VALUATION TECHNIQUES FOR AIRPORT INVESTMENTS: MAXIMIZING VALUE THROUGH FLEXIBILITY

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ABSTRACT

Investing in large transport infrastructures, as is the case of airports, is a risky venture subjected to all kind of uncertainties. Traffic volatility is one of the major concerns to airport authorities, public policy makers, regulators, and other stakeholders.

Traditional airport planning paradigms, based on master plans and forecasts, seem inadequate to deal with a highly volatile environment in terms of economic, technological, and technical conditions.

To try to overcome those sources of uncertainty concepts like flexible design of projects has arisen. To be successful in highly competitive and uncertain markets, airports have to be (dynamically) adaptable to changeable engineering systems, and create reliable links to the air transport value chain.

This research focus on the analysis of the economic value of flexible airport design under a *real options* approach, which provides a framework to fill in the limitations of traditional valuation models, like the standard net present value.

The analysis was conducted using a model developed by the authors, which was empirically implemented in a sample of Portuguese airports, to estimate the value underlying the flexibility in the design of different airport subsystems.
The model can be regarded as a support system, able to help decision makers and project managers in strategic and tactical decisions regarding airport infrastructure project design, execution and management. The model uses both the free cash flow model, which requires an estimation of financial leverage of the project, and the more recent capital cash flow model, adequate for projects with high levels of financial leverage and/or variable capital structure.

Keywords: Real Options, Uncertainty, Flexibility, Airport Design, Project Evaluation.

INTRODUCTION

For decades, traditional airport planning based on, most of the times, predetermined master plans and forecasts for aviation activity, has been accepted as the correct way of implementing a strategy, both economical and physical, to develop an airport (Caves and Gosling, 1999).
However, recent changes in the aviation sector, like the liberalization of the air space and the emergence of Low-Cost Carriers (LCC), and major international events, like the 9/11 attacks in the United States of America in 2001, the international recession of late 2008, and the health crisis of the Severe Acute Respiratory Syndrome (SARS) in 2002/2003, the avian flu (H5N1) since 2005 and the *influenza* A (H1N1) outbreak in 2009, have rendered this model, with its fixed forecasts, questionable and a new vision on airport design and management is required.
Rather than changing the design of an airport altogether (most airport's subsystems – like terminal buildings, baggage processing and runways –, regardless all technological improvements, remain in essence the same), the new trend is to focus on the flexible development of those subsystems (Neufville, 2008).
In this paper we aim at appraising the subsystems that maybe able to be developed in a modular way (like the taxiways, terminal buildings, etc.) and valuate that flexibility using different models.
Those models include the standard discounted cash flow (DCF) model, which assumes the project will meet the expected cash flows with no intervention by the management in the process, with all the uncertainty being handled in the risk-adjusted discount rate.
As is widely recognized, this model has some limitations, like the aforementioned managerial inflexibility, which treats every project like a go-or-no-go decision and is unable to reflect new information on project implementation and execution, that may be acceptable in a simple everyday small scale project, but in more complex systems, like an airport, may biases managerial in the project decision-making.
The seminal work of Black and Scholes (1973) and Merton (1973), provides the theoretical formulation for valuing contingent financial assets, such as options. This valuation model subsequently was applied to the valuation of optionalities on real assets: the so called real options.

The paper shows an application of real options to value the flexibility in designing and managing an airport project.

UNCERTAINTY IN AIRPORT DEVELOPMENT

The modern aviation sector started to take shape in the 1950's, since the end of World War II. In those days, the airlines, most of them government owned (at least in Europe), operated in an highly regulated environment, which was stable and predictable, which allowed the stakeholders in the business – airlines and airports owners – to make long-term forecasts and to have the assurance that the conditions in the following years would remain essentially the same (Neufville, 2008).

Nowadays the scenery is different: with the deregularization process that started in the United States in 1978, companies started losing markets they have taken for granted and kept for decades, while new opportunities arose in routes that previously were overly protected by regulations. Airports, free of the bureaucratic process that hindered competition between them, started to compete for the airlines attention, which lead to huge successful hub airports, like Atlanta – home of Delta Air Lines, among others –, with over 90 million passengers in 2008, while others airports, like Kansas City, fell almost empty when their main customers went bankrupted or simple rerouted their hub to another airport – the case of Kansas City when TWA moved to St. Louis (Neufville, 2008).

In Europe the process was similar, starting with initiatives of the European Union (EU) in 1987, lead to a regulatory situation, in 1997, similar to the American one (Button, Costa and Reis, 2005). More recently, even the air space between Europe and the USA became deregularized.

The economic effects for consumers of the deregulation process are well reflected in Figure 1, which shows an average annual geometric growth rate of -2,63percent over a period of 71 years.

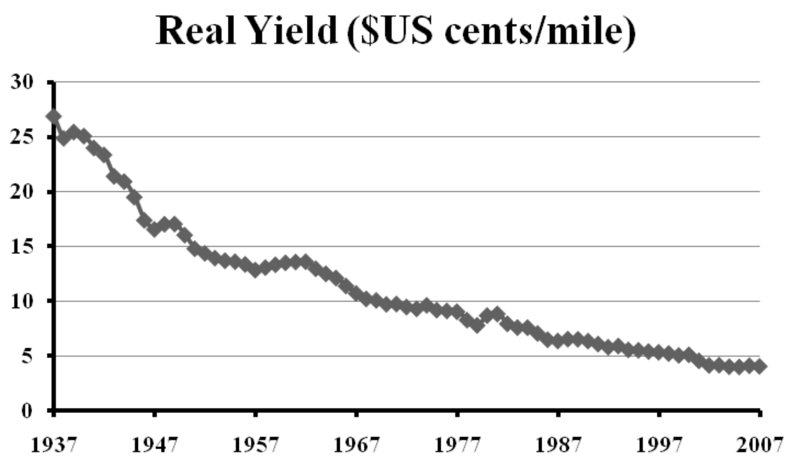

Figure 1 – Yield – price (in $US cents) a passenger pays to fly a mile – from 1937 to 2007, adjusted to 1978 prices (the year of passenger airline deregulation in the US). Source: Air Transport Association – www.air-transport.org

Regarding airport design, the common practice was – and still is – to make a master plan, which encompasses such aspects as the airport's size, layout and costs (Kazda and Caves, 2007). This approach, sanctioned by the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA), among others, has two main phases, namely, the determination of the correct forecast, and the selection of a single plan that best suited this forecast (Neufville, 2008). The main problem of this approach resided in the former: choosing one, and only one, *correct* forecast (which are said to be *always wrong*, as many empirical results suggest), leads to inflexible frameworks for the development of airports.

The traditional method of designing complex engineering systems (being the airport master plan just an example), too often focus on a deterministic view of the environment in which the system operates. In an uncertain world, flexibility is a major attribute that can result in the success, or not, of a project. It can take advantage of unexpected upside opportunities, and/or reduce exposure to downside risks (Cardin and Neufville, 2008).

Flexibility is especially valuable for the most uncertain projects. It is thus especially valuable for major, unique, and long-term investments – where the future prospects are most difficult to predict. Flexibility thus differs from other classes of assets. Indeed, the general rule is, the greater the risk, the less something is worth. The situation is just the opposite for flexibility assets. This particular feature is due to the hockey-stick value of flexibility. Because the value of the flexibility is either zero or something, the positive values are not cancelled out by the zero values. Events that are farthest from the trend, give the highest value (Neufville and Scholtes, 2006).

STANDARD VALUATION MODELS

Discounted Cash Flow

To assess the value of an investment, a basic principle in finance must be taken into account: *a dollar today is worth more than a dollar tomorrow*, because the dollar today can be invested to start earning interest immediately (Brealey and Myers, 2000). With that principle in mind, it is easy to understand that future cash flows will not worth as much as cash flows made in the present.

To evaluate the value of a project in *today's* money, it has been common to use the figure of net present value (NPV), which is nothing more than the sum of all cash flows, adjusted to present value, deducted from the investments initially made (1).

$$NPV = C_0 + \sum_{i=1}^{n} \frac{C_i}{(1+r)^i} \qquad (1)$$

Where,
C_0: cash flow at time zero, usually the investment made
C_i: cash flow at time i
r: discount rate

After applying that discount rate to every future cash flow, it is possible to estimate the net present value (NPV) of the project. If NPV is positive, the project is expected to create economic value and therefore increase the wealth of project owners and should be undertaken, if negative, the project should be abandoned.
A critical component of this type of valuation is the choice of an accurate discount rate. Typically the rate has been chosen by application of the free cash flow model (FCF), which estimates the discount rate using the weighted average cost of capital (WACC) (2):

$$WACC = K_E \times (1 - g) + K_D \times (1 - t) \times g \qquad (2)$$

Where,
K_E: cost of equity
K_D: cost of debt (pre-tax)
g: level of financial leverage, measured by the Debt-to-Total-Assets ratio

t: corporate tax

The cost of debt (K_D) is estimated adding the risk-free rate (r_F) to a spread that reflects the market price for credit risk.
The cost of equity (K_E) was estimated using the Capital Asset Pricing Model (CAPM) (3):

$$K_E = r_F + \beta_E \times (r_M - r_F) \qquad (3)$$

Where,
r_F: risk-free rate
β_E: equity beta
r_M: level of market return
$(r_M - r_F)$: market risk premium

The risk-free was estimated using a treasury bond as a benchmark, with a maturity close to the life of the project being valued. The market risk premium is the level of return the investors expect to achieve when holding risky securities, over investing in risk-free assets.
The equity beta is the price of the project's systematic risk.

Free Cash Flow vs. Capital Cash Flow

Although being constantly used when valuating risky cash flows, the FCF model should be used in projects with a relatively low gearing and with a capital structure that remains essentially the same during the life of the project (Coutinho dos Santos and Pinto, 2008).
Clearly, that is not the case of large transport infrastructures like an airport.
For projects with high levels of financial leverage and/or variable capital structure, Capital Cash Flow (CCF) model (Ruback, 2002), addresses this problems by treating debt tax shields differently. In the FCF model, the debt tax shields are disregarded in the estimation of cash flows and incorporated in the calculation of the WACC. On the other hand, in the CCF

model the risk-adjusted discount rate is calculated before taxes, and the debt tax shields are a relevant cash flow.
The appropriate discount rate to value CCFs is a before-tax rate because the tax benefits of debt financing are included in the CCFs. That said, the before-tax rate should correspond to the riskiness of the cash flows, and is the expected asset return, K_A, (4)[1]:

$$K_A = r_F + \beta_A \times (r_M - r_F) \qquad (4)$$

Where,
r_F: risk-free rate
β_A: asset beta
r_M: level of market return
$(r_M - r_F)$: market risk premium

With this model it is possible to avoid the estimation of the financial leverage of the project (a necessary step in the FCF model), normally a difficult task in projects with long duration like an airport, in which the gearing is always changing (Coutinho dos Santos and Pinto, 2008).
In our model, both FCF and CCF models will be used in order to allow comparisons between them.

The DCF Models Shortcomings

The DCF models, explained in the preceding chapters, make a number of assumptions that sometimes do not apply to the real economy and are often overlooked. It assumes one of two things: either the investment is *reversible* and can be undone (and the expenditures recovered) if the market conditions are worst than anticipated or the investment is *irreversible*, i.e., the initial cost of investment is at least partially sunk and cannot be recovered, the company will have to decide to take the investment now or will lose the opportunity to do it in the future (Dixit and Pindyck, 1994 and Dixit and Pindyck, 1995).
In those models, cash flows are assumed to follow a deterministic path into a distant future, with no management intervention, and the risk associated with the project being accounted in the discount rate (Mittal, 2004).
Although this may be true for some projects, clearly that is not the case of a large transportation system like an airport, where the estimation of future cash flows is very difficult and subjected to traffic forecasting and so, management has a very important role in deciding whether investments should be undertaken, postponed or even cancelled.
In short, the DCF procedures fail – when applied to systems operating in an uncertain environment – to recognize that effective management of the risks enhances the value of the system. Put another way, the DCF models are adequate over a limited range that does not include major technological investments operating in the midst of considerable technological and market uncertainties (Neufville, 2003), but can be used for decisions involving a

[1] In his paper, Ruback (2002), shows that K_A is equivalent to WACC, equation (2), before taxes, i.e., equation (2) without the $(1 - t)$ parameter.

moderately straightforward business, unsophisticated projects, and a steady environment that allows for dependable forecasts (Miller and Park, 2002).

OPTIONS

Financial Options

In a stock market, an *option* is *the right, but not the obligation* to buy (a call option) or sell (a put option) an asset at a fixed price (the *strike* or *exercise* price) at or before the expiration date of the option[2]. To have this option to buy or sell the asset the buyer pays a price (the *option price* or *value*). Of course this option will only be exercised if the price of the asset is below the strike price, in case of a call option, or if the price of the asset is greater than the strike price, in case of a put option. Otherwise, the holder of the option will let the expiration date pass and the option will expire (Damodaran, 2000).
To estimate the value of a European option, the Nobel Memorial Prize in Economic Sciences option pricing model of Fischer Black and Myron Scholes from 1973 (with contributions, in the same year, of Robert Merton, who shared the prize with Scholes in 1997) is often used.
This continuous-time model, an analytical solution to solve a partial differential equation, has five variables, with a sixth one – dividends paid on the underlying asset – being added to the original model by Merton.
Those variables are (Damodaran, 2000):

1. Current value of the underlying asset, S
2. Variance in value of the underlying asset, σ^2
3. Strike price of option, K
4. Time to expiration of option, t
5. Riskless interest rate corresponding to life of option, r

A few years later, Cox, Ross and Rubinstein (1979) proposed a discrete-time model, based on binomial lattices, that requires only elementary mathematics, yet it contains as a special limiting case the Black-Scholes (BS) model. This approach can also be used to solve for the value of early-exercise American option, whereas the Black-Scholes model can only value European options (Hahn and Dyer, 2008).
This model assumes that the asset price in a given period can only increase by a fixed factor, u, or decrease by another fixed factor, d. This make the lattice recombine at each node (Figure 2), which means an upward movement followed by a downward one leads to the same result as a downward movement followed by an upward one (Chambers, 2005).

[2] An option which can only be exercised at the expiration date is called a *European option*. One than can be exercised at any time until the expiration date is called an *American option*.

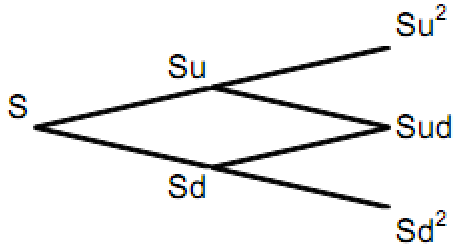

Figure 2 – Initial stages of a binomial lattice. Source: Carvalho (2005)

With this model it is also possible to determine the probability of each outcome, being p the probability increase factor, and $(1-p)$ the probability decrease factor (5):

$$p = \frac{1}{2} + \frac{1}{2} \times \left(\frac{\nu}{\sigma}\right) \times \sqrt{\Delta t} \qquad (5)$$

Where,
ν: average growth rate (%)
σ: standard deviation (%)
Δt: length of each period

The increase and decrease factors can be determined using equations (6) and (7), respectively:

$$u = e^{\sigma\sqrt{\Delta t}} \qquad (6)$$
$$d = \frac{1}{u} = e^{-\sigma\sqrt{\Delta t}} \qquad (7)$$

Real Options

With the rapid expansion of option-pricing theory application on financial assets, it did not take much time for someone to realize that this concept could be applied to real assets and non-financial investments. First coined by Myers in 1977, the term *real options* appeared to differentiate this kind of options from the *options* used in the financial world.
In this context *option* has a specific, technical meaning. It is not a synonym for “alternative” as it is in ordinary language. An option refers to a choice, but a choice that the system designers and managers have deliberately made possible through some effort. It refers to flexibility, to the ability to adjust a design of a system in significant ways that enable the system managers to redirect the enterprise in a way that either avoids downside consequences or exploits upside opportunities (Neufville, 2004).
Table I presents the differences between an American call option and a real option on a project:

Table I – Comparison between an American call option and a real option on a project
Source: Adapted from Li and Johnson (2002) and Carvalho (2005)

American Option on Stock	Real Option on a Project	Variable
Current stock price	Present value of expected cash Flows	S
Option exercise price	Investment cost	K
Time to expiration	Time window of the investment opportunity	t
Riskless interest rate	Discount rate	r
Stock price uncertainty	Project value uncertainties	σ^2
Right to exercise the option earlier	Right to invest in the project before the opportunity disappears	-
Traded in a financial market	Usually not traded	-
Easy to find a replicating portfolio	Hard to find a replicating portfolio	-
Only the holder has rights over them	The holder and his competitors might share the rights to exercise the option	-

The use of options, although not explicitly, has been used by corporate executives for a long time. Every time a project is postponed or a contingency plan is prepared the management is exercising an option. Real options recognize and value this kind of flexibility and the staged nature of many investments. Projects that turn out to have negative NPV on a full-scale basis may actually create value if undertook in stages and projects that may look attractive on a full-scale basis may look more attractive if undertaken in stages after resolving uncertainty (Herath and Park, 2002). They tend to be most valuable in situations of high uncertainty and where the project without flexibility is near breakeven (Copeland and Keenan, 1998).
Real options analysis will not be needed when a project is either incredibly valuable or a complete disgrace. In those cases a simple DCF approach will tell the managers that the first one should be undertaken and the second one abandoned. But when uncertainty is large enough to make flexible solutions possible and waiting for more information a sensible decision, and when the value seems to be captured in possible project updates and mid-course strategy corrections, then real options provide a valuable framework to study those projects (Amram and Kulatilaka, 1999).
If there is no possible flexible solutions in a project, computing the NPV by standard models and by option valuation will give the exact same value. They diverge when there is a possibility of making choices within a project. For example, when there is a possibility of deferring a project. Choosing to defer a project may be good for a number of reasons, namely, the assumption that is always good to pay later than sooner (while waiting we can earn the time value of money on the deferred expenditure). Another reason for waiting is the constant changing world we live in: the value of the assets may change during the waiting period, an apparent good business can turn into a bad one if prices goes down and vice-versa. By waiting, the ability to participate in good outcomes is still intact, while remaining sheltered of possible bad ones (Luehrman, 1998).
According to Miller and Park (2002), using real options bring two advantages when compared to DCF models. First, greater volatility does not translate into greater losses,

because losses are limited to the initial investment. Second, the real options' value increases with a longer decision horizon, contrary to the DCF approach, where a lengthy time horizon just increases the project uncertainty, which lowers the project's value.

Additionally, real options compensate for the uncertainty inherent in investments by risk-adjusting cash flows and discounting them at a risk-free rate. DCF, on the other hand, compensates for this uncertainty by adjusting the discount rate. Adjusting cash flows forces analysts to be more explicit about assumptions underlying the projections and eliminates interminable discussions about the appropriateness of one discount rate versus another (Latimore, 2002).

Overall, the point of using real options analysis is to calculate the value of flexibility in present value terms. This is most important information for systems designers. By comparing the value of flexibility with the cost of acquiring it, they can make an informed, analytic judgment about whether this flexibility should be incorporated into design (Neufville, 2002).

Types of Real Options

Several types of real options can be found within a project. Table II sums up a classification often used.

Table II – Different types of real options.
Source: Adapted from Ohama (2008).

Type	Description	Implementing Criteria
Options to wait	Investing now might be profitable, but it might be also profitable tomorrow. Leaving investment opportunity open and waiting for more profitable opportunity indicates holding a Call-Like option.	Max [immediate investment, waiting, 0]
Options to expand	Expanding the level of projects allows greater participation in upside. Cost of expansion is analogous to strike price.	Max [current status, expanded project]
Options to restart temporarily closed operation	Similar to options to wait to invest or expand.	Max [remain closed, re-open operation]
Options to abandon	Abandoning investment can eliminate further losses in projects, which includes shut down costs and salvage prices.	Max [continuing, abandoning]
Options to contract	Options to contract can reduce the participation level and exposure to losses, although it basically incurs in short-term scale down costs.	Max [current status, contracted project]
Options to shut down operations temporarily	This is a special case of options to contract, and it can eliminate losses, but incur in shut-down costs.	Max [current status, temporarily shut down]
Combinations of options	Combinations of options above.	-

The options presented in Table II, which closely mirror financial options in terms of use, are normally referred as real options *on* projects. This kind of options treat technology as a black box and are applied when uncertainty comes from the market factors that firms cannot control such as future demand (Wang and Neufville, 2006 and Ohama, 2008). Most of real options literature focuses on this type of options.

Alternatively, when the flexibility lies within the design of the system or projects, these options can be called real option *in* projects, and are created by changing the actual design of the technical system.

Real options *on* projects are mostly concerned with the valuation of investment opportunities, while real options *in* projects are mostly concerned with design of flexibility. Real options *on* projects do not require knowledge on technological issues, and interdependency/path-

dependency is not frequently an issue. However, real options *in* projects need careful consideration of technological issues. Complex technological constraints often lead to complex interdependency/path-dependency among projects (Wang and Neufville, 2005).
Table III presents a comparison between real options *in* and *on* projects.

Table III – Comparison between real options *in* and *on* projects.
Source: Wang and Neufville (2005).

Real Options *on* Projects	**Real Options *in* Projects**
Values opportunities	Design flexibility
Valuation important	Decision important (go-or-no-go)
Relatively easy to define	Difficult to define
Interdependency/path-dependency not an issue	Interdependency/path-dependency an important issue

THE MODEL

In order to evaluate the benefits of considering flexibility when designing and managing an airport, a model was developed.[3]
Two different scenarios, each with two different settings, were considered. In the first, inflexible, scenario the airport is considered to be constructed all at once, for a maximum annual capacity of 50 million passengers (MPax). In the second, flexible, one, the airport is built in different stages only when needed (a few years before, actually). The model assumes there are no restrictions (environmental, etc.) for building an airport of this size.
In both scenarios, two different types of airports were considered: *low-cost airports* (LCA), primarily intended to serve LCC and *full service airports* (FSA), which are mainly used by regular, non low-cost, carriers. The distinction between the types of airports is used to accommodate the differences in cash flows patterns each type of airline generate to an airport.
In the flexible scenarios, a small airport (15 MPax for a full service and 5 MPax for a low-cost airport) is opened in year 0, and is upgraded, in 5 MPax increments, when the capacity is exceed in 90%, in the case of a full service airport, and in 95% in the case of a low-cost airport.[4] The construction of these *upgrades* will start 2 or 3 years (for a low-cost and for a full-service airport, respectively) before the mentioned threshold in order to allow the opening of the new facilities when they are really needed.
In order to evaluate the different scenarios, it was necessary to forecast traffic for the future, which led to a range of expected future cash flows for a period of 51 years (from year 0 – when the airport opened – to year 50). The starting demand at year 0 was established to be 2 MPax. If the maximum capacity of 50 MPax was exceed in a year (or several), it was assumed that the airport continued to serve only 50 MPax, even if the demand was higher.

[3] This model was used in a Master thesis developed by one of the authors and is available publicly at http://realoptions.pt.vu/.
[4] We considered that the construction of new facilities in a low-cost airport should be done more rapidly, since they are normally simpler than the equivalent ones in a full service airport, and therefore the expansion is only needed when the airport is closer to reach the capacity limit than in a full service airport.

By applying a discount rate to those cash flows, it was then possible to evaluate the inflexible scenarios, allowing the computation of a NPV for both the full service and the low-cost airport.

The process to evaluate the flexible settings was not so straightforward. First, a binomial lattice (for each type of airport) containing expected passenger movements was built and the probabilities for each node were calculated. Afterwards, if there was a need for expansion in a certain node (following the assumptions already mentioned), the investment was made 2 or 3 years before, depending on the type of airport.

With that information regarding the necessary expansions, it was the possible to estimate cash flows for each one of the 1326 nodes of the lattice. The expected cash flow of each period was then calculated as the sum of the probability weighted cash flows of the nodes in that period.

Applying the discount factors of the both FCF and CCF models, and then applying the corporate tax to the latter, it was possible to estimate the expected NPV values for 10, 20, 30, 40 and 51 years, and the corresponding option value, which is simply the difference between the inflexible scenarios NPVs and the ones calculated in the flexible scenarios (8).

$$Option\ value = NPV_{inflexible\ scenario} - NPV_{flexible\ scenario} \quad (8)$$

In the end, in order to estimate how changing the input variables affect the final results, a sensitivity analysis was conducted in order to estimate the most influent variables in the final results and then a number of Monte Carlo simulations were run using those variables.

This approach, which considers the airport as a whole, is different from other studies regarding this subject, like the Master thesis developed by Chambers (2005) in the Massachusetts Institute of Technology, in which two different models, one for the airside and one for the landside, were developed.

Flexible Subsystems Considered

Table IV presents the costs considered in the model, with all subsystems being aggregated into one value:

Table IV – Investments in the two types of airports considered.
Source: Adapted from the *Portela + 1 Report*, (Centro de Estudos de Gestão e Economia Aplicada - Faculdade de Economia e Gestão da Universidade Católica Portuguesa and TRENMO, 2007)

	Total Investment Needed (€)	
Capacity (MPax)	**Full Service Airport**	**Low-Cost Airport**
5	-	292.110.000
10	-	365.619.000
15	846.370.000	446.618.000
20	976.910.000	538.638.000
25	1.135.591.000	643.819.000
30	1.477.991.000	863.169.000
35	1.596.440.000	936.678.000
40	1.737.359.000	1.017.677.000
45	1.899.999.000	1.109.697.000
50	2.074.730.000	1.214.878.000

These costs were adapted from the report Avaliação Económica do Mérito Relativo da Opção "Portela + 1" - Estudo de impacte da localização de um novo aeroporto na região de Lisboa (hereafter referred as CEGEA and TRENMO, 2007), and include, between others, the construction of two runways, each one with a capacity of 25 MPax (therefore, the second runway is constructed after the 25 MPax capacity is exceed), terminal areas (with luggage processing facilities, offices, etc.), technical equipments (like control tower, police station, firemen headquarters, etc.), support systems (parking places, fuel storage facilities, etc.) and environmental systems (air, water and noise monitoring systems). All site-specific costs, like raising a rampart before the construction and other foundation works, are not included in these costs. In the end, a 7% multiplier was applied to account for possible unexpected costs.
It is assumed in this model that the costs of expanding the airport in the future are the same as expanding it now.
In the appendices, a table with the costs of the different subsystems is presented (Tables XVIII and XIX).

Traffic Forecast

A major component in a real options valuation, with vast implications in the performance of the binomial lattices, is the accurate estimation of the growth rate (v) and corresponding volatility (σ^2) of the parameter being analyzed – in this case, the traffic in an airport.
To estimate those two variables, data regarding European airports from 1993 to 2007 was collected from Eurostat. To have more relevant results, we decided to ignore the airports with one or more years of data missing and the ones that had less than 100.000 passengers in

the first year of data (1993). Those constraints meant that only 30 airports (with 11,11% of annual growth and a volatility of 16,55%), mainly from Austria and Germany, would be taken into account.

A new period, ranging from 2002 to 2007[5], was then chosen. The constraints applied were the same, and resulted in a total of 221 airports from 20 countries. The average annual growth of this sample was 8,11% with a volatility of 4,38%.

In order to evaluate the construction of an airport targeted for LCC it was necessary to estimate separately average growth rates and volatilities for this kind of project. The choice of which airports represent *low-cost airports* was based on CEGEA and TRENMO (2007) and on a paper by (Neufville, 2007). These sources cited 10 airports from 5 countries (from the original 221 airports from 20 countries) that could be considered low-cost airports. Those airports had an average annual growth, in the same 2002-2007 period, of 22,83 percent with a volatility of 7,11 percent.

Inflows and Outflows

To determine the cash flows patterns generated at an airport, CEGEA and TRENMO (2007) used data collected from ANA[6] and Instituto Nacional de Estatística[7] about Lisbon airport (which represents the full service airport) and Faro airport (which was considered as a low-cost airport) from 2001-2005 to estimate the inflows resulting from passenger movements. Those inflows included not only revenues directly attributed to passenger movements, but also other revenues like aircraft taxes. All those inflows were then aggregated into one inflow per passenger (the quotient between total revenues and the total number of passengers), that aims to represent the total revenue one passenger generate when in the airport.

Since ANA does not reveal detailed information about its expenses, CEGEA and TRENMO (2007) used a large database of European airports in order to estimate outflows per passenger (like in the case of inflows, outflows *per passenger* include all expenses, not only those directly related to passenger movements). This calculation resulted in ratios between operating expenses and revenues for the two types of airports considered in the paper:

65 percent for full service airports;

75 percent for low-cost airports.

The results are presented in Table V.

Table V – Investments in the two types of airports considered.
Source: CEGEA and TRENMO (2007)

		Expenses (€\Pax)	**Revenues (€\Pax)**	**Profit (€\Pax)**
Type of Airport	**Full Service**	7,20 €	11,07 €	3,87 €
	Low-Cost	7,17 €	9,56 €	2,39 €

[5] This period was specifically chosen in order to represent the evolution of air traffic after 9/11.
[6] *ANA, Aeroportos de Portugal, S.A.* is the government-owned company that is responsible for all Portuguese airports in the mainland and in the Azores.
[7] The Portuguese Institute for Statistics.

The assumption, implied in this model, that there are no economies of scale with the increase of the number of passengers, makes the number of passengers the only risky variable in the project (CEGEA and TRENMO, 2007).

Model Specification and Parameterization

To apply equations (2), (3) and (4), some variables need to be defined.
The risk-free rate (r_F) was estimated with the 30-year Portuguese Treasury bond[8] as a proxy, and its value in May 13, 2009, was 4,642 percent. The cost of debt (K_D) used was the risk-free rate plus a spread of 2,0 percent.
The corporate tax was based on the Portuguese income tax rates, and assumed a value of 27,5 percent, being 25 percent the national income tax rate and 2,5 percent the local tax rate surcharge.
The gearing considered in the model was based on the work of (Kleimeier and Megginson, 2001), which studied 4956 project finance loan operations (worth $634,4 thousand millions) and concluded that they had an average gearing ("average loan to project value ratio" in the quoted paper) of 67%.
The market risk premium used, was the total market risk premium for Portugal (6,50 percent in January 2009) as estimated by Professor Aswath Damadoran[9].
The asset beta value for airports in Europe (β_A) was estimated by (Alexander, Estache and Olivern, 1999) and its value is 0,5877.

Binomial Lattices Inputs

Using the data from the traffic forecast calculations it is possible to estimate the increase factor, *u*, decrease factor, *d*, and the probability increase and decrease factors, *p* and *1-p*, respectively, for both types of airports considered (Table VI). The time factor, Δt, considered was one year.

Table VI - Data to use in the binomial lattices. Calculations by the authors.

	Type of airport	
	Full Service	**Low-cost**
Annual Growth Rate (ν)	8,11%	22,83%
Volatility (σ^2)	4,38%	7,11%
Time factor (Δt)	1	1
Increase Factor (u)	1,23	1,31
Decrease Factor (d)	0,81	0,77
Probability Increase Factor (p)	0,69	0,93
Probability Decrease Factor ($1-p$)	0,31	0,07

8 Portugal does not issue treasury bonds with a maturity longer than 30 years.
9 http://pages.stern.nyu.edu/~adamodar/

RESULTS

Inflexible Scenario

With the mentioned input data, both airports – especially the full service one – prove to be highly unprofitable, using both discounted cash flow models, even in a time horizon of 51 years (Table VII).

Table VII –Results for the inflexible settings, for both valuation models.

	Type of Airport			
	Full Service		Low-Cost	
Results	**FCF**	**CCF**	**FCF**	**CCF**
NPV - 10 years	-1.998.741.878 €	-2.006.693.231 €	-1.126.302.058 €	-1.139.273.342 €
NPV - 20 years	-1.926.000.584 €	-1.953.132.325 €	-875.646.437 €	-954.621.179 €
NPV - 30 years	-1.856.367.387 €	-1.901.307.961 €	-712.065.298 €	-832.959.075 €
NPV - 40 years	-1.789.709.484 €	-1.851.163.838 €	-640.235.543 €	-778.961.129 €
NPV - 51 years	-1.736.264.563 €	-1.810.535.672 €	-606.743.687 €	-753.502.770 €

With the annual growth rates considered, the full service airport (with an annual growth rate of 8,11 percent, which mean passenger movements would double every 9 years), would have its capacity exceed in year 42, operating at full capacity for 9 years. In the low-cost airport, with its growth rate of 22,83 percent (passenger movements double every 4 years), capacity would be exceed in year 16, operating at full capacity for 35 years, which translates into higher NPVs in the final decades analyzed (in the first 10 years the difference between FSAs and LCAs is a little bit below 1,0 thousand million euros in both valuation models, and expands to almost 1,5 thousand million in the final NPV considered at year 51).

Remarkably high construction costs combined with relatively low net profit ratio (25 percent for the LCA and 35 percent for the FSA) pave the way for the achieved results.

Chambers in his 2005 Master thesis produced at MIT, developed two models, one for an airport's terminal and other for a runway. As already mentioned in Chapter 5.1., these models were subsequently applied to a case study in Portugal, regarding the now-defunct *Ota* International Airport project. In the terminal model Chambers used a range of cash flows very different from the ones used in the present thesis, with net profit ratios of over 80 percent.[10]

Although applied in a case study based in the Portuguese situation, these cash flows greatly differ from the ones estimated by CEGEA and TRENMO (2007), representing profits more than three times the ones estimated in the mentioned report. It was decided to use this data[11]

[10] This model considers the following revenues per passenger: $20 (€14,29, being €1=$1,4) for full service airports and $16 (€11,43) for the low-cost airport. Expenses were considered to be equal to both type of airports and its value is $3 (€2,14).

[11] Since Chambers' terminal model only includes the cost of construction for the terminal – unlike the current thesis, which considers the airport as a single system with different subsystems –, it was decided to only change the range of expected cash flows while maintaining the construction costs unchanged.

merely as a mean of comparison, since if it can represent revenues for some airports, certainly they do not represent Portuguese ones, at least in current market conditions.
Table VIII presents the results for this new valuation

Table VIII– Results for the inflexible settings, for both valuation models, with new data.

	Type of Airport			
	Full Service		**Low-Cost**	
Results	**FCF**	**CCF**	**FCF**	**CCF**
NPV - 10 years	-1.899.591.549 €	-1.917.917.935 €	-939.884.907 €	-980.155.589 €
NPV - 20 years	-1.731.936.430 €	-1.794.470.034 €	-161.698.837 €	-406.884.020 €
NPV - 30 years	-1.571.444.897 €	-1.675.024.539 €	346.155.576 €	-29.171.546 €
NPV - 40 years	-1.417.810.861 €	-1.559.451.686 €	569.158.415 €	138.470.611 €
NPV - 51 years	-1.294.630.284 €	-1.465.811.339 €	673.137.316 €	217.508.696 €

In this new scenario the airport proves to be a much more desirable investment, especially the low-cost one, which turns out profitable after 32 years even in the worst case scenario (using the CCF model), since the full service airport remains with a negative NPV even after 51 years (but even in this case, its NPVs are 500 million euros higher than before).
Comparing the results from the different sources of data used, it appears that in order to make the construction of an airport a more appealing project for the investors (at least in Portugal, where the base data comes from) the focus should be on maximizing the net profit ratio, while reducing construction costs.

Flexible Scenario

Using binomial lattices, it was possible to forecast passenger activity in the 51 years considered, along with the probabilities associated with each forecast (Figures 3 and 4), which is a more dynamic way, compared to the deterministic forecast explained earlier.

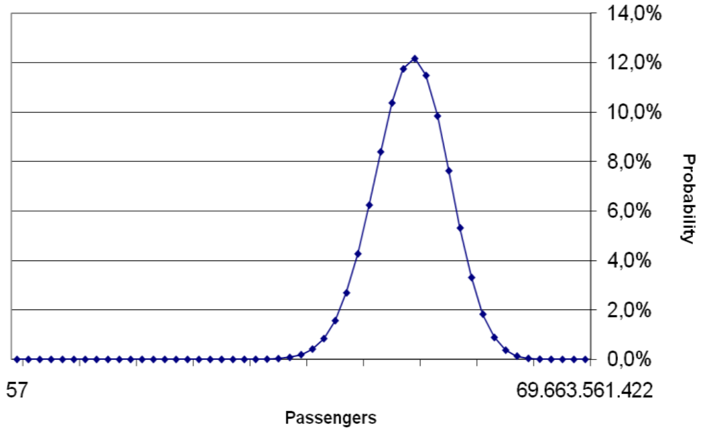

Figure 3 – Probabilities for passenger activity in year 51 for a full service airport
(top value of 131.165.696 Pax, with probability of 12,18%)

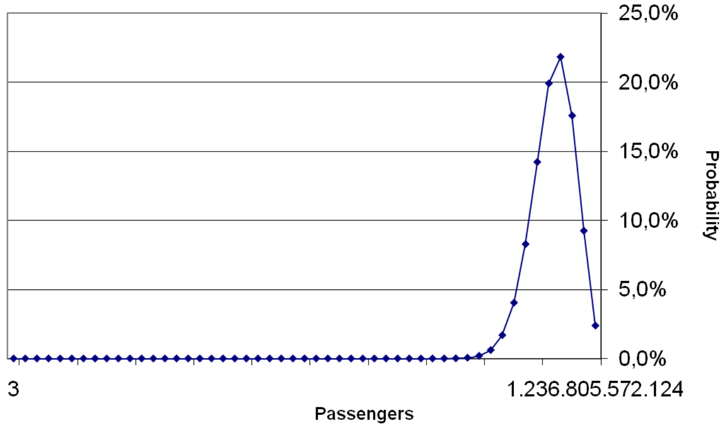

Figure 4– Probabilities for passenger activity in year 51 for a low-cost airport
(top value of 249.659.939.356 Pax, with probability of 21,82%)

This approach lead to several extreme and very unlikely results in the final year of the lattice, at least in the one corresponding to a FSA, where a range between 37 and 460 MPax has a combined probability 71,71 percent (even though the last value is very high, one must take into attention the fact that the prediction is done for half a century in the future, which may severely affect the accurateness of the results – for example, in year 25, a range between 9 and 46 MPax has a combined probability of 71,07 percent, a result that one might consider much more *realistic*).

On the other hand, in the lattice for the LCA the highest 10 results (being the lowest of these ten, 10.000 million Pax/year) have a combined probability of 99,73 percent, which is total unrealistic, since even the lowest of those values equals 1,5 times the current world population, and the highest value equals more than 180 times that value. Even at year 25, values ranging from 110 to 1500 million have a combined probability of 99,25 percent.

These results might indicate that this approach is not very good when used to model this kind of variables, that represent something physical (and not financial, for example) with high annual geometric growth rates, especially in a period as long as the one chosen in the model. So, the results obtained from this lattice should be seen with care, since they very likely represent a situation not possible to translate to the real world.

After applying all the assumptions and restrictions already mentioned when the model was explained in the preceding chapter, it was then possible to estimate the expected NPVs for both FCF and CCF models, over the 51 years considered (Table IX).

Table IX – Results for the flexible setting, for both valuation models.

	Type of Airport			
	Full Service		**Low-Cost**	
Results	**FCF**	**CCF**	**FCF**	**CCF**
NPV - 10 years	-788.264.337 €	-803.728.821 €	-525.717.713 €	-533.774.317 €
NPV - 20 years	-904.296.290 €	-921.653.637 €	-437.837.343 €	-493.343.129 €
NPV - 30 years	-938.924.165 €	-958.261.064 €	-275.311.157 €	-372.463.164 €
NPV - 40 years	-908.238.460 €	-935.167.531 €	-203.482.496 €	-318.466.040 €
NPV - 51 years	-873.880.395 €	-909.035.323 €	-169.990.641 €	-293.007.681 €

Once more, the projects seem highly unprofitable, although not as much as in the inflexible scenarios, and the low-cost airport, considering the FCF valuation model, even becomes profitable after 40 years.

To compare the results with the inflexible scenario, the same values for the expenses and revenues per passenger used in the second evaluation, were also used in this setting (Table X).

Table X – Results for the flexible setting, for both valuation models, with new data

	Type of Airport			
	Full Service		Low-cost	
Results	**FCF**	**CCF**	**FCF**	**CCF**
NPV - 10 years	-679.352.213 €	-719.841.791 €	-304.078.217 €	-332.879.937 €
NPV - 20 years	-667.670.888 €	-719.959.768 €	380.199.555 €	164.481.086 €
NPV - 30 years	-572.227.778 €	-648.875.174 €	886.288.632 €	540.884.614 €
NPV - 40 years	-447.336.400 €	-554.941.637 €	1.109.289.605 €	708.525.372 €
NPV - 51 years	-356.257.048 €	-485.686.390 €	1.213.268.504 €	787.563.456 €

With these new inputs, the low-cost airport becomes profitable after only 16 years, considering the FCF model, and 18 years, using CCF. In the remaining years studied, this LCA become highly profitable with NPVs close to the 1000 million euros mark.

The FSAs, even in this scenario with high net profit ratios, never become profitable, but the NPVs estimated are much less negative than the ones obtained using the original data obtained from CEGEA and TRENMO (2007).

Option Value

To assess the real value of considering flexibility when developing an airport, the value of that option must be computed. In this model, that option is simply calculated by using equation (8).

The results are presented in Table XI, for the original inputs, and in Table XII for the inputs by Chambers (2005).

Table XI – Option value.

	Type of Airport			
	Full Service		Low-cost	
Option Value	**FCF**	**CCF**	**FCF**	**CCF**
10 years	1.210.477.541 €	1.202.964.410 €	600.584.344 €	605.499.025 €
20 years	1.021.704.294 €	1.031.478.687 €	437.809.094 €	461.278.050 €
30 years	917.443.222 €	943.046.897 €	436.754.142 €	460.495.910 €
40 years	881.471.024 €	915.996.307 €	436.753.046 €	460.495.090 €
51 years	862.384.168 €	901.500.348 €	436.753.045 €	460.495.089 €

Table XII – Option value, for the new data.

	Type of Airport			
	Full Service		Low-cost	
Option Value	**FCF**	**CCF**	**FCF**	**CCF**
10 years	1.220.239.335 €	1.198.076.144 €	635.806.690 €	647.275.652 €
20 years	1.064.265.543 €	1.074.510.266 €	541.898.392 €	571.365.105 €
30 years	999.217.119 €	1.026.149.365 €	540.133.057 €	570.056.160 €
40 years	970.474.460 €	1.004.510.049 €	540.131.189 €	570.054.761 €
51 years	938.373.236 €	980.124.949 €	540.131.188 €	570.054.760 €

As demonstrated in Tables XI and XII, the option of waiting before investing huge amounts of money in an over dimensioned airport is always rational, at least in financial terms. This is especially true in the first years of operation, when the airport is expected to function well below the maximum capacity of 50 MPax. After the first decades the option value starts to stabilize around one value, a trend that can be especially noticed in the LCA, where the option value at 10 years is practically the same as the option value at 51 years (the differences are below 0,5 percent).

Low-Cost Airport with lower Annual Growth Rate

Since the annual growth rate used in the analysis produced very unrealistic results for the low-cost airport (the growth rate considered meant that traffic would double every four years and capacity would be exhausted after only 15 years), it was decided to make a new valuation using the annual growth rate as in the analysis regarding FSAs (which was estimated as the average annual geometric growth rate of a total of 221 European airports in the 2002-2007 period), which was considered to be a much more realistic growth rate in the long term.

This new valuation obviously produced the same traffic forecast as in the full service airport valuation already presented, but since construction costs are very different, NPV results should be also different.

In Tables XIII and XIV a comparison between the NPVs obtained by using data only regarding low-cost airports and data comprising all airports is presented, for both inflexible and flexible scenarios.

The option value is presented in Table XV.

Table XIII – Results for inflexible low-cost airports, with different annual growth rates.

	Data Source			
	Low-Cost Airports		All Airports	
Results	**FCF**	**CCF**	**FCF**	**CCF**
NPV - 10 years	-1.126.302.058 €	-1.139.273.342 €	-1.168.004.439 €	-1.172.909.262 €
NPV - 20 years	-875.646.437 €	-954.621.179 €	-1.123.133.696 €	-1.139.870.014 €
NPV - 30 years	-712.065.298 €	-832.959.075 €	-1.080.180.195 €	-1.107.901.958 €
NPV - 40 years	-640.235.543 €	-778.961.129 €	-1.039.062.015 €	-1.076.970.366 €
NPV - 51 years	-606.743.687 €	-753.502.770 €	-1.006.094.314 €	-1.051.908.728 €

Table XIV – Results for flexible low-cost airports, with different annual growth rates..

	Data Source			
	Low-Cost Airports		All Airports	
Results	**FCF**	**CCF**	**FCF**	**CCF**
NPV - 10 years	-525.717.713 €	-533.774.317 €	-317.457.531 €	-321.796.592 €
NPV - 20 years	-437.837.343 €	-493.343.129 €	-403.424.151 €	-409.097.172 €
NPV - 30 years	-275.311.157 €	-372.463.164 €	-435.505.227 €	-441.991.769 €
NPV - 40 years	-203.482.496 €	-318.466.040 €	-422.077.822 €	-431.878.859 €
NPV - 51 years	-169.990.641 €	-293.007.681 €	-402.838.945 €	-417.244.447 €

Table XV – Option value for flexible low-cost airports, with different annual growth rates..

	Data Source			
	Low-Cost Airports		All Airports	
Option Value	**FCF**	**CCF**	**FCF**	**CCF**
10 years	600.584.344 €	605.499.025 €	850.546.908 €	851.112.669 €
20 years	437.809.094 €	461.278.050 €	719.709.545 €	730.772.841 €
30 years	436.754.142 €	460.495.910 €	644.674.968 €	665.910.190 €
40 years	436.753.046 €	460.495.090 €	616.984.194 €	645.091.507 €
51 years	436.753.045 €	460.495.089 €	603.255.369 €	634.664.281 €

Considering the lower annual growth rates used in the new valuation, it was expected to obtain lower NPVs, since the airport operates under maximum capacity for considerably longer periods of time, which affects the level of cash flows generated at the airport.
In the inflexible scenario that assumption is true for all five periods considered, resulting in NPVs under -1000 million euros.
In the first two decades of the flexible scenario the results are different and the new NPVs values are higher than in the previous estimation. In the remaining 31 years newly estimated NPVs become lower as in the inflexible scenario.
These results make the option of waiting before making the total investment even more valuable than before, with an average increase in option value of around 200 million euros.

Monte Carlo Simulations

The choice of the variables to use in these simulations was done by conducting a sensitivity analysis.
That analysis consisted of changing each variable individually by $+/-$ 15 and assess how this change affected the final results.
Total costs, inflows and outflows proved to be the most sensitivity variables in almost every setting and were chosen to run the simulations.
Since some of those variables tend to vary together in a systematic manner – they are said to be *correlated* – a number of numeric correlations were established.
The exact assessment of the value of those correlations is not needed, since their purpose is not to produce high statistical accuracy but rather restraining the model from generating grossly inconsistent scenarios in large scale.

With that principle in mind, the following correlations were established:

1. A positive correlation of 0,950 between all partial investment costs, i.e., if a partial investment has an increase in its costs the following partial investments have a very high probability of having also an increase in its costs. For example, if the initial investment on the FSA is 900 million euros instead of 846 million, there is a high probability that the next expansion for 20 MPax will cost more than the estimated 130 million euro;

2. A positive correlation of 0,800 between the partial investment costs and the outflows, i.e., if investments costs increase, the outflows (which in this model is a percentage of the inflow values) have a relatively high probability of increasing and profit will consequently decrease. Using the same example as before, if the initial investment in the FSA increase to 900 million euros, operating expenses also have a tendency to increase, therefore outflows would have a value slightly higher than the initial estimation of 65 percent, and the net profit ratio would be lower than 35 percent.

Although there might be a correlation between investment costs and inflows (if investment cost increase, taxes for using the airport would probably also increase), it was decided not to include it in the simulation, since it might counter-balance the correlation between investment costs and outflows (if operating expenditures increase due to higher investment costs (for example, a 10% increase in costs leads to a 5% increase in operating expenditures), management could raise taxes (by 5% in this example) to increase inflows and maintain net profit ratios in the same level as before, which would lead to a situation very similar to the initial condition).

A way of avoiding this counter-balance effect would be to set a correlation coefficient between investment costs and inflows lower than the coefficient between investment costs and outflows (which is probably true since it might be difficult to reflect the increasing investment costs into the taxes the airport receives – if taxes increase too much passengers and airlines would simply avoid the airport, so there is a limit to the increase in their value). Using a correlation of 0,500 between investment costs and inflows lead to variation in the simulation's final results less than 0,5 percent different from the simulation without that correlation, so it was decided to exclude it from the simulations ran.

The final correlation possible between this set of variables was between outflows and inflows, which was already set in the model (outflows are defined as a percentage of inflows), so there was no need to set a new correlation.

Because of the complex nature of the variables at hand, and considering that the purpose of running Monte Carlo simulations is not to obtain the exact probability of achieving positive NPVs, but only to give a rough estimate whether that is possible or not, there is no need to correctly assess the probabilistic distribution of the variables.

Therefore, simple triangular distributions, where the likeliest value is the deterministic value used in the previous valuations and the minimum and maximum values are a $+/-$ 15 percent variation of that value (the same variation used in the sensitivity analysis) were used. Figure 4 shows an example of a triangular distribution.

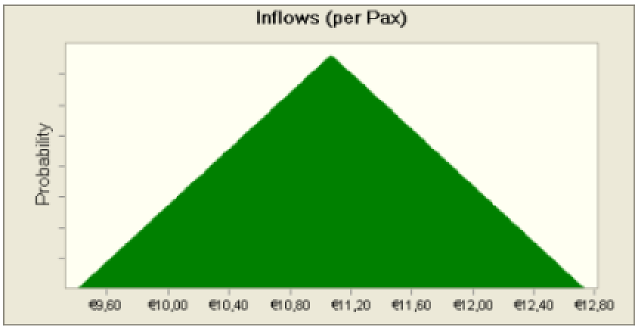

Figure 4 – Example of a triangular distribution.

After the definition of the variables to be used in the simulation, their correlations and their probabilistic distribution it was possible to run the Monte Carlo simulations. A total of 50.000 trials of each variable were run.
A summary of the results of the Monte Carlo simulations ran for the FSA is presented in Table XVI.

Table XVI – Monte Carlo simulations for a full service airport.

	Forecast Values		
Statistics	**FCF Inflexible**	**CCF Inflexible**	**FCF Flexible**
Minimum	-2.162.120.834,84 €	-1.810.174.749 €	-1.202.288.852 €
Mean	-1.735.887.599 €	-2.210.031.268 €	-873.582.604 €
Maximum	-1.291.761.784,70 €	-1.396.502.010 €	-523.576.923 €
Statistics	**CCF Flexible**	**FCF Option Value**	**CCF Option Value**
Minimum	-1.222.243.997 €	752.460.019 €	789.489.333 €
Mean	-909.444.855 €	862.304.995 €	900.729.894 €
Maximum	-588.342.371 €	970.426.955 €	1.010.488.534 €

Using the mentioned correlated assumptions, with their triangular distributions, the probabilities of achieving positive NPVs is far from positive. Even in the best case scenario (flexible scenario valued by the FCF model) NPV is lower than -500 million euros and achieves values as low as -1400 million euros.
Option value is in the 750-1000 million euros range which indicates that even in the worst case scenarios the option to wait and make partial investments instead of spending huge amounts of money up front is very valuable.
Table XVII presents the results for the low-cost airport:

Table XVII – Monte Carlo simulations for a low-cost airport.

	Forecast Values		
Statistics	**FCF Inflexible**	**CCF Inflexible**	**FCF Flexible**
Minimum	-1.095.370.850 €	-1.166.613.164 €	-627.905.498 €
Mean	-607.667.176 €	-754.234.979 €	-171.022.767 €
Maximum	-51.285.086 €	-291.031.904 €	362.069.255 €
Statistics	**CCF Flexible**	**FCF Option Value**	**CCF Option Value**
Minimum	-684.374.247 €	388.362.857 €	410.543.786 €
Mean	-293.953.520 €	436.644.409 €	460.281.458 €
Maximum	150.393.347 €	486.387.649 €	511.130.142 €

Opposite to the full service airports, low-cost airport projects appear to have small probabilities of becoming profitable after 51 years of operation.
Those positive NPVs appear only on the flexible scenarios, although in the inflexible scenario valued by the free cash flow model the maximum value almost reaches the break-even point.
While the CCF model has an extremely low (1,81 percent) probability of reaching a positive NPV, the FCF model has a more respectable probability of 16,85%, with a maximum value of 360 million euros and a 90th percentile value over 50 million euros.
Regarding option values, they do not reach such high values has in the full service airport simulations, but even the worst case scenarios are around 400 million euros, a value large enough to again confirm the value of taking flexibility into account when developing an airport project.

CONCLUSIONS

Uncertainty is now a major concept in almost every aspect of our society. Recent global and local crisis have underlined the crucial importance of flexibility in almost every scale, from the decisions we make in our personal life, to the huge investments governments commit themselves to make.
Airports, and the aviation sector in general, have not been affected only by those factors transversal to all society, but also by other internal changes, like the still ongoing liberalization of the sector throughout the world, which makes an already unpredictable world into a tough challenge for planners.
In this paper we tried to tackle that uncertainty, by considering flexibility when developing and managing an airport project.
That flexibility, already put into action in various fields in the industry, was then evaluated by the real options theory, which aims exactly to assess the value underlying such flexible designs.
With the development of a model, we aimed to demonstrate the value of waiting before investing huge amounts of money into an infrastructure that has the chance of not being used in full capacity for years.
The results produced by the model, although being very simplistic and thus only rough estimates of real cash flows, might be a proof, by comparison, that waiting for more

information before committing to an investment might be a good idea, especially in a case where high levels of capital expenditures are needed.

Using data mostly based on studies regarding Portuguese airports investments and results, the model showed that although less unprofitable, constructing a *flexible* airport is not still a very good investment, since the huge amounts of investment money needed are not followed by large net profit ratio during operation, thus creating largely unattractive investments for project owners.

Ways of reducing capital expenditures and simultaneously improve profit margins are needed to ensure that possible new projects have higher possibilities of generating economic value.

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APPENDICES

Table XVIII – Investment in a full service airport (all prices in euros).
Source: Adapted from CEGEA and TRENMO (2007)

Capacity (MPax)	Operations Area	Terminal	Technical Equipment	Support Systems	Environmental Systems
15	185.000.000	402.000.000	24.000.000	175.000.000	5.000.000
20	43.000.000	75.000.000	1.500.000	2.500.000	0
25	49.000.000	95.000.000	1.800.000	2.500.000	0
30	155.000.000	160.000.000	2.500.000	2.500.000	0
35	32.000.000	75.000.000	1.200.000	2.500.000	0
40	33.000.000	95.000.000	1.200.000	2.500.000	0
45	43.000.000	105.000.000	1.500.000	2.500.000	0
50	49.000.000	110.000.000	1.800.000	2.500.000	0

Capacity (MPax)	Unexpected Costs (7%)	Partial Investment	Total Investment	Cost/ Passenger
15	55.370.000	846.370.000	846.370.000	56
20	8.540.000	130.540.000	976.910.000	49
25	10.381.000	158.681.000	1.135.591.000	45
30	22.400.000	342.400.000	1.477.991.000	49
35	7.749.000	118.449.000	1.596.440.000	46
40	9.219.000	140.919.000	1.737.359.000	43
45	10.640.000	162.640.000	1.899.999.000	42
50	11.431.000	174.731.000	2.074.730.000	41

Table XIX – Investment in a low-cost airport (all prices in euros).
Source: Adapted from CEGEA and TRENMO (2007)

Capacity (MPax)	Operations Area	Terminal	Technical Equipment	Support Systems	Environmental Systems
5	120.000.000	33.000.000	15.000.000	100.000.000	5.000.000
10	32.000.000	33.000.000	1.200.000	2.500.000	0
15	33.000.000	39.000.000	1.200.000	2.500.000	0
20	43.000.000	39.000.000	1.500.000	2.500.000	0
25	49.000.000	45.000.000	1.800.000	2.500.000	0
30	155.000.000	45.000.000	2.500.000	2.500.000	0
35	32.000.000	33.000.000	1.200.000	2.500.000	0
40	33.000.000	39.000.000	1.200.000	2.500.000	0
45	43.000.000	39.000.000	1.500.000	2.500.000	0
50	49.000.000	45.000.000	1.800.000	2.500.000	0

Capacity (MPax)	Unexpected Costs (7%)	Partial Investment	Total Investment	Cost/ Passenger
5	19.110.000	292.110.000	292.110.000	58
10	4.809.000	73.509.000	365.619.000	37
15	5.299.000	80.999.000	446.618.000	30
20	6.020.000	92.020.000	538.638.000	27
25	6.881.000	105.181.000	643.819.000	26
30	14.350.000	219.350.000	863.169.000	29
35	4.809.000	73.509.000	936.678.000	27
40	5.299.000	80.999.000	1.017.677.000	25
45	6.020.000	92.020.000	1.109.697.000	25
50	6.881.000	105.181.000	1.214.878.000	24