, we must take into account that the number of users per pedestrian path is a variable endowed with uncertainty because it depends on weather conditions which, when adverse, may force the closure of routes for safety reasons or make it impossible for planes to land at Madeira Airport. Other variables that were previously unthinkable, with the COVID-19 pandemic, which forced the closure of borders, are now on the table, since they also make it impossible for tourists to enter the archipelago and other conflicts, although still less frequent, should not be completely ruled out.

Therefore, it is not certain to register a minimum number of users capable of making the project financially viable. Thus, there is a need to create an investment incentive at an early stage of the project, by sharing this risk between promoters and the government, through an MRG.

However, we must not forget that it is necessary to agree on the levels of sustainability for each pedestrian path, which “despite being a major concern in natural resource management” (Mota et al., 2021, p. 1), have not yet received the necessary attention from the Regional Government.

Madeira Island is endowed with a laurel forest, the Laurissilva, on which it depends for freshwater supply and for tourist activity (Mota et al., 2021; United Nations Educational, Scientific and Cultural Organization (UNESCO), 1999). Upon its designation as a World Natural Heritage Site by UNESCO, in 1999, conservation recommendations were raised in relation to the impacts of tourism, namely the control of visitors and the assessment of carrying capacity (Mota et al., 2021; UNESCO, 1999). But, despite recent reports on the conservation status of the Laurisilva on Madeira Island, warning of various threats from overexploitation that could compromise the

sustainability of the forest (Mota et al., 2021), according to a study carried out by the University of Madeira, up to its publication date, “there were no studies on tourism carrying capacity” (Mota et al., 2021, p. 7) in Madeira Island.

In addition, although investments have already been made for the acquisition and installation of user counting systems on pedestrian paths (Secretaria Regional de Ambiente, Recursos Naturais e Alterações Climáticas (SRARNAC), 2022), data are scarce and trail access has not yet been restricted (Mota et al., 2021). However, for sustainability reasons it should be one of the first measures to be taken and to be part of the problem, and as it reduces the willingness of promoters to invest in this project, since the revenues to cover the aforementioned expenses are limited to the maximum number of users defined by the carrying capacity, investments in pedestrian paths must be seen and evaluated as collar contracts.

4.3 Data

Assuming that during the period established in the contract the Tourist Tariff is constant and set to 1€, following the empirical evidence from the study by Cárdenas-García et al. (2022) on how much visitors are willing to pay, it is clear that the main variable that influences the promoter's decision-making is the number of users per pedestrian path (Q). However, one can easily calculate an alternative price by multiplying the alternative price by the quantity.

In a first evaluation, we assume that there is only a MRG, where the government undertakes to bear the amount whenever the number of users on the route is lower than the pre-established floor between both parts. In this case, we must define the level of the number of users floor (L), which corresponds to the minimum value guaranteed by the Regional Government of Madeira.

For this purpose, we took into account the data provided by the SRARNAC regarding the number of registered users in *Levada das 25 Fontes* and *Levada do Risco* (see **Table 4.1**), two pedestrian paths recommended by the Government of the Autonomous Region of Madeira located in *Rabaçal*, belonging to the Madeira *Laurissilva*, through a set of counting systems between November 2022 and April 2023. Therefore, to define the quantity floor for the base-case we assumed the minimum number recorded in the mentioned period, which corresponded to the month of February on both routes, resulting in an average value of 46,946 and 8,759 users per year, respectively.

Table 4.1: Number of registered users

		Pedestrian Path	
		<i>Levada das 25 Fontes</i>	<i>Levada do Risco</i>
2022	November	10,400	13
	December	9,234	800
2023	January	5,221	829
	February	3,682	687
	March	8,388	1,028
	April	10,765	787

Source: SRARNAC

It is important to highlight that due to the adverse weather conditions that are felt in the Autonomous Region of Madeira, according to the compilation of news shared in the regional media, without considering the pandemic year 2020, the IFCN closes pedestrian paths, on average, 8 days a year, in order to guarantee the safety of users. Therefore, for the annual basis we considered only 357 days.

In a second assessment, we assume that the Regional Government of Madeira requires promoters, in exchange for the minimum guarantee, to limit routes to a certain number of users for sustainability purposes, which translates into a collar contract. So, at this stage, we have to define the level of the number of users ceiling (H), which corresponds to the maximum possible amount received given the carrying capacity.

To overcome the research gap mentioned in the problem description section, Mota et al. (2021) carried out a study at the University of Madeira, using “a specific formulation relating physical aspects to environmental correction factors” (Mota et al., 2021, p. 1), through which it was concluded that *Levada das 25 Fontes* should be limited to 1420 visits per day, which means a carrying capacity of 507,295 users per year and, in the case of *Levada do Risco*, a limitation of 1220 visits per day, resulting in 435,845 per year.

However, it should be noted that the Mota et al. (2021) study only considers part of the length of the routes (2.8 km vs. 4.6 km in *Levada das 25 Fontes* and 1.2 km vs. 3 km in *Levada do Risco*) because it assumes *Casa do Rabaçal*, “an old shelter converted into a café, and a two-bedroom lodging for visitors in the middle of the laurel forest” (Mota et al., 2021, p. 7), as a starting point, given the ease of counting users.

For the desired evaluation to be possible, we must also define the initial number of users per route. Based on data provided by SRARNAC regarding the number of users registered between the period of November 2022 and April 2023 (see Table 3.1), we extrapolated to an annual basis and obtained an average value of 105,014 and 9,125 users per year in *Levada das 25 Fontes* and *Levada do Risco*, respectively (see Appendix A).

In addition, it is also necessary to define the riskless interest rate (r) which, according to Ritzenhofen and Spinler (2016), can be used instead of a risk-adjusted discount rate that is normally hard to estimate. Thus, we will assume 10 years for the duration of the contract (T) and use the average 10-year Portuguese government bond yield over the last 10 years that, according to data from *Banco de Portugal*, is equal to 3.13%.¹

Regarding the dividend yield (q), we continue to follow the work of Ritzenhofen and Spinler (2016), which endogenously derives it as the difference between the exogenously given r and the drift term of future market quantities μ , and the assumption of the risk-neutral drift (Adkins et al., 2019; Barbosa et al., 2018), where $\mu = r - q = 0\%$, that results in a $q = 3.13\%$. Hence, we are assuming that $\mu < r$, so that the problem makes sense.

Because the uncertainty of the number of users is a crucial parameter for the model, its volatility (σ) must be defined, but there is no historical data, so for the base case we will assume that it is equal to 20%.

Table 4.2 summarizes the base case parameters of the problem.

Table 4.2: The base case parameters

Parameter	Description	Pedestrian Path	
		<i>Levada das 25 Fontes</i>	<i>Levada do Risco</i>
		Value	
Q	Number of users per pedestrian path	105,014	9,125
L	Number of users floor (quantity floor)	46,946	8,759
H	Number of users ceiling (quantity cap)	507,295	435,845
K_1	Investment in fixed capital (initial investment cost)	€232,401.69	€187,768.12
K_2	Security and maintenance costs (annual marginal cost)	€2,026,639.52	€1,756,687.59
I	Total investment cost	€2,259,041.20	€1,944,455.70
σ	Volatility of the number of users	20.00%	20.00%
r	Riskless interest rate	3.13%	3.13%
q	Dividend yield	3.13%	3.13%
μ	Risk-neutral drift	0.00%	0.00%
T	Duration of the contract	10	10

¹ <https://bpstat.bportugal.pt/conteudos/quadros/484>

In order to be able to carry out the project feasibility assessment, we also need to know, on a yearly basis, the total investment cost. Based on the methodology used, it will have to include the total investment in fixed capital, namely costs with the rehabilitation and signaling of the roads, with monitoring of users and control of entrances and those with information and support structures, and the annual costs with maintenance of the paths and security of users.

However, we only have access to the costs presented in the Regional Government database, namely in the documents referring to public contracts carried out between 2020 and 2022 (IFCN, 2020, 2021a, 2021b, 2021c, 2021d, 2022a, 2022b, 2022c, 2022d) , and data evidenced in the media of the Autonomous Region of Madeira in the 2017-2020 period, namely in *Diário de Notícias*, *Jornal da Madeira* and *RTP*, by the Regional Government and by the Municipal Councils of the Region which are already promoters of some pedestrian paths.

Official data is scarce again and, from the Regional Government, only costs of some recommended routes are available related to maintenance, namely cleaning interventions, clearing and removal of infesting vegetation on the edges of the trails, and to improvement and recovery, which correspond to removal of obstacles that are obstructing the route, leveling the pavements, reconstruction and placement of steps, execution and reinforcement of support walls for the paths, supply and installation of safety railings. Additionally, there is specific data on the paths belonging to the *Rabaçal* area, which concerns not only their improvement, but also the acquisition of information and support structures and the purchase and installation of systems for counting and monitoring the number of users. In media, in addition to the expenses mentioned above, costs with the expansion, maintenance and signaling of the recommended pedestrian paths are also disclosed. In turn, the Municipal Councils present the expenses they have with the recovery, maintenance and safety conditions of their trails.

However, there is no detailed description of the costs by both entities; these are, normally, presented in a global value for a certain number of routes, on an annual basis and, sometimes, by approximations. In this way, in order to be able to evaluate this investment project, we will have to make some assumptions regarding the mentioned expenditures.

As previously mentioned, since *Levada das 25 Fontes* and *Levada do Risco* are the only pedestrian paths on Madeira Island that already present studies related to their carrying capacity, these are the ones that we will consider. Due to the fact that these routes already exist and belong to the *Rabaçal* area, we will give preference to the data available on this matter.

That said, the rehabilitation, monitoring and maintenance costs incurred on the *Rabaçal's* Pedestrian Paths were gathered and the average cost per kilometer was calculated (€26,024.19, €1,871.79 and €436.44, respectively), which we assume as base costs for the pedestrian paths under study. Regarding the user safety costs, as there is no data regarding the *Rabaçal's* Pedestrian Paths, we calculated them through the average per kilometer of those incurred on the Recommended Pedestrian Paths and Others, which resulted in an amount of €2,204.03 per kilometer. In order to obtain the total costs of rehabilitation, monitoring, maintenance and security for each pedestrian path, we multiplied the above values by the considered distance from *Levada das 25 Fontes* and *Levada do Risco* previously mentioned (2.8 km and 1.2 km, respectively).

In addition, we assume that there will only be improvement and monitoring interventions before the start of the project, that is, they correspond to fixed capital investment. On the other hand, due to adverse weather conditions that imply the closure of routes that normally happen twice a year, maintenance and safety charges are annual costs that, for reasons of simplification, we have multiplied the respective values mentioned above by two and we assume it as the annuity.

As previously mentioned, since we are studying two existing routes, we find it pertinent to consider the investments that have already been made in the *Rabaçal's* Pedestrian Paths with support structures, namely with the *Rabaçal* reception center and its respective use, in the total amount of €101,925.00, and with the information structures, in the total of €20,350.00. In addition, we will take into account the extraordinary cost of an interactive table, worth €9,325.00, acquired to integrate the support structure.

Regarding the expenditures with the information panels, we calculated the value per Recommended Pedestrian Path (€2,187,50) which, once again, we assumed the same for the routes under study.

As entry control systems will have to be implemented in order to be able to charge users, the amount invested in the *Cabo Girão* viewpoint, carried out by the Government of the Autonomous Region of Madeira, will be taken into account. However, the value presented by the Regional Government corresponds to 13 turnstiles (Pacífico, 2023), which results in a value of €5,148.86 per equipment, and, considering the access points to *Levada das 25 Fontes* and *Levada do Risco*, it is only necessary to purchase 4 units for each path.

Finally, we assume that two employees are needed per route, to help users in case of lack of information or access problems, which results in an annual cost of €48,647.20 for the promoter. To

calculate this value, given the fact that it can be an added value in the dissemination of specialized information regarding the natural heritage of Madeira Island and the risks involved in an activity in nature, we considered the monthly remuneration of a senior technician with a degree, which corresponds to level 16 of the *Tabela Remuneratória Única da Função Pública* in 2023 (€1,320.15 per month). Furthermore, for reasons of simplification for the simulation of annual costs (Aires, 2023), we assume that these two people are residents of the Autonomous Region of Madeira, single and without dependents, and receive food subsidy in remuneration of €6 per day.

Table 4.3 summarizes the cost structure for the base case of the problem.

Table 4.3: The base case costs

Type of Costs	Pedestrian Path	
	<i>Levada das 25 Fontes</i>	<i>Levada do Risco</i>
Rehabilitation	€72,867.72	€31,229.02
Monitoring	€5,241.03	€2,246.15
Support Structures	€101,925.00	€101,925.00
Information Structures	€20,350.00	€20,350.00
Interactive Table	€9,235.00	€9,235.00
Information Panels	€2,187.50	€2,187.50
Control Systems	€20,595.44	€20,595.44
Total Initial Investment Cost	€232,401.69	€187,768.12
Maintenance	€2,444.07	€1,047.46
Safety	€12,342.55	€5,289.66
Staff	€48,647.20	€48,647.20
Total Marginal Cost	€63,433.82	€54,984.32

5. Solving the Case Study

After processing the data, in this section we put the methodology into practice, through the real cases of *Levada das 25 Fontes* and *Levada do Risco*. In a first phase, we present the results for the base case and subsequently, we perform a sensitivity analysis on the main drivers of the model.

5.1 Results

In this part we present the results of the implementation of the methodology under study with a brief comparison between the two types of contracts that may be implemented in both projects.

5.1.1 *Levada das 25 Fontes*

As previously mentioned, the *Levada das 25 Fontes* project was evaluated, in the first phase, assuming a MRG and, in the second phase, a Collar contract. Therefore, in this subsection, we

present the project and the NPV value, the investment trigger and the floor value that induces immediate investment, for the perpetual and finite cases.

5.1.1.1 Minimum Revenue Guarantee

Assuming that the *Levada das 25 Fontes* project has a MRG, it is possible to verify that it presents positive values, $V_M(Q)$, for both perpetual and finite duration contracts, of 1.610 and 1.334 million euros respectively. That said, it is straightforward to state that the duration of the minimum guarantee, that is, the longer the promoter is protected if demand for the route is not as expected, the greater the value added to the project.

Positive values were also found in the NPV calculations, 1.377 million euros for the perpetual scenario and 1.101 million euros for the MRG with finite duration. According to traditional evaluation methods, these NPV results mean that the promoter should invest in this project.

However, according to the methodology adopted, the promoter must wait for the number of users, Q , to touch the optimal level, that is, the investment trigger, Q_M^* , to optimally invest in this project. Based on the obtained results, this happens when an annual value of 130,928 and 153,918 users is reached in *Levada das 25 Fontes* when we evaluate the project with perpetual and finite guarantees, respectively. That said, the promoter is encouraged to invest earlier in a perpetual MRG scenario when compared to the case of a finite duration contract.

Even so, if the government's objective is to induce promoters not to wait any longer to invest in the *Levada das 25 Fontes* project, the quantity floor, L , initially agreed between both parties in the amount of 46,946, would have to be changed. In the case of MRG with a perpetual guarantee, the value of L_M^* , that is the floor value that induces immediate investment, would have to be defined at 70,708 annual users and at 125,588 in the finite MRG scenario.

5.1.1.2 Collar Contracts

Now, in a second assessment of the project, we assume that in addition to the minimum quantity guarantee, there is also a quantity cap, H , to limit *Levada das 25 Fontes* to 507,295 annual users for sustainability reasons.

Under these conditions, the calculated project value, $V_C(Q)$, is lower than those verified in the MRG scheme. Assuming a perpetual collar, the value of the project remains positive at 1.282 million euros. However, in the case of the finite-lived contract, the value of the project is negative

at 0.149 million euros, which means that promoters should not invest under these conditions in the *Levada das 25 Fontes* project.

Furthermore, based on the NPV calculations and following the rule of traditional methods, the decision continues to be to invest the *Levada das 25 Fontes* project in a perpetual collar contract scenario, since the NPV value remains above from zero (1.050 million euros). On the contrary, in the finite case, the obtained value is negative (-0.381 million euros), which means that according to traditional methods, it is not worth investing in the project.

Regarding the value that induces the promoter to invest, Q_C^* , optimally speaking, no changes were recorded in the case of the perpetual collar contract, when compared with the perpetual MRG scheme, remaining at the annual level of 130,928 users in *Levada das 25 Fontes*. However, assuming a finite-lived collar contract, the promoter optimally invests earlier, when compared to the MRG with the same duration (153,467 versus 153,918 annual users).

Table 5.1 summarizes the results obtained from the evaluation of the *Levada das 25 Fontes* project.

Table 5.1: Results of the *Levada das 25 Fontes* project

Minimum Revenue Guarantee		Pedestrian Path <i>Levada das 25 Fontes</i>	
		Perpetual MRG	Finite-lived MRG
Project value	$V_M(Q)$	€1,609,859.57	€1,333,569.42
Project NPV	NPV	€1,377,457.88	€1,101,167.73
Investment trigger	Q_M^*	130,928	153,918
	L_M^*	70,708	125,588
Collar Contract		Perpetual Collar	Finite-lived Collar
Project value	$V_C(Q)$	€1,281,971.15	-€148,784.98
Project NPV	NPV	€1,049,569.46	-€381,186.67
Investment trigger	Q_C^*	130,928	153,467

5.1.2 *Levada do Risco*

In this subsection, we present the project value, the NPV value, the investment trigger and the floor value that induces immediate investment, for the perpetual and finite case of MRG and Collar Contract, assumed for the *Levada do Risco* project.

5.1.2.1 Minimum Revenue Guarantee

Now, evaluating the MRG scheme in the *Levada do Risco* project, we see that the value of the project, $V_M(Q)$, is clearly lower than that of *Levada das 25 Fontes* and is even negative in both scenarios (-1.365 and -1.454 million euros in the perpetual and finite case, respectively).

Similar to the project value, the results obtained in the NPV calculation are negative both in the case in which a perpetual guarantee is assumed (-1.553 million euros) and in the case of the finite-lived MRG (-1.642 million euros). Therefore, according to traditional evaluation methods, promoters should not invest in *Levada do Risco*.

However, according to the methodology under analysis, the promoter invests optimally in the *Levada do Risco* project when the demand for the pedestrian route, Q_M^* , reaches the annual value of 131,658 users in the perpetual contract and 132,698 in the finite duration scenario. So, once again, the promoter is encouraged to invest earlier in a perpetual MRG scenario when compared to the case of a finite duration contract.

In the case of the *Levada do Risco* project, we assume that the government will guarantee the promoter a minimum number, L , of 8,759 users. However, according to the obtained results, if the government aims to induce the promoter to invest immediately in this project, it should change what was agreed between the parties and guarantee a higher volume floor, L_M^* , that corresponds to 60,861 and 108,099 users in the perpetual and finite support scheme, respectively.

5.1.2.2 Collar Contracts

Assuming now the collar contract at *Levada do Risco* with a maximum limit, H , of 435,845 users, the results continue to show a negative project value, $V_C(Q)$, of 1.369 and 2.739 million euros, for the perpetual and finite contracts respectively.

Additionally, based on the NPV calculation, the decision remains to not invest in the *Levada do Risco* project, given that the calculated values are negative by around 1.557 million euros in the scenario of a perpetual collar contract and 2.927 million euros in the case of a finite-lived collar.

However, based on the obtained results, in *Levada do Risco* the promoter is induced to invest earlier, optimally speaking, in a scenario of a perpetual collar contract, with an investment trigger, Q_C^* , of 131,658 users, than in a scenario of a collar with limited duration, which translates into an optimal investment level of 132,306 users.

Table 5.2 summarizes the results obtained from the evaluation of the *Levada do Risco* project.

Table 5.2: Results of the *Levada do Risco* project

Minimum Revenue Guarantee		Pedestrian Path <i>Levada do Risco</i>	
		Perpetual MRG	Finite-lived MRG
Project value	$V_M(Q)$	-€1,364,827.11	-€1,454,249.22
Project NPV	NPV	-€1,552,595.23	-€1,642,017.33
Investment trigger	Q^*_M	131,658	132,698
	L^*_M	60,861	108,099
Collar Contract		Perpetual Collar	Finite-lived Collar
Project value	$V_C(Q)$	-€1,368,916.59	-€2,738,826.86
Project NPV	NPV	-€1,556,684.71	-€2,926,594.98
Investment trigger	Q^*_C	131,658	132,306

5.2 Comparative statics

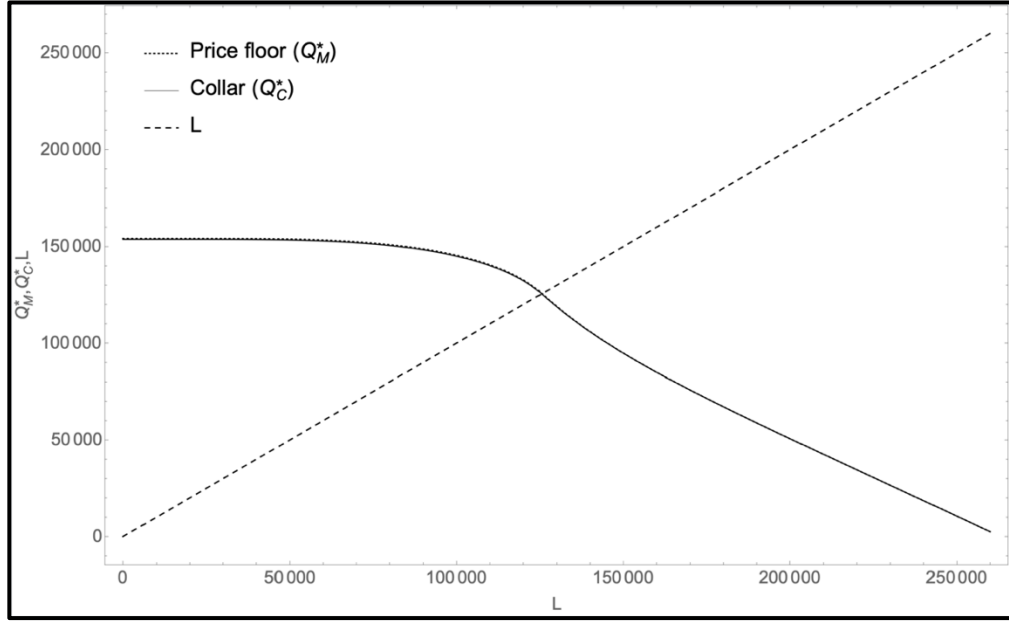
In this section, we conduct a comparative static analysis of the main drivers of our model. Specifically, we investigate how certain parameters impact the optimal investment triggers and the value of the option to invest in the projects with MRG and collar schemes. However, it should be noted that the following results only concern finite cases because we are analyzing real case studies and subsidies, as long as we know, have a finite duration. Our numerical study is rooted in the base-case parameters outlined in the case study presented in Section 4.

Table 5.3: Base-case parameters

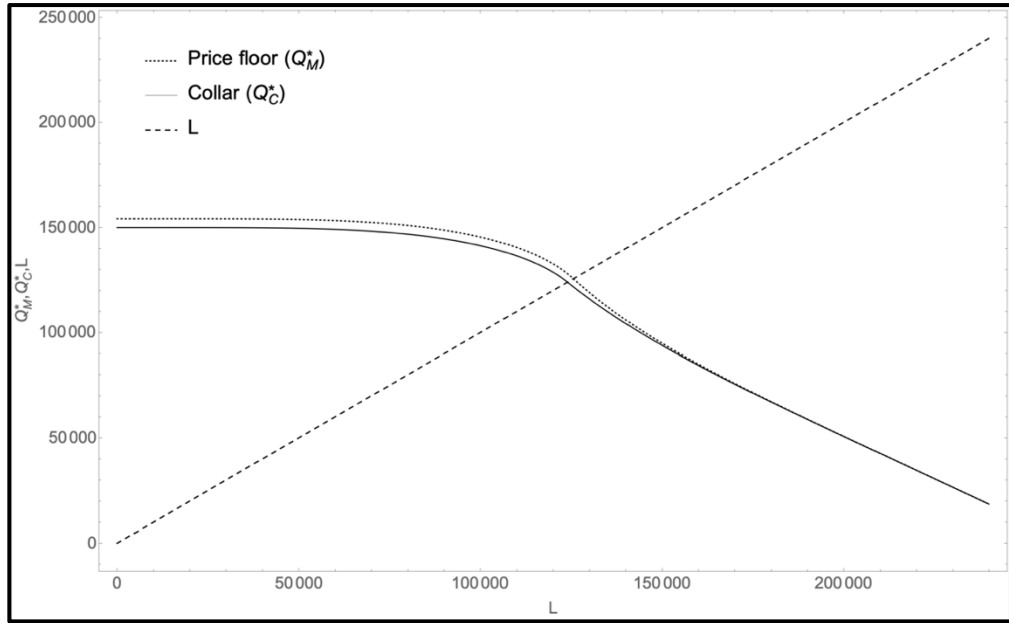
Parameter	Description	Pedestrian Path	
		<i>Levada das 25 Fontes</i>	<i>Levada do Risco</i>
		Value	
L	Quantity floor	46,946 pedestrians per year	8,759 pedestrians per year
H	Quantity cap	507,295 pedestrians per year	435,845 pedestrians per year
T	Duration of the contract	10 years	10 years
r	Risk-free rate	3.13%	3.13%
σ	Volatility	20.00%	20.00%
q	Dividend yield	3.13%	3.13%
μ	Risk-neutral drift	0.00%	0.00%
K_1	Initial investment cost	€232,401.69	€187,768.12
K_2	Annual marginal cost	€2,026,639.52	€1,756,687.59

5.2.1 *Levada das 25 Fontes*

Based on the base-case parameters identified in Table 5.3 for the case of *Levada das 25 Fontes*, we present the following graphs and respective analysis.



a) $H = 507,295$



b) $H = 250,000$

Figure 5.1: Triggers as a function of the quantity floor L for high and low cap H

Figure 5.1 presents the value of the investment thresholds for a finite MRG (Q_{Mf}^*) and collar contracts (Q_{Cf}^*) as a function of the quantity floor L when the cap H is equal to 507,295 (Figure 5.1a) and 250,000 (Figure 5.1b). As expected, the investment triggers decrease as the quantity floor L increases. The figures suggest that investors hasten their decision in the presence of a cap.

Furthermore, with a low value of the cap (H), investors make their decision earlier compared to a higher cap value (H). This result is consistent with Barbosa et al. (2020). Moreover, from the standpoint of policymakers, this outcome implies that the collar regime might offer a more favorable policy option compared to the MRG regime. This is due to its potential to accelerate investments while preventing undue producer profits or excessive costs for consumers.

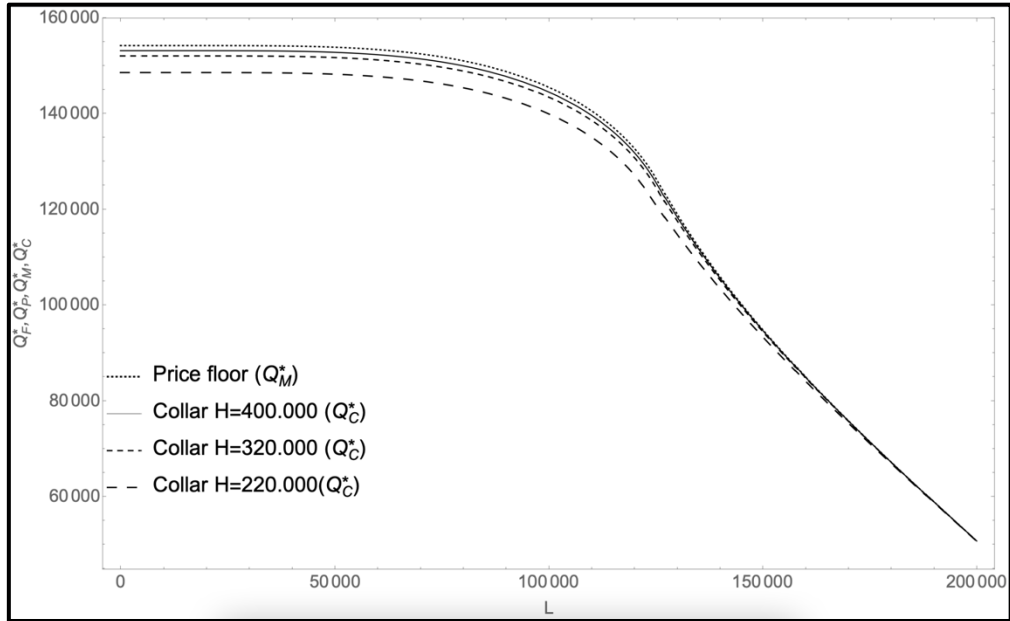


Figure 5.2: Triggers as a function of the quantity floor L for different values of the cap H

Figure 5.2 presents the value of the investment thresholds for a finite MRG and collar contracts as a function of the quantity floor L for different values of the cap H . As expected, the investment threshold of a collar scheme converges to the MRG regime as we increase the value of the cap H and the decision to invest is faster the lower the maximum ceiling is, up to a certain level.

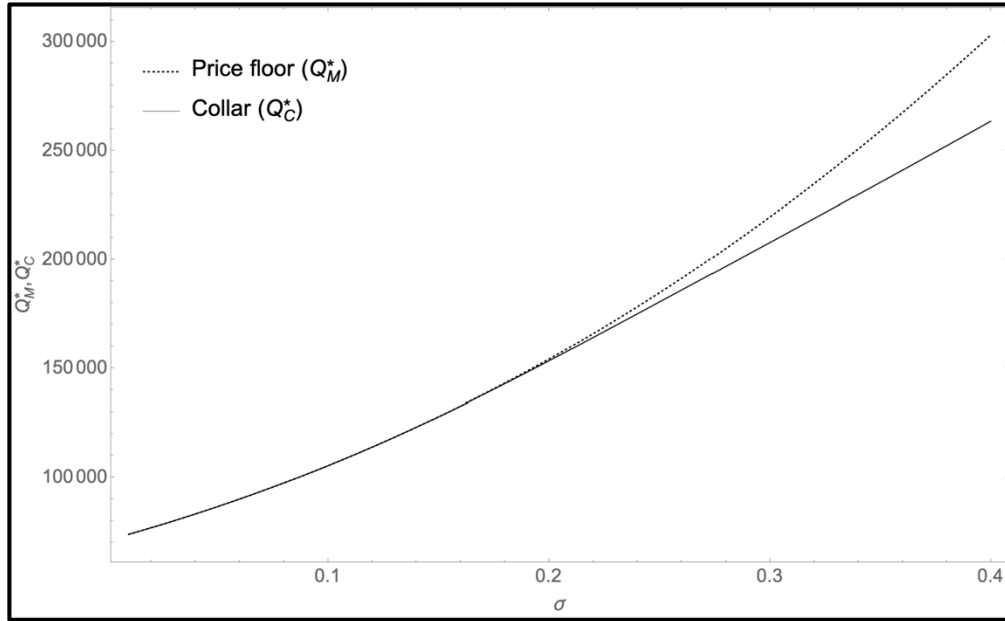


Figure 5.3: Triggers as a function of the volatility σ

Figure 5.3 presents the graph of the investment thresholds for different values of the volatility σ . The outcomes align with the principles of real options theory, wherein higher volatilities increase the thresholds, consequently deferring the investment decision. However, the investment trigger for the MRG policy shows a steeper increase compared to the investment trigger associated with the collar scheme. This observation suggests that the MRG policy demonstrates greater sensitivity to risk.

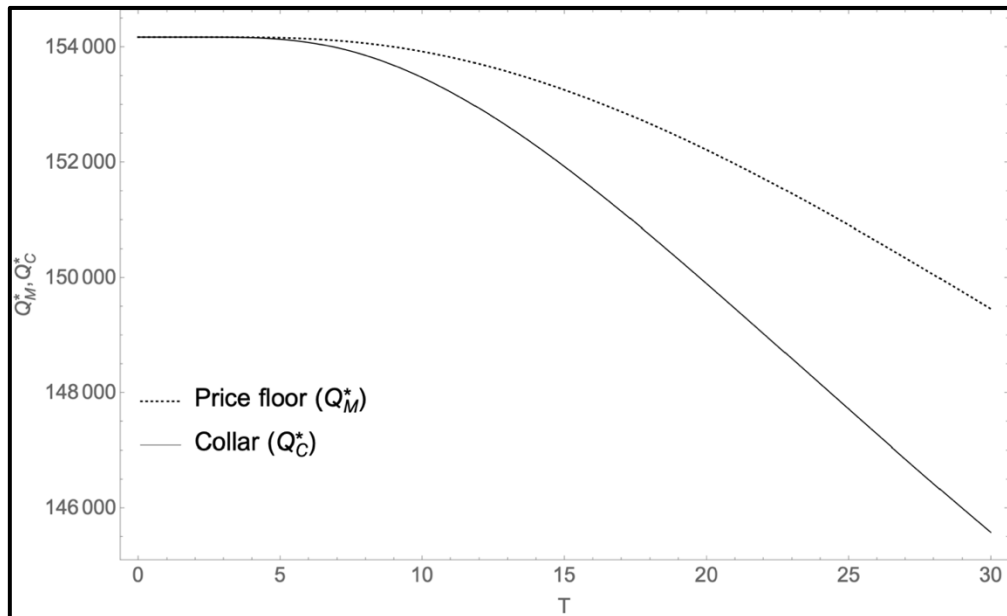


Figure 5.4: Triggers as a function of the duration of the contract T

Figure 5.4 presents the value of the investment thresholds as a function of the duration of the contract T . As expected, the investment triggers decrease as the duration of the contract T increases. Nonetheless, the investment trigger within the collar scheme experiences a more rapid decrease when contrasted with the investment trigger linked to the MRG scheme. This observation implies that the collar policy is more sensitive to the contract's duration in comparison to the MRG scheme.

We can see very interesting results in Figures 5.3 and 5.4. While the MRG policy showcases heightened responsiveness to risk, the collar policy exhibits enhanced sensitivity to the contract's duration. In the context of policymaking, it is important for policymakers to exercise caution when considering the implementation of a MRG contract in scenarios marked by high volatility. This is due to the potential outcome of investors deferring their investment decisions. Moreover, policymakers can strategically promote accelerated investment within a collar regime by extending the contract's duration. This conclusion implies that the collar regime presents a more favorable policy approach, as it not only expedites investments but also safeguards against disproportionate producer profits or excessive consumer costs.

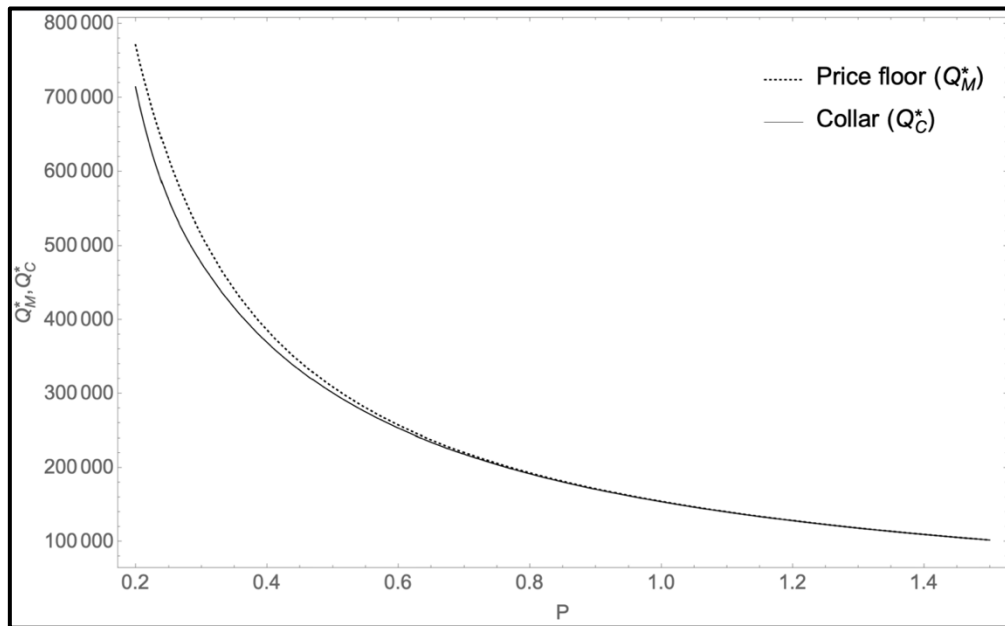


Figure 5.5: Triggers as a function of the price P

Figure 5.5 presents the value of the investment triggers as a function of the price P . As expected, the investments thresholds decrease as the price P increases. In addition, the graph suggests that the difference between the investment triggers of an MRG policy and a collar scheme is more significant for lower prices, but they converge as the price P increases.

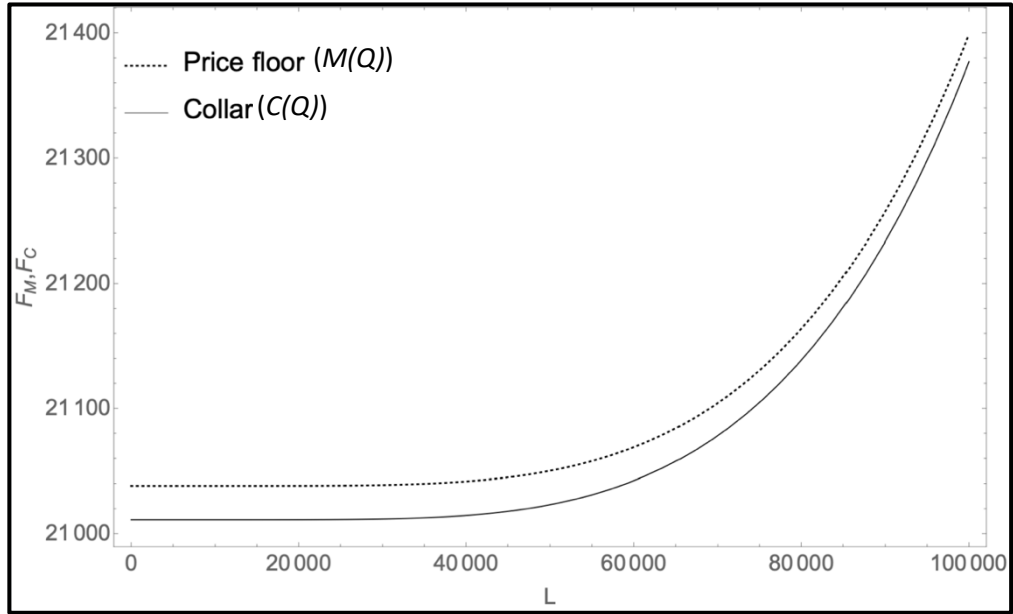


Figure 5.6: Options as a function of the quantity floor L

Figure 5.6 presents the value of the option to invest in a project with a finite MRG, $M(Q)$, or a finite collar contract, $C(Q)$, as a function of the quantity floor L . The figure suggests that the value of the option increases as the quantity floor L increases. As expected, the option associated to the MRG policy creates more value for the project when compared to the option linked to the collar scheme, since the MRG regime does not limit the revenues for the investor.

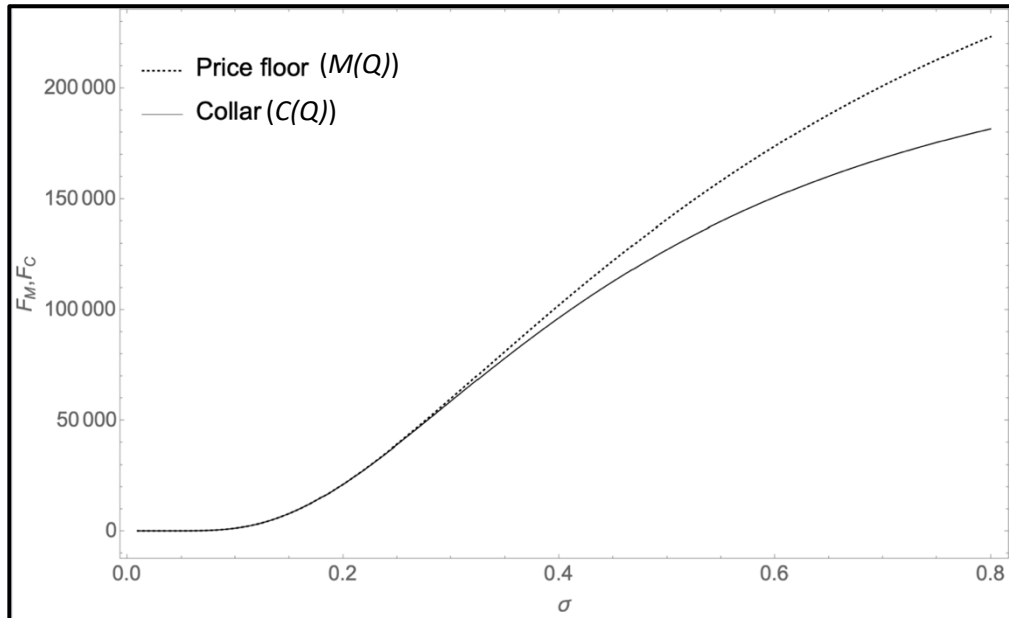


Figure 5.7: Options as a function of the volatility σ

Figure 5.7 presents the graph of the option' value for different values of the volatility σ . The outcomes suggest that higher volatilities increase the value of the option. However, the value of the option to invest in a project with a MRG regime experiences a steeper increase when contrasted with the value of the option linked to the collar scheme. This observation implies that MRG policy is more sensitive to risk.

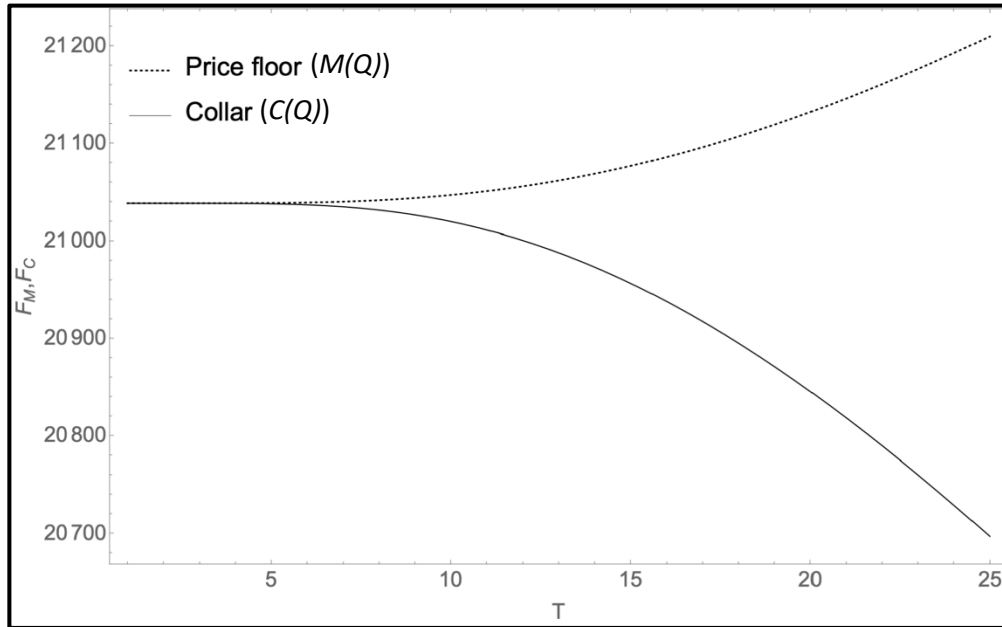
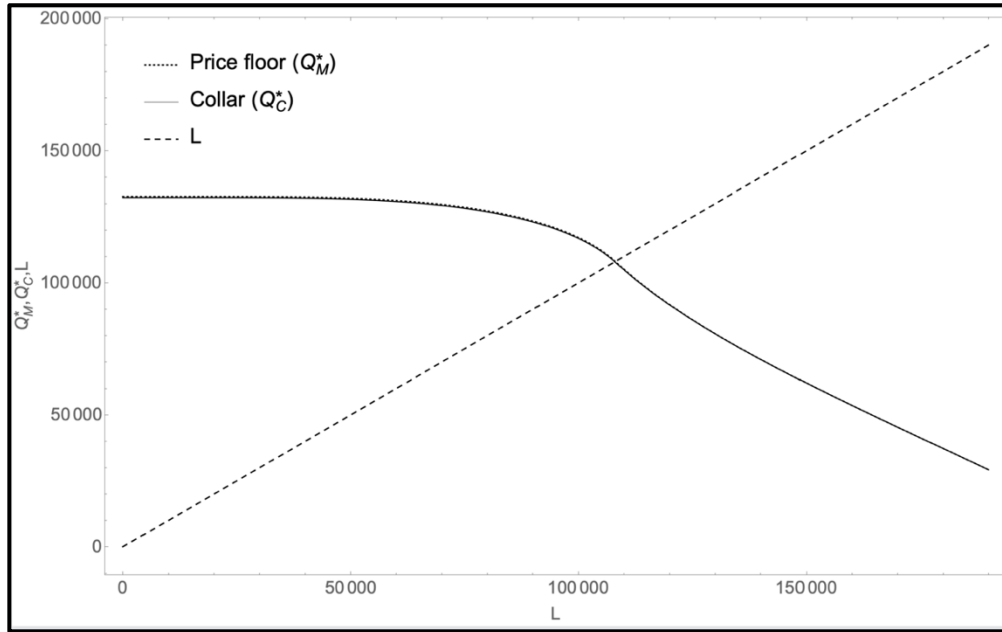


Figure 5.8: Options as a function of the duration of the contract T

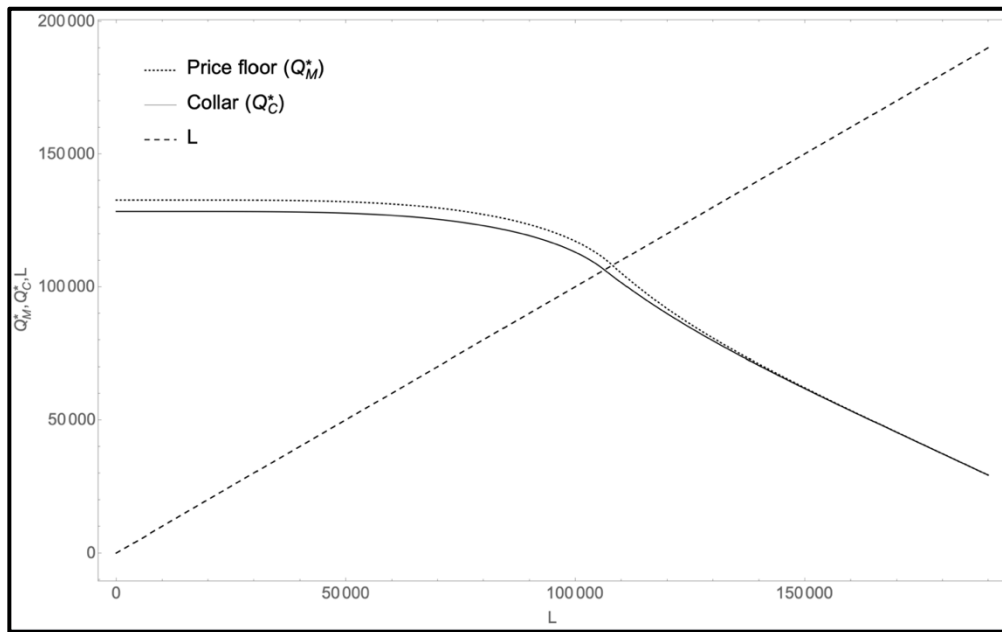
Figure 5.8 shows the value of the option to invest in a project with a finite MRG or a finite collar contract as a function of the duration of the contract T . The graph suggests that the value of the option associated with a project with an MRG policy increases as the duration of the contract increases, unlike the value of the investment option in a project with a Collar regime, which decreases as the duration of the contract increases. This interesting result can be explained by the fact that in a MRG regime, as the contract duration increases, the investor has a larger time window to receive the value linked to the quantity L . In turn, in the case of the collar scheme, a longer duration of the contract means that the investor is tied to the ceiling (cap) for an extended period, being prevented from receiving revenues above the defined maximum amount.

5.2.2 *Levada do Risco*

Regarding the *Levada do Risco* project, the economic intuition is the same and, therefore, as evidenced in the graphs presented below, the results are qualitatively similar to those of *Levada das 25 Fontes*.



a) $H = 435,845$



b) $H = 200,000$

Figure 5.9: Triggers as a function of the quantity floor L for high and low cap H

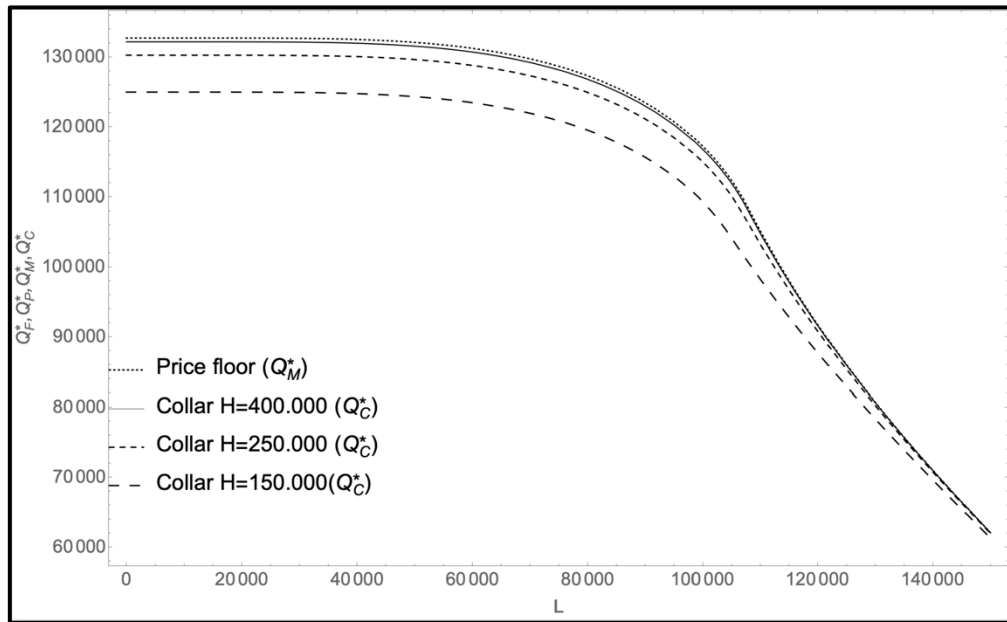


Figure 5.10: Triggers as a function of the quantity floor L for different values of the cap H

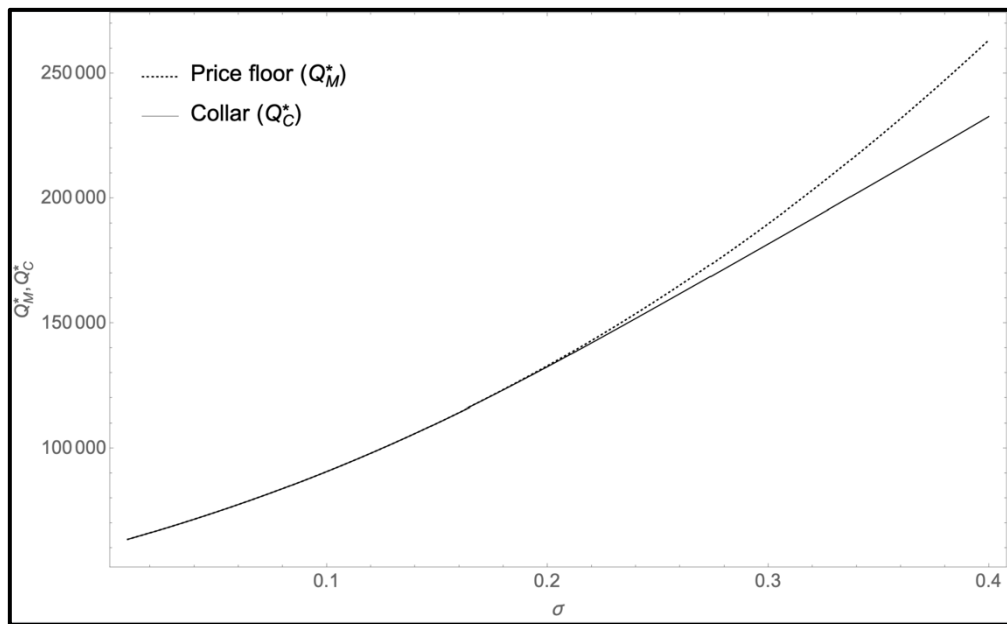
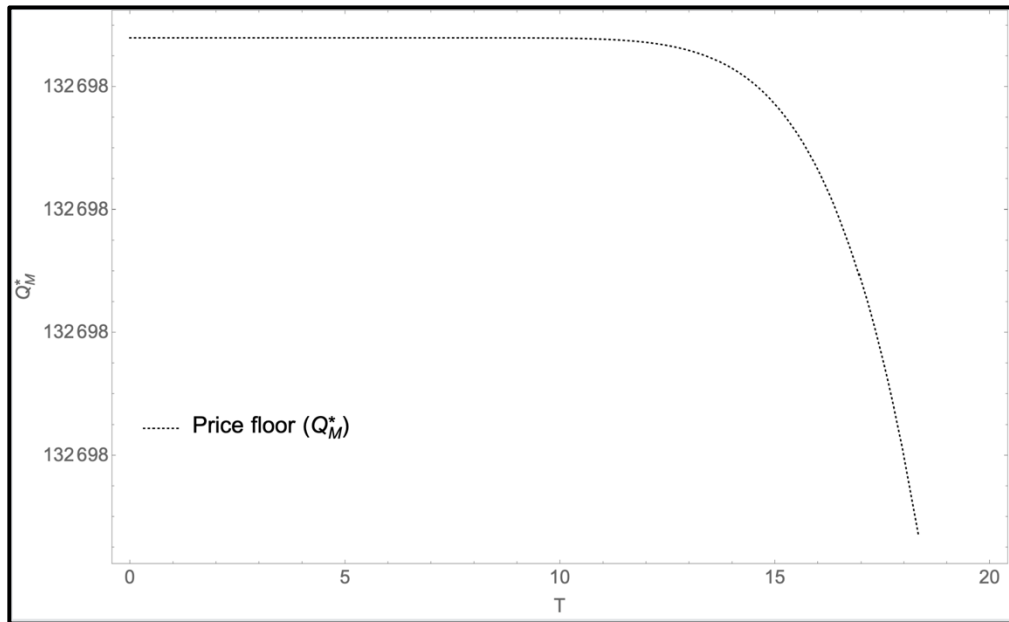
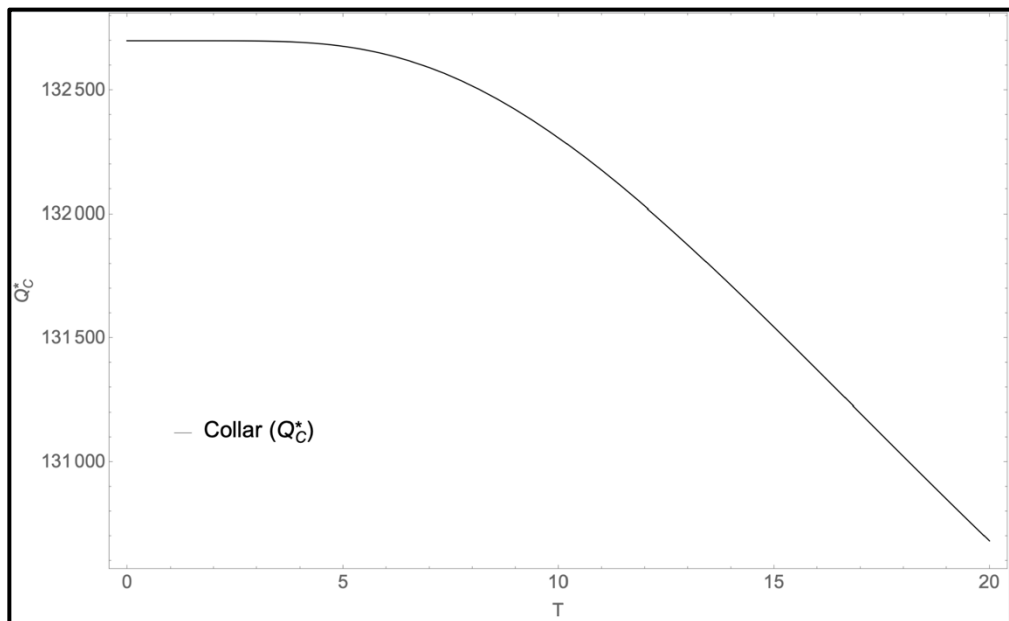


Figure 5.11: Triggers as a function of the volatility σ



a) Q_M^* as a function of T



b) Q_C^* as a function of T

Figure 5.12: Triggers as a function of the duration of the contract T

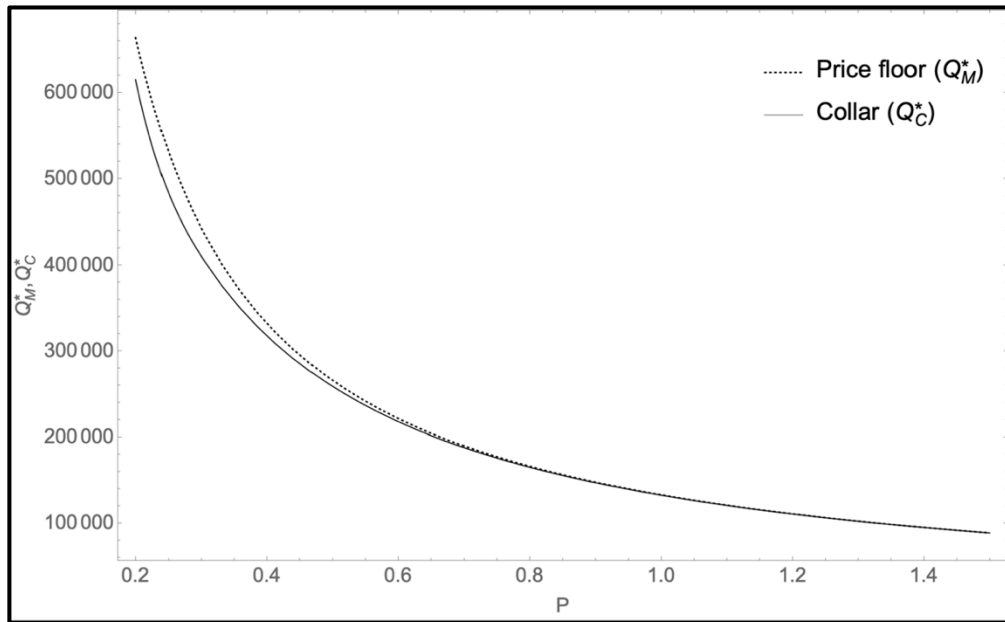
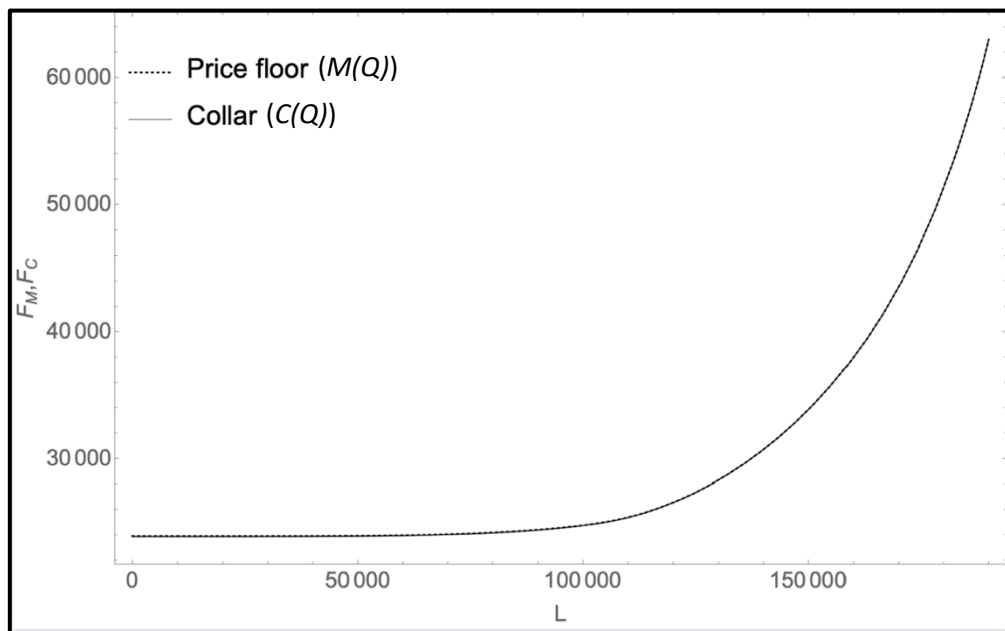
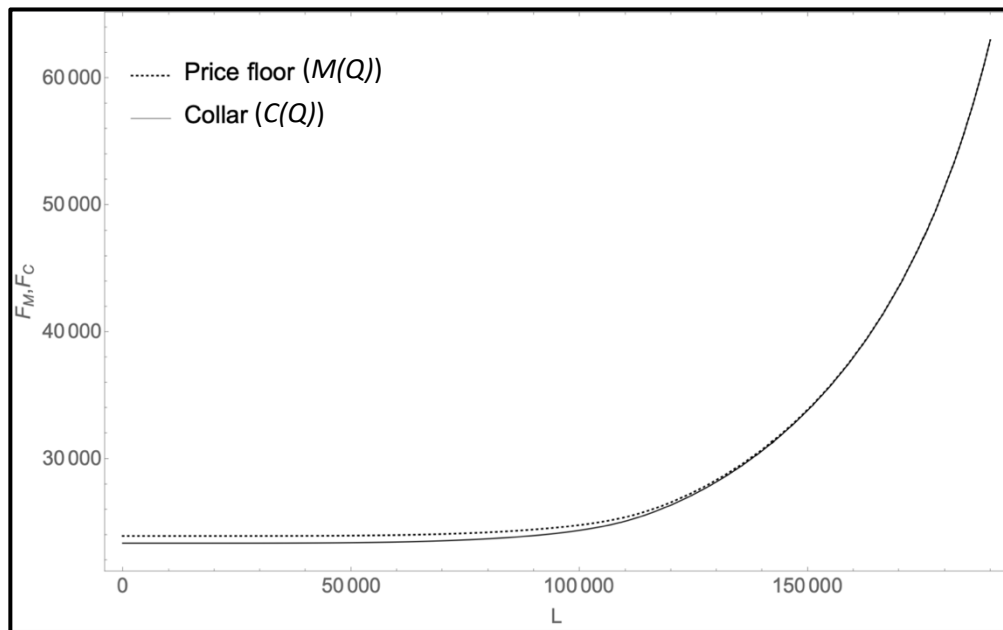


Figure 5.13: Triggers as a function of the price P



a) $H = 435,845$



b) $H = 200,000$

Figure 5.14: Options as a function of the quantity floor L for high and low cap H

6. Conclusions

The present study, through the real options method, analyzes the feasibility of investing in pedestrian paths in Madeira Island, more specifically in the real cases of *Levada das 25 Fontes* and *Levada do Risco*. It contributes to the literature since, to the best of our knowledge, there are no studies on the evaluation of real options in pedestrian path projects, and because of the adaptations that were made in the methodology to the perspective of quantity uncertainty, rather than price, and its connection to environmental sustainability.

Given the uncertainty of the number of users per route, and assuming that it follows a GBM process, in a first phase, we evaluate the investment projects with a MRG, in two different scenarios, perpetual and finite, supposing that the Regional Government of Madeira guarantees the minimum number of users to make the investment viable. However, according to the Legal Regime for Pedestrian Paths in Madeira Island, there is an emerging need to guarantee the sustainability of these tourism destinations, which have been increasingly sought after and, consequently, the target of unregulated and abusive use. Therefore, in a second analysis, the limitation of users' entries to *Levada das 25 Fontes* and *Levada do Risco* was considered, based on their carrying capacity. For that reason, we evaluated the projects considering finite and perpetual collar contracts.

Adopting these schemes, we are basically dealing with options. In the case of MRG, there is an option for developers to recover part of their losses, through the government, if the project performs poorly. In turn, in the collar contract, in addition to the option associated with the guarantee, there is the option for the government to be compensated. For this reason, besides to the fact that investments in natural resources are endowed with uncertainty, the real options method should be used instead of traditional valuation methods. Traditional ones systematically undervalue investments as they fail to capture uncertainties and flexibilities and this affirmation can be confirmed through the obtained results in the two projects under study, in which the NPV value is consistently lower than the project value calculated through real options approach.

Our numerical results show that, if the goal is to get promoters to invest immediately in the *Levada das 25 Fontes* and *Levada do Risco* projects, assuming the same parameters of the study, the quantity floor guaranteed by the government would have to be equal to 125,588 and 108,099 annual users, respectively. Additionally, through the sensitivity analysis developed, it was possible to conclude that offering a Collar contract, from the point of view of accelerating investment, is preferable compared to an MRG. Initially it is not an intuitive result, since for the investor it would

be preferable to have only a minimum guarantee than to be limited by a maximum ceiling. However, through Figure 5.1, it was possible to verify that for the same floor, if a cap is considered, the investor accelerates the investment, in order to take advantage of the market price, in this case the number of users. Therefore, setting a maximum ceiling is more advantageous to accelerate investment, and it will be faster the lower the cap level, up to a certain level (Figure 5.2).

Furthermore, the investment trigger decreases as the duration of the contract increases and in the Collar policy this decline is faster compared to the MRG regime, which means that the government can promote the acceleration of investment extending the duration of the contract.

On the contrary, when analyzing the values of the options associated with the different policies, they do not present the same behavior for both cases. The value of the option linked to the MRG scheme increases as the duration of the contract increases, because the promoter has more time to receive the value associated with the number of registered users. On the other hand, in the case of the Collar, the value of the option decreases as the duration of the contract increases, because it means that the investor will be tied up to the maximum limit for a longer period of time. Even so, according to the option values obtained, promoters should invest in both projects. However, it is important to note that the value of the option increases as the quantity floor increases and that the option linked to the MRG regime creates more value compared to the collar contract, even though it is more sensitive to risk.

Furthermore, based on the analysis, the investment trigger decreases as the price paid by users increases. In this way, increasing the tourist tax can also be a measure adopted by policymakers to accelerate investment, since, as mentioned in the literature, those who look for pedestrian paths are willing to pay a higher amount for the sake of sustainability. However, this measure cannot involve donations, as suggested by the Regional Government of Madeira, but rather fees with well-defined applications that translate into an improvement in the conditions of the routes.

In this study, we shed some light on how to evaluate pedestrian path projects, but there were some limitations, namely the lack of studies and data in Madeira Island, more specifically on the number of users and carrying capacity of the routes and the specification of associated costs. For future research, we recommend that the study be extended to others pedestrian paths noting that it is necessary to update the data on the number of users, given the high demand evidenced in the last year, and, consequently, the carrying capacity.

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Appendix A

Table A.1: Extrapolation for the average annual value of users

		International tourist arrivals per month	International tourist arrivals per semester	Levada das 25 Fontes				Levada do Risco			
				Number per semester	Pedestrian Paths' Users In % of the International tourist arrivals per semester	Number per day	Number per year	Number per semester	Pedestrian Paths' Users In % of the International tourist arrivals per semester	Number per day	Number per year
2022	May	174,679	1,064,321	57,324	5.39%	321	114,648	4,981	0.47%	28	9,962
	June	173,080									
	July	187,279									
	August	188,483									
	September	168,809									
	October	171,991									
2023	November	133,013	885,447	47,690	5.39%	267	95,380	4,144	0.47%	23	8,288
	December	127,940									
	January	121,481									
	February	139,962									
	March	171,477									
		April	191,574								
					Average	294	105,014		Average	26	9,125