Optimal time to invest in the new Montijo airport in Portugal

André Oliveira[a], Pedro Pimentel[b] & Gualter Couto[c]

[a] Fundo de Maneio, Ponta Delgada, Portugal.
Rua Bento José Morais, 23, 1º N-E
9500-772 Ponta Delgada
São Miguel – Açores
Email: aoliveira@fundodemaneio.com

[b] School of Business and Economics and CEEAplA, Universidade dos Açores, Ponta Delgada, Portugal.
Rua da Mãe de Deus
9500-321 Ponta Delgada
São Miguel - Açores
Email: pedro.ms.pimentel@uac.pt

[c] School of Business and Economics and CEEAplA, Universidade dos Açores, Ponta Delgada, Portugal.
Rua da Mãe de Deus
9500-321 Ponta Delgada
São Miguel - Açores
Email: gualter.mm.couto@uac.pt

Funding

This paper is financed by Portuguese national funds through FCT – Fundação para a Ciência e a Tecnologia, I.P., project number UIDB/00685/2020

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Abstract

Lisbon airport, the most important air transport infrastructure in Portugal, has reached its capacity due to an enormous boost in the tourism sector. A solution was designed in order to avoid economic constraints: build a new airport in Montijo in order to receive point-to-point flights. Using real options analysis and utility theory, optimal time to invest in a new airport was assessed, considering the option to defer and benefit from demand uncertainty clarification. The results show that, although investment opportunity value is slightly superior to NPV, it is better to defer the investment until demands reaches the threshold. Empirical contribution to literature with an infrastructural investment that has major implications in economic welfare of Portugal is what this paper aims.

Keywords: economic welfare; airport investment; real options analysis; stochastic processes; uncertainty.

1 Introduction

Lisbon, capital of Portugal, one of the most distinguished destinations in Europe today, was rewarded multiple times due to its features. The number of guests and overnights have been growing fast and, since 2014, it is the Portuguese region with more guests in hotels and similar establishments.

Humberto Delgado airport (official name) is the main gateway for visitors to Lisbon. It is expected that activity at this airport will continue to increase in the coming years due to the expected increase in the number of tourists in Portugal, associated with a more competitive tourism industry and an economy that is recovering from the economic and financial crisis. Moreover, it is a very important infrastructure to connect the Portuguese population to the world.

According to data from Statistics Portugal (INE), there have been significant volume increases in passenger traffic in Lisbon in the last decades, but the pronounced growths happened in the last years (above 10% in 2014, 2015 and 2016, and near 20% in 2017). In 2017, Lisbon airport was responsible for handling 50.6% of all passengers who embarked, disembarked, or were in transit in the Portuguese airports.

The concession contract between Portugal and ANA – Aeroportos de Portugal, S.A. (owned by VINCI, Airports International, S.A. since 2013) states that a process to construct a new airport in Lisboa should start when, among other capacity factors, the numbers of passengers exceeds 22 million. This limit was reached, for the first time, in 2016 (near 22.5 million). Multiple reports on this airport exceeded capacity point out long delays and waiting lines, harmful to destination image.

After multiple studies, it was concluded that the construction of a new airport in Lisbon was not suitable at this time. So the alternative solution found was to expand the Air Force Base of Montijo, a military facility installed near the Lisbon Airport.

Using the Real Options Analysis (ROA), we aim to assess if is optimal to implement the investment now or if is better to wait, starting with actual demand for Montijo airport. Unlike most literature, we will determine the optimal time to invest in terms of economic welfare instead of return on investment to investors. As stated by Pimentel et al. (2012), the decision to deploy a large infrastructure needs to consider the interest of all taxpayers.

This paper aims to contribute to literature with ROA empirical application to large infrastructure investment, as is the case of Montijo airport, considering economic welfare instead of return of investment. According to Garvin and Ford (2012), more ROA research studies about real options analysis on infrastructure investments is necessary to improve managers options thinking and models reliability. Additionally, as far as we know, there are few studies that assesses infrastructural investments using real options analysis on a social welfare perspective.

Following introduction, literature review focus on the advantages of ROA and how it has been treated by the practitioners, especially in air transport sector. After, new Montijo airport epecific case is described, foloowing methodology, data, results, discussion, main conclusions, outline contributions to literature and potential flaws that future research may overcome.

2 Literature Review

Infrastructure investments are crucial to the economic and social development of a region, as explained, for example, by Smit (2003). They represent benefits to shareholders and opportunities for other economic players. It assigns added importance to the government, either because they establish the regulatory framework, or because they often have a key role in providing the infrastructure. The author also states that the option value is shared by other players in the region where the investment is made.

Nonetheless, this kind of projects usually represent high amounts of expenditures and have high levels of complexity, leading to great challenges for their evaluation, planning and execution. If, on one hand, technical complexity could lead to construction costs overruns and delays, on the other hand it is difficult to predict and forecast costs and benefits, as highlight Flyvbjerg, Holm, and Buhl (2002). These authores concluded that nine out of ten transport infrastructure projects cost more than originally planned. They add that, when carried out by the public sector, the projects show a greater disparity between the predicted values and real values, not only in terms of construction costs but also in terms of time to build. Poor traffic forecasting can be even more damaging, since it can lead to the construction of a more expensive infrastructure for a low utilization rate. As Chambers (2007) points out, infrastructure investments face several sources of uncertainty: the investment expenditures, the expected traffic demand, operating revenues, among others.

As explained by the European Commission (2014), these projects evaluation, when carried out by public entities or funded by public money, should not be carried out just on a purely financial point of view, but on a social and economic perspective as well, since they have high benefits to different stakeholders. These projects tend to have negative Net Present Value (NPV), demanding high financial efforts to implement and sustain the projects, but they could have high economic value.

In fact, public infrastructural investments with negative NPV and positive economic value are eligible for EU co-funding to substantially reduce the efforts made by national authorities. The project is assessed by a cost-benefit analysis, that evaluates the investment from a financial and economic perspective. The amount of EU aid will depend on the potential for the project to generate net cash flows that can fund the project itself, covering the funding gap between investment expenditures' present value and the net operational cash flows' present value. Nonetheless, this framework is a traditional discounted cash flow method and it has limitations that can lead to irrational use of public funds.

Traditional investment valuation methods do not consider market dynamics surrounded by change, uncertainty and competitive interactions, which may affect the cash flows (Trigeorgis, 1995). ROA is an integrated solution that uses financial theory, economic analysis, management science, decision-making process, statistics and econometrics to apply the options theory in the evaluation of real assets (Mun, 2006). Real options analysis allows recapturing some of the value lost through more conservative evaluation methods, since different scenarios are designed for the operation (Putten & MacMillan, 2004). In this way, and according to Trigeorgis and Reuer (2017), management has an asymmetric decision to only execute the option if it is worth, maintaining the option alive otherwise. For Brach (2003), real options analysis assumes that managers can mitigate the risk over time, which means that volatility is seen as a positive factor that increases assets value since managers have the option to capture the value when positive scenarios accurs and mitigate the losses on the negative scenarios.

There are different options that firms may face, as explains Brach (2003). One of them is the growth option that allows the firm to expand their capacity to take advantage of future growth opportunities. According to Vo and Le (2017), this kind of options, if associated with high levels of uncertainty and irreversibility, reduce the incentive for firms to immediately invest but increase the incentive to wait. It happens because they maintain their option to invest when future business conditions become more attractive. If the investment is deployed, the option to postpone it until a better moment is ”killed”. In this way, it is important to consider not only the option value but also the optimal time to invest (Pimentel et al., 2012)

There are several methods in financial theory to price options, from network models (more simpler models) to simulation or partial differential equations (more complex models), as identified by Čulík (2016). Network models are the most commonly used since they are easy to run and interpret. Nonetheless, as deterministic models may underestimate the value of projects since input data are constant or assumed to be known with certainty, stochastic models optimizes the outcome since input data follows probability distributions (Mun, 2006).

Many authors have developed models using ROA to evaluate investment projects. For example, Pimentel et al. (2012) developed a model to determine the optimal time to invest in high-speed transport in continuous time with stochastic demand and stochastic investment cost. Kerr (2014) assessed a forest investment by a Brazilian cellulose industry companies with ROA and the optimal time to harvest, based on a method of fully implicit finite differences, considering that wood prices followed a stochastic process. Kostrova et al. (2016) developed a complex model to evaluate American-type real options based on Monte Carlo simulation and network models.

Smit (2003) explains that investments in infrastructure require more careful scrutiny and analysis than traditional discounted cash flow methods offer. This author framework combines real options and game theory using a binomial model. Other authors developed studies regarding airport investments and ROA. For example, Pereira, Rodrigues, and Armada (2007) developed a model to assess the optimal time to invest in the construction of a new airport using two stochastic factors and shocks. Xiao et al. (2017) modeled the choice of airport capacity *a priori* (i.e. to invest immediately) and the real option value for future expansion based on different objectives (maximization of profits or social welfare). More recently, Oliveira, Couto, and Pimentel (2020) have extended Smit’s (2003) framework regarding investments in airport infrastructures to assess Ponta Delgada airport expansion in the Azores.

ROA still face some limitations, inducing managers and practitioners relutance, as explains Machiels, Compernolle, and Coppens (2020): the mathematical complexity of some models (especially when it is considered more than one uncertainty factor); the undefinition of which model is more suitable for each type of investment project and context; the difficulty or incapacity to incorporate other uncertainty sources than just market factors (like technological and political factors). The same authors refer that one of the major critics made to ROA is that it cannot capture the “big picture” of the investmnt project. Another critic, referred by Copeland and Tufano (2004), is that ROA is too optimistic and may over evaluate the projects, since it assumes that managers will have the opportunity to make decisions on the optimal time. Copeland and Tufano (2004) refute this critic because the problem is not the model or the results, but managers capacity to make decisions on the optimal time.

In order to managers and decision makers see ROA reliable and useful, more research on ROA field is needed, especially empirical research and more acessible and suitable frameworks.

3 The airport expansion

3.1 Methodology

This research uses ROA to determine the optimal time to invest in Montijo airport. According to Figure 1, demand in Lisboa airport in last decades show high volatility, with a grow path.

[Insert Figure 1 here]

Although demand is expected to grow, the airport expansion entails high uncertainty. As referred by Chambers (2007), demand is exogenous and the high competition between tourist destinations worldwide may mean that demand growth may not be realized. With this scenario, real options analysis is the most suitable method to assess this type of decision, that involves large amounts of capital and irreversible investments, since it will capture the management flexibility value on adjusting the decisions according to the evolution of demand.

In this study, we use Pimentel et al. (2012) framework. They evaluate the implementation of a high-speed rail in Portugal using real options analysis and utility theory, since large infrastructures investments should be assessed in terms of economic welfare.

For Montijo airport, the main source of uncertainty comes from the level of future demand for the new airport. Any transport mode user is a potential user of the new airport, and the competition between the different transport modes are incorporated in demand stochastic process parameters. Users will decide to fly to the new airport if, at least, utility remains.

Similar to Pereira et al. (2007), we consider that demand for the new airport (x_t) follows a geometric Brownian motion process:

$$\mathrm{d}x_t = \mu_x x_t \mathrm{d}t + \sigma_x x_t \mathrm{d}w_t \tag{1}$$

In this equation, μ_x represents the growth rate and σ_x the standard deviation of demand, that will be constant in time. The Wiener process (w_t) has zero mean and a standard deviation of $\sigma_x\sqrt{\mathrm{d}t}$.

Each user faces a cost for travel between two destinations (ψ), that is a function of the total value of travel time for the user (η) and the airport taxes for passengers (p). According to an IATA Report (2008), short flights (that will be the main type of flights in the new airport), have a greater competition with other transport modes. In this way, it is reasonable to accept that both of these variables show a relationship to the air demand. It is important to clarify that we are not considering the ticket price, but just passenger taxes, since ticket prices are defined according to air company policies.

To illustrate the relationship between the total value of travel time and the demand for air transport, we assume the following functional form:

$$\eta(x_t) = \beta x_t^{\delta_\beta} \tag{2}$$

In this equation, δ_β represents the elasticity between the total value of travel time and the demand for the new airport and β is the scale parameter between demand for the new airport and the total value of travel time. A positive elasticity between the total value of travel time and the demand for the new airport means that increases in the value of travel time will be directly related to the demand for the new airport.

In the same way, the functional form that illustrates the relationship between demand for the new airport and airport taxes is:

$$p(x_t) = \alpha x_t^{\delta_\alpha} \tag{3}$$

δ_α represents the elasticity between the airport taxes and the demand for the new airport and α is the scale parameter between demand for new airport and airport taxes. A positive elasticity between airport taxes and demand for the new airport means that increases in airport taxes of other airports will be directly related to demand for the new airport. It can be understood as the cross elasticity between travel fares of substitute services and the demand for the new airport.

The value that each user confers to an air flight is represented by the following value function (V), with m representing the individual disposable income by unit of time:

$$V(x_t) = m_t - \psi(x_t) \tag{4}$$

The new airport will allow reducing the travel time since it will operate point-to-point flights. This means that not only it will reduce the time that passengers are in waiting lines, but also the processes will be more fluid. In this way, it is expected that the total value of travel time reduces from η_0 (before the investment) to η_2 (after the investment). η_1 represents the total value of travel time during investment implementation that we assume that will be equal to η_0. The difference between β_0 and β_2 reflects the decrease in travel time.

Similarly, the cost of traveling before the investment is deployed is ψ_0 and ψ_2 is the cost of travelling after the investments is ready. The equations that represents each of them are:

$$\psi_0(x_t) = \beta_0 x_t^{\delta_\beta} + \alpha_0 x_t^{\delta_\alpha} \tag{5}$$

$$\psi_2(x_t) = \beta_2 x_t^{\delta_\beta} \tag{6}$$

The cost function ψ_2 is not affected by airport taxes because this framework implicitly assumes that each user will support a part of the investment expenditures and the corresponding operating costs. So, a socially acceptable tax is already implicitly and it does not make sense to duplicate it, as supported by Pimentel et al. (2012).

Until the new airport starts to operate, the value function per user is given by:

$$V_0(x_{t+n}) = m_{t+n} - \beta_0 x_{t+n}^{\delta_\beta} + \alpha_0 x_{t+n}^{\delta_\alpha} \tag{7}$$

The value function per user is given after the investment is ready is given by:

$$V_2(x_{t+n}) = m_{t+n} - \beta_2 x_{t+n}^{\delta_\beta} - w - \frac{\varphi}{x_{t+n}} - \frac{\rho\gamma e^{\rho n}}{x_{t+n}} \tag{8}$$

Note that this equation continues to reflect a travel cost, the variable operating cost (w), the investment expenditures (γ) and fixed operating costs (φ). ρ is the discount rate. We are assuming that investment cashflows will last for an unlimited time horizon.

This framework computes the optimal time to invest, preserving utility function balance. So, it is necessary to find the new airport demand threshold (x^*), above which it will be optimal to invest. In their work, Pimentel et al. (2012) came with a close form solution for this maximization problem. The demand threshold is calculated thought the following equation:

$$x^* = \exp[\frac{\ln\big(1 - r_1(C_{tc} + D)\big) / ((A_{tc} + B_{tc})(r_1 - \theta)}{\theta}] \tag{9}$$

With:

$$A_{tc} = \frac{2(\beta_0 - \beta_2)e^{\left(\mu_x\theta_\beta + (1/2)\theta_\beta(\theta_\beta - 1)\sigma_x^2 - \rho\right)n}}{2\rho - 2\mu_x\theta_\beta - \theta_\beta^2\sigma_x^2 + \theta_\beta\sigma_x^2} \tag{10}$$

$$B_{tc} = +\frac{2\alpha_0 e^{\left(\mu_x\theta_\alpha + (1/2)\theta_\alpha(\theta_\alpha - 1)\sigma_x^2 - \rho\right)n}}{2\rho - 2\mu_x\theta_\alpha - \theta_\alpha^2\sigma_x^2 + \theta_\alpha\sigma_x^2} \tag{11}$$

$$C_{tc} = -\frac{\varphi e^{-\rho n}}{\rho} \tag{12}$$

$$D = -\gamma \tag{13}$$

In these equations, A_{tc} reflects the present value of travel time savings, B_{tc} reflects the present value of airport taxes, C_{tc} reflects the present value of fixed operation costs and D represents the present value of investment expenditures. The subscript tc indicates the time-to-build effect. Moreover, r_1 is the positive root of the quadratic equation:

$$\frac{1}{2}\sigma_x^2 r(r-1) + \mu_x r - \rho = 0 \tag{14}$$

It can be calculated with the following equation:

$$r_1 = \frac{((1/2)\sigma_x^2 - \mu_x) + \sqrt{(\mu_x - (1/2)\sigma_x^2)^2 + 2\rho\sigma_x^2}}{\sigma_x^2} \tag{15}$$

It is important to refer that, according to Pimentel et al. (2012), in order to obtain demand threshold through equation (9), two assumptions need to be made: 1) the total value of travel time/demand elasticity and the airport taxes/demand cross elasticity are equal ($\theta_\beta = \theta_\alpha = \theta$); 2) the operational variable costs are negligence. In fact, considering the characteristics of an airport investment, all major operational costs tend to be fixed.

The investment opportunity value is given by the following terms:

$$v(x) = \begin{cases} \left(\frac{x}{x^*}\right)^{r_1}\left[\frac{\theta(C_{tc} + D)}{\theta - r_1}\right], \text{for } x < x^* \\ (A_{tc} + B_{tc})x^\theta + C_{tc} + D, \text{for } x \geq x^* \end{cases} \tag{16}$$

The first term of the equation (16) gives the investment opportunity value until demand threshold is reached. The second term of the equation gives the

Net Present Value (NPV) of the investment. Note that, when actual demand exceeds the demand threshold, it is better to invest and receive NPV. Until there, there is an inherent value of waiting for new information about the new airport demand. The defer option value is the difference between the first and second terms of equation (16).

3.2 Data and Results

New airport in Montijo information is very scarce, since the memorandum of understanding between the Portuguese Government and ANA, Aeroportos de Portugal, S.A., the private company that holds the rights to explore Lisbon airport, was signed very recently. In this memorandum, the concession contract was revised, which will include ANA's right to explore the new Montijo airport and the investments terms in this and other projects. In this way, we gather all public information available and other information from Portuguese media. The basic parameters values are in Table 1.

[Insert Table 1 here]

Investment expenditures' present value is around 650 million euros, which include expenses to transform the air base in a civil airport and to minimize and repair environment impacts. The construction period is 3 years. According to the project, the new airport will start operate for 4.5 million passengers.

According to the Portuguese Civil Aviation Authority (ANAC), traffic passengers should rise, in the long run, around 2% per year in Lisbon. We will assume a standard deviation of 18%, which corresponds to the standard deviation of historical growth rates in Lisbon airport (1970-2017).

The new airport will allow reducing passenger's waiting time on arrivals and departures. Note that Lisbon airport has been experiencing its worst rates of punctuality, registering, at peak activity levels, waiting periods longer than 2 hours. With the new airport, which will be dedicated to point-to-point flights, it is reasonable to accept that waiting times will be reduced by half, even considering that the new airport is around 15 minutes away to downtown. So, an average waiting time of 1 hour in Lisbon airport will be converted in an average waiting time of 30 minutes in Montijo airport (15 minutes in the airport plus 15 minutes by car or boat).

According to official EU guide to appraise infrastructural investments, the estimated value of travel time per hour for air transports in the EU is 13.62 euros. The total value of travel time in each airport is given by the multiplication of the value of travel time per hour and the average time that passengers spend in each airport. Cross-price elasticity between rail and air travel is around 0.43 and 0.5 (Kopsch, 2012).

[Insert Table 2 here]

The results (Table 2) show that airport construction should only begin when the demand reaches 4,931 million passengers. It is interesting to note that the actual demand is near this value, which helps to justify the discussion about the need for a new airport in Lisbon in the short run.

The investment has a positive NPV. If a traditional capital budgeting analysis was used, the decision was to invest now. However, the demand uncertainty may force a delay in the investment, since option value is not deep in the money. This investment opportunity has a value of 1,192 million euros, with a defer option value of 9.8 million euros. The option value represents just 0,8% of the investment opportunity value. In this particular case, with a positive NPV and a defer option value almost 0, the option value is near at-the-money. In this way, the decision maker, facing other non-economic factors that influence his decision to invest, can neglect the defer option value and implement the investment right now.

4 Final considerations

This paper evaluates the investment in the new Montijo airport in Lisbon using ROA. The capacity of the existing airport is already exceeded and a solution was designed in order to avoid economic constraints in Portugal, especially in the tourism sector. In a context surrounded by uncertainty, a real options approach is recommended. Using a framework developed by Pimentel et al. (2012), it was assessed the optimal time to invest in the new airport. Unlike most frameworks in literature to assess infrastructural investments, this case evaluates the investment in terms of economic welfare, considering stochastic demand, users' utility and value of time travel savings. The net benefits were calculated in economic welfare perspective instead of shareholder's perspective.

According to our results, the actual demand is near to demand threshold, which means that the optimal time to invest in the new airport may be in the near future. The value of the option to defer is just 0.8% of the investment opportunity value.

During research, some scope limitations were found: public information about the new airport and studies about the characteristics of air demand are scarce yet.

For future research, the framework should be extended in order to include more economic factors that influence demand for air transport sector, as is the example of demand shocks caused by externalities like COVID-19.

5 References

Brach, M. (2003). *Real Options in Practice.* New Jersey: John Wiley & Sons, Inc.

Chambers, R.-D. (2007). Tackling Uncertainty in Airport Design: A Real Options Approach. *Master's Thesis, Massachusetts Institute of Technology, Engineering Systems Division, Technology and Policy Program*. Retrieved from https://dspace.mit.edu/bitstream/handle/1721.1/41765/226294248-MIT.pdf?sequence=2

Copeland, T., & Tufano, P. (2004). *A Real-World Way to Manage Real Options.* Harvard Business Review, Financial Analysis.

Čulík, M. (2016). Real options valuation with changing volatility. *Perspectives in Science, 7*, 10-18. doi:10.1016/j.pisc.2015.11.004

European Commission. (2014). *Guide to Cost-Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020.* Brussels: European Commission. Retrieved from https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

Flyvbjerg, B., Holm, M., & Buhl, S. (2002). Underestimating Costs in Public Works Projects: Error or Lie? *Journal of the American Planning Association, 68*(3), 279-295. doi:10.1080/01944360208976273

Garvin, M., & Ford, D. (2012). Real options in infrastructure projects: theory, practice and prospects. *The Engineering Project Organization Journal, 2*, 97-108. doi:10.1080/21573727.2011.632096

Kerr, R. (2014). Competitiveness of the brazilian pulp industry: a real options analysis of a forestry investment. *Práticas em Contabilidade e Gestão, 2*(1), 8-30. Retrieved from http://editorarevistas.mackenzie.br/index.php/pcg/article/view/7036/5159

Kostrova, A., Britz, W., Djanibekov, U., & Finger, R. (2016). Monte-Carlo Simulation and Stochastic Programming in Real Options Valuation: the Case of Perennial Energy Crop Cultivation. *Discussion Paper - Food and Resource Economics, Institute for Food and Resource Economics, University of Bonn, 2016:3*. Retrieved from http://ageconsearch.umn.edu/record/250253/files/dispap16_03.pdf

Machiels, T., Compernolle, T., & Coppens, T. (2020). Real option applications in megaproject planning: trends, relevance and research gaps. A literature review. *European Planning Studies*. doi:10.1080/09654313.2020.1742665

Mun, J. (2006). *Real Options Analysis: Tools and Techniques for Valuing Strategic Investments Decisions.* New Jersey: John Wiley & Sons, Inc.

Oliveira, A., Couto, G., & Pimentel, P. (2020). Infrastructure investment: Application of real options analysis to the Ponta Delgada airport expansion. *Research in Transportation Economics.* Retrieved from 10.1016/j.retrec.2020.100845

Pereira, P., Rodrigues, A., & Armada, M. (2007). The Optimal Timing for the Construction of an International Airport: a Real Options Approach with Multiple

Stochastic Factors and Shocks. *SSRN Electronic Journal*. doi:10.2139/ssrn.986716

Pimentel, P., Azevedo-Pereira, J., & Couto, G. (2012). High-Speed rail transport valuation. *The European Journal of Finance, 18*(2), 167-183. doi:10.1080/1351847X.2011.574984

Putten, A., & MacMillan, I. (2004). Making Real Options Really Work. *Harvard Business Review, 82*(12), 134-142. Retrieved from https://hbr.org/2004/12/making-real-options-really-work

Smit, H. (2003). Infrastructure Investment as a Real Options Game: The Case of European Airport Expansion. *Financial Management, 32*(4), 27-57. doi:10.2307/3666135

Trigeorgis, L. (1995). *Real Options in Capital Investment: Models, Strategies, and Applications.* London: Greenwood Publishing Group.

Trigeorgis, L., & Reuer, J. (2017). Real options theory in strategic management. *Strategic Management Journal, 38*(1), 42-63. doi:10.1002/smj.2593

Vo, L., & Le, H. (2017). Strategic Growth Options, Uncertainty and R&D Investment. *International Review of Financial Analysis, Forthcoming*. doi:10.2139/ssrn.233

Xiao, Y.-b., Fu, X., Oum, T., & Yan, J. (2017). Modeling airport capacity choice with real options. *Transportation Research Part B: Methodological, 100*, 93-114. doi:10.1016/j.trb.2017.02.001

Table 1 – Parameters for the Montijo airport investment

Parameter	**Value**
x - Airport demand at the actual time	4.5 M
γ - Present value of the investment expenditures	650 M€
η_0 - Total value of travel time without investment	13.62 €
η_2 - Total value of travel time in Montijo airport	6.81 €
p_0 - Airport taxes	19.53 €
φ - Fixed operating cost (in % of CAPEX)	3%
ρ - Discount rate	9%
μ_x - Demand expected growth rate	2%
σ_x - Demand standard deviation	18%
n - Time to build (years)	3
δ - Cross-price elasticity between rail and air travel	0.43

Note: M - Millions

Source: Own elaboration

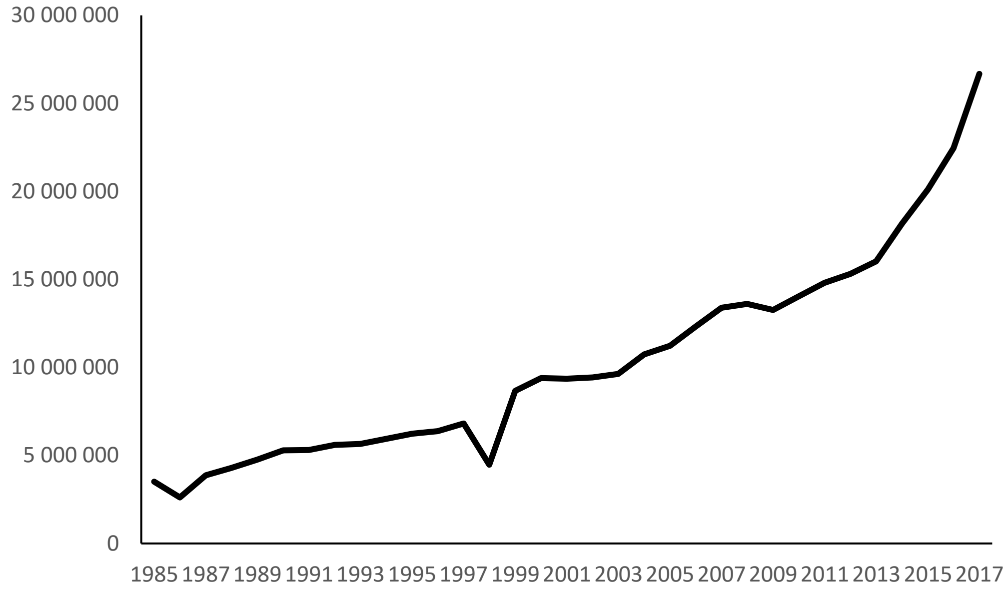
Table 2 – Montijo airport valuation results

Output	**Value**
x^* - Demand threshold	4.931 M
$v\ (x)$ - Investment opportunity value	1,191 M€
npv - Net present value	1,181 M€
vod - Value of the option to defer	9.841 M€

Note: M - Millions

Source: Own elaboration

Figure 1 - Number of passengers at Lisbon airport (1970-2017)



Source: Statistics Portugal (INE)