Value of Options in Airport Expansion -
- Example of AICM

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Abstract

Investments decisions for airport capacity expansion are usually taken, either when demand exceeds the current capacity and the airport is working under congestion, or when current demand is expected to overcome current capacity sometime in the near future. In any case, decisions are taken taking into account forecasts of future demand. In many situations, deterministic analysis lead to a discouraging net present value (NPV) which in turn causes delays in the deciding process and eventually leads to further losses.

This paper takes the Mexico City International Airport (AICM) as example, and performs an analysis of expansion investment, both in runways and terminals capacity, taking a perspective that is twofold: we take uncertainty of demand into account based on historical data of relevant parameters; we use flexibility in design by incorporating options in project, for both new runways and new terminal. Using a binomial lattice model, we calculate the value of options, perform sensitivity analysis and determine the expected statistical distribution of NPV. We obtain significant differences when compared with the deterministic perspective, and illustrate by example how real options and flexible design may dramatically improve the attractiveness of an investment decision.

Keywords: airport expansion, real options, value of options, flexibility in design, binomial lattice model.

Introduction

AICM is a busy international airport, operating close to the limit of its capacity in a scenario where demand continues to grow. This is not an unusual situation, as we observe the same problem in many other airports around the world. When capacity expansion is possible, investment analysis are performed taking into account, on one hand, the necessary lump and sunk costs for the infrastructure to satisfy the expected growth in number of passengers and operations for a certain number of years, and on the other hand, the expected corresponding revenue. Deterministic approaches are very often followed, and discouraging results often obtained both in terms of project net present value (NPV) and internal rate of return (IRR).

This paper illustrates the importance of bringing real options analysis into the calculations of NPV, using the example of possible future expansion of AICM. We will show how a number of sources of uncertainty justify that this project is not limited to a deterministic approach.

In order to consider uncertainty in demand (considered the key parameter for investment project success), we take statistical data from the past, and build a binomial lattice model, expanded in a spreadsheet for 20 years, from 2010 till 2030. Flexibility in design is introduced in the process of building new runways and a new terminal, to allow competent reactions to different future demand scenarios. With this methodology we obtain significant changes in the calculation of NPV, eventually dramatically changing the value of the project, making it an attractive investment.

Value of each option is calculated and sensitivity analysis is performed in order to complement the analysis and highlight the potential of this simple model.

As some of the model inputs had to be estimated, this paper is to be seen more as a motivation for the use and incorporation of uncertainty, real options and flexibility in design, and less as a complete and accurate study for AICM expansion.

Description of example project: AICM

The motivation for choosing the expansion of the current AICM is related to news about the following urgent expansion requirements as per Airport Development News, a service provided by ACI World in co-operation with Momberger Airport Information:

> *Mexico: The US$ 1.5 billion Aeropuerto del Lago project, in Mexico state's (Edomex) Nezahualcóyotl municipality, is becoming the preferred option for the expansion of Mexico City's international airport (AICM), according to the local environmental expert and project spokesperson Ramón Ojed. (…) Aeropuerto del Lago is projected to be built on*

420 hectares of Federal land that covers the Bordo Poniente landfill and the dry bed of lake Texcoco. The project was announced on 28 November 2008 by a committee comprised of representatives of AICM, the Federal District (DF), Edomex, Nezahualcóyotl and the local chapter of the International Court of Environmental Arbitration and Conciliation, headed by Ojeda. (…). In addition to solving congestion problems at AICM, the project would enable the immediate ecological recuperation of Bordo Poniente, which was originally scheduled for permanent closure on 15 January 2009. (…). The location of the new airport in Edomex is becoming increasingly urgent as the current terminal is operating at the limit of its capacity and traffic continues to increase. While Texcoco municipality is considered a viable option by SCT, others studies are under way to resolve the issue, and SCT is looking at a number of options, ranging from building a series of terminals to a single new airport need.

The location selection for the new airport either in Texcoco or in an alternative location has been studied in the past, using multiattribute preference analysis, and taking into account level of service, type of aircraft activity, and other (Keeney and de Neufville, 1973). In this paper we are assuming that adding capacity to the existent Mexico City airport will be made by airport expansion in current site, rather than building a completely new airport from scratch elsewhere.

So, as of 2010, situation of AICM was the following:

- Terminal 1 capacity with yearly peaks near its rated limit of 16.5 million passengers (16.21 million in 2008, 14.24 million in 2009, 12.41 million in 2010);
- The recent Terminal 2 approaching its projected limit of about 20 million passengers;
- Runway capacity is close to its limit.

Due to the above, the traditional deterministic approach will consider the following expansion:

- Addition of airfield capacity by construction of two parallel runways;
- Addition of capacity to process passengers by construction of a new Terminal 3;
- Addition of the necessary aprons, taxiways, etc so that the new project interconnects with current facilities, in order that easy movement of passengers and aircraft is possible between new and old runways, and Terminals 1, 2 and the new Terminal 3.

Major sources of uncertainty

"In the current climate, long-term forecasts cannot be developed with any degree of confidence. On the contrary, as has been extensively documented, forecasts of airport traffic

today are 'always wrong'." (de Neufville, 2008). We will show that our case study follows this general rule and that there are significant uncertainties over the life span of the expansion of the AICM. We will classify uncertainty under three major groups:

- Political issues and Government policy;
- Construction and environmental;
- Demand during operation.

Political issues and Government policy

- Delays in decision taking process: The project for the expansion of the current main airport serving Mexico City, has gone through many advances and drawbacks. As of today either Netzahualcoyotl or Texcoco municipalities are possible sites for the new airport. The 'Aeropuerto del Lago' is the solution to be built in Netzahualcoyotl, just by the current airport, is the most likely solution (Texcoco, considered a possibility 40 years ago, only recently resurfaced as an alternative and lacks supportive studies, while current congestion requires an urgent decision) and is the one considered in this project[1]. Even if there is no change in government, economic interests from alternative locations may force additional public discussions and debate, ultimately leading to additional studies which in turn delay the whole process.

  The main advantage of Netzahualcoyotl over Texcoco is that the former is built next to the current airport allowing future use of the current terminals and runways (including the latest built Terminal 2), while the latter would imply dismantling the current airport and build a higher capacity (and cost) airport in a different location[2].

- Change in government: Choice of location is very much a political issue, so any instability in the Mexican government might lead to postponing decisions and ultimately changing solutions. Note that Mexico still has two active guerrilla groups[3], and that this alone brings unpredictable effects on overall planning.

- Expropriations: The whole site that is planned for 'Aeropuerto del Lago' (426 hectares) is already federal land, so no need for expropriations will be required, which is a positive issue, and does not introduce uncertainty related to this factor.

Construction and environment

- Cleaning costs: The site for the new airport currently includes Bordo Poniente, one of the world's largest landfill sites, receiving 12,500 tons of waste every day[4]. The whole area will need full cleaning before any construction takes place. There is usually a degree of uncertainty associated with costs associated with this because of lack of information on the degree of soil contamination.

▪ <u>Building on a lake</u>: The new airport will be built on an area where an old lake existed. This will require careful geological analysis before any construction takes place. Uncertainty exists and high costs may occur due to the need of deeper excavations searching for the 'hard soil' required for the foundations of buildings and runways, taxiways and parking. Also, increased draining capacity may also be required, to avoid possible water accumulation.

Demand during operation

▪ <u>Worldwide reduction of demand</u>: Some aspects affect demand on a wider scale then just Mexico, each of them having a degree of uncertainty:

o <u>Oil prices</u>: Oil prices increased substantially over the last decade[5], thus affecting airlines and cost of travelling by air. Monthly average oil cost (Brent) shows huge variations, as depicted in Figure 1.
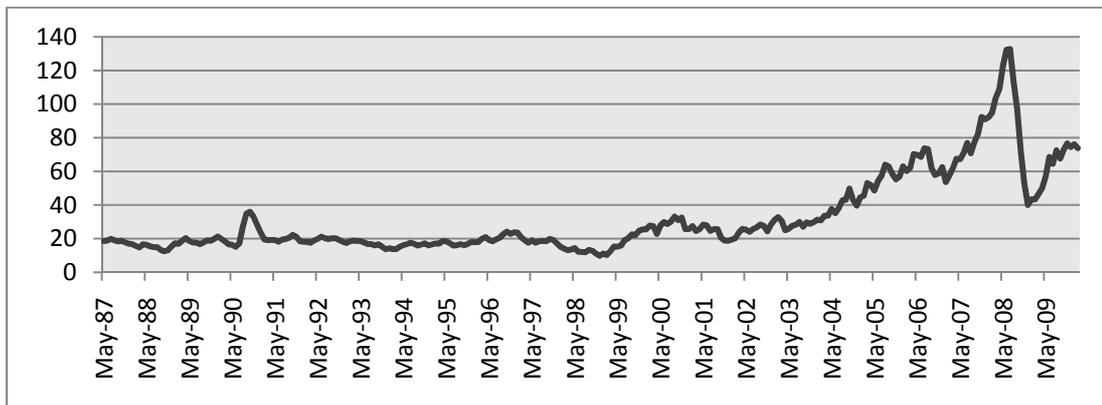

Figure 1: Oil price (US$/barrel) – Brent [6,7]

o <u>Technological advanced alternatives</u>: Videoconference with 3D telepresence and holographic perspective are a real future alternative to travelling, with unpredictable effects on overall air travel (technology has already been developed and Cisco trials is one example[8]).

o <u>Terrorist attacks</u>: Although Mexico is not the most likely target for international large scale attacks, it will still suffer consequences in case of worldwide shock effects similar to those of New York 9/11. Attacks are unpredictable in time, mode of operation. They have negative consequences, both near term and long term, over economies in general and transportation in particular.

o <u>Regulatory changes</u>: We note that the above unpredictability is extended to stringent safety measures that may require enforcement after such attacks[9], thus driving air passengers to other modes of travel (mostly bus and private car for domestic and near border US travel, noting that train lines are almost inexistent or

non-functioning).

- Tourism reduction in Mexico: Tourism is the 3rd most important industry of Mexico, with a contribution of about 8% in GDP[10]. This activity is directly linked to air travel, with many foreign visitors using AICM either as final destination or as a transfer airport. So any uncertainty on tourism will be reflected on demand at AICM. Possible causes are, among others:

    o Safety related issues: As already mentioned, Mexico has two guerrilla groups, one of them (ERP) active in violent actions. If any attack aims at touristic destinations (Mexico City, Cancun, Acapulco, etc), demand might suffer a significant reduction.

    o Environmental reasons: Many resorts are exposed to extreme weather events (tsunamis, hurricanes, earthquakes) – and greenhouse effects increase probability of these occurring in the future, thus bringing uncertainty on the overall national tourism industry.

- Competition from alternative airports: Toluca Airport has become a major alternate airport[11], mostly for low-cost airlines (LCA) being a less crowded and cheaper alternative, while at a reasonable small distance from the city (about 30 minutes drive). The future of LCA's in Mexico will determine the future of Toluca and indirectly of AICM (two LCA's - Interjet and Volaris – are even based in Toluca).

- Competition from alternate modes of transport: Depending on Government decision, train lines may be restored and put into operation and even High Speed Train could be used between Mexico City and a couple of key high intensity domestic destinations.

- Gross Domestic Product (GDP) evolution: Mexican GDP affects national passengers' capacity to travel both on domestic flights and abroad. Over the years the evolution of this indicator has occurred as depicted in figure 2, showing small uncertainty on this issue.
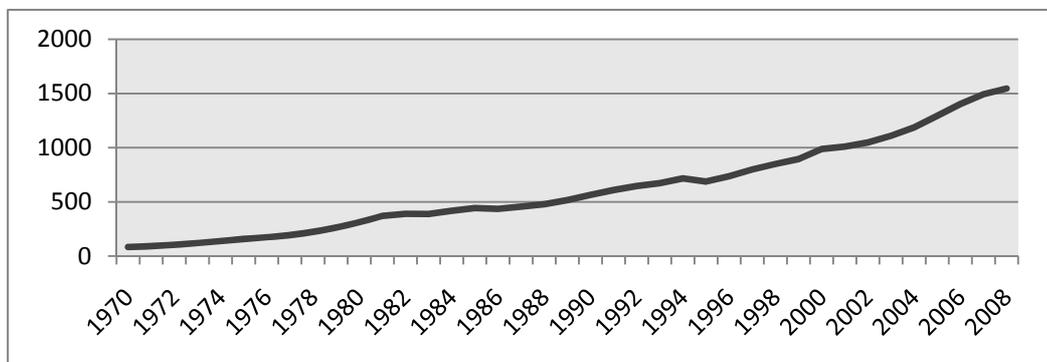

Figure 2: Mexican GDP (billion $US, current prices) – source OECD[12]

- Exchange rate: rate between national peso and $US or Euro affects demand on international flights (positive for inbound flows, negative for outbound). There are significant changes (and consequent uncertainty) on this factor as depicted in figure 3.
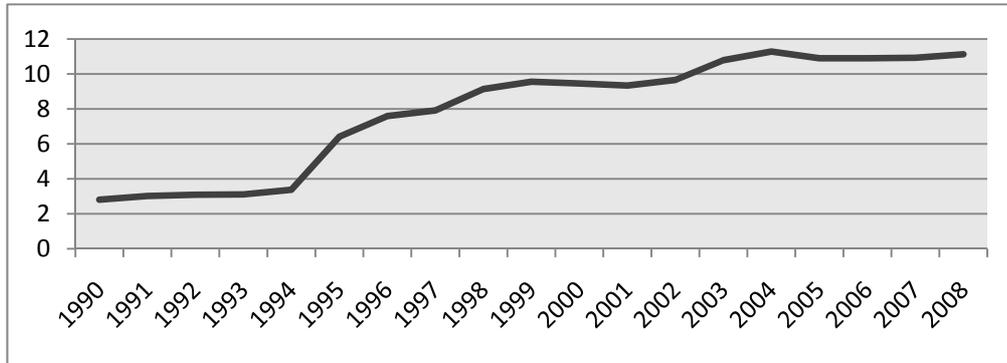

Figure 3: Mexican peso MXN per $US – source OECD

Latest information, as of 10th January 2011 we had (average[13] from 15th July 2010 to 10th January 2011), 1 US$ = 12.55 $MXN, showing an approximate devaluation of about 15% every 5 years.

- Change of airlines operations: AICM has become both main hub for Mexico's largest airline Aeromexico and a secondary hub for its subsidiary Aeromexico Connect. Also AICM has become a SkyTeam hub and a Oneworld hub (currently going through major uncertainty due to bankruptcy in 2010 of Mexicana and its subsidiary MexicanaClick)[14]. Any major change or (in)success in these airlines may affect demand, so uncertainty exists on this respect.

- Available data for AICM: Information made available by AICM relates to years 2005 to 2010[15] and is depicted in figure 4.
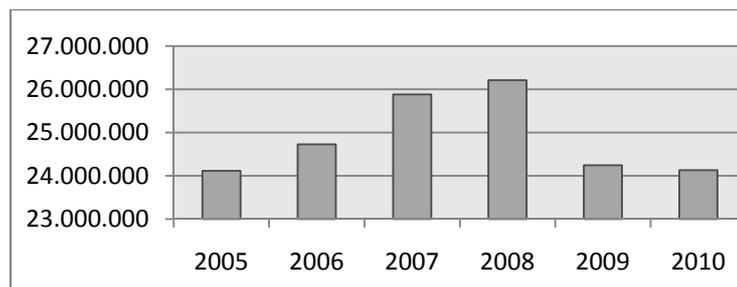

Figure 4: Number of passengers per year at AICM – source: AICM

There was a significant reduction of passengers in 2009, and this was mostly due to the H1N1 flue, originated at Mexico, at that time on the early stages of propagation and threatening to be worldwide pandemic. This event caused social alarm and made many passengers cancel their trips (see Figure 5 for example where values lower than 1.5 million were observed in May'09). In 2010 volume of passengers remained low mainly due to the world financial crisis.
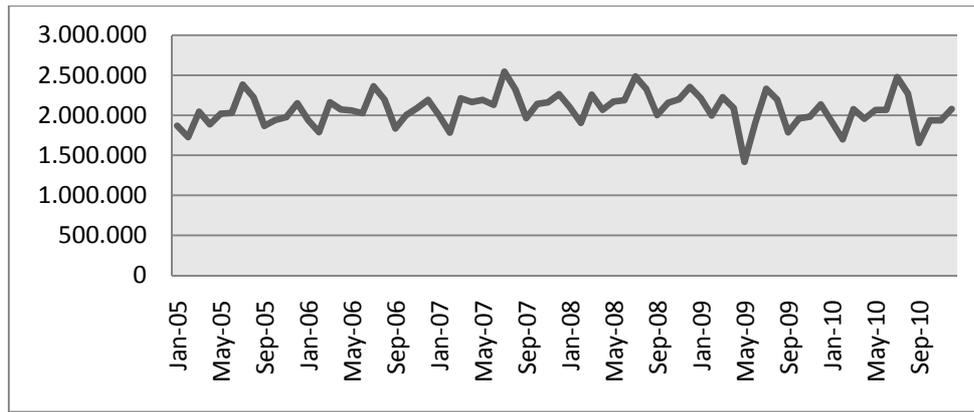
Figure 5: Number of passengers per month at AICM – source: AICM

- <u>Available data for all air traffic in Mexico:</u> To obtain additional information on the yearly trend, we accessed general data on passengers on all airports in Mexico and this can be depicted as in Figure 6[16].
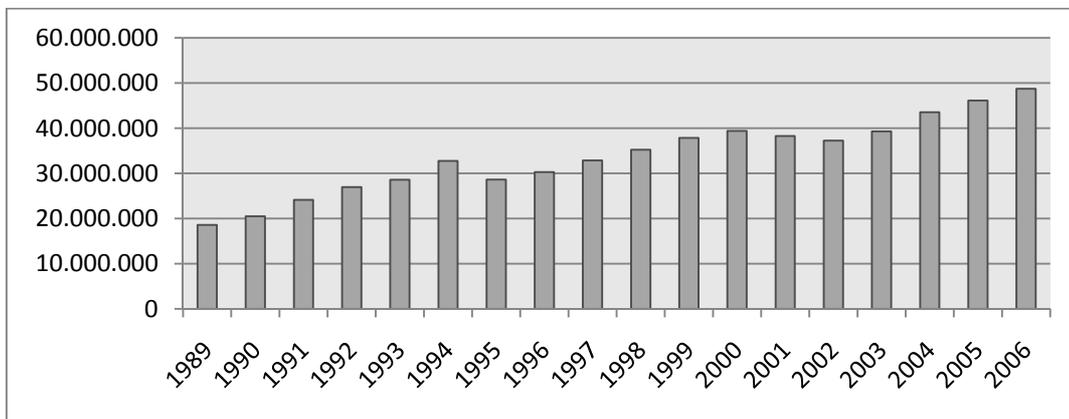

Figure 6: Number of passengers per year in all Mexican airports.
Source: US Department of Commerce.

Estimating demand for next 20 years (2011 to 2030)

Deterministic approach

Assuming that future yearly growth for AICM is equivalent to the overall past yearly growth of all Mexican airports (average growth is 5.67%, as shown further down this paper), and taking the initial value of 2010 as actual data, we can extrapolate the demand for AICM as in Figure 7. The expected value of demand after 20 years is 73 million passengers. However, if we were to build airport capacity expansion to this exact figure, we would experience the 'flaw of averages' and obtain inferior revenue than expected, due to, on one hand, the inherent uncertainty of the process, and, on the other hand, the lack of capability to exploit any higher than expected value of demand (Savage, 2000 and 2009).
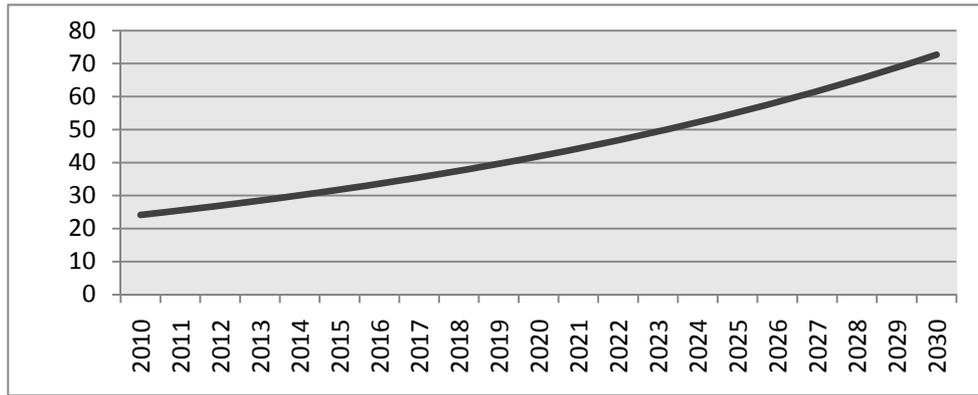
Figure 7: Million pax per year in AICM for the next 20 years (yearly growth 5.67%)

Analysis using the binomial lattice model

We use demand as the determining factor for success of the project, thus we use it as for uncertainty analysis on a discrete-time lattice model. As in similar previous and recent studies (Chambers, 2007; Neiva et al, 2010a and 2010b; Huber, 2010), a log normal concept is applied, assuming that percent deviations from a trend line have a normal distribution.

According to this model, demand (D) in any specific year, is a function of demand of last year together with either the result of an upshift (u), or a downshift (d), with probability of the upshift being (p):

$$D_y = \begin{cases} D_{y-1} \cdot u & \text{with probability } (p) \\ D_{y-1} \cdot d & \text{with probability } (1-p) \end{cases}$$

Values of (u), (d) and (p) are determined based on statistical past information, namely on average growth rate and standard deviation of demand. Firstly, we determine these parameters for the growth of demand since 1989 to 2006 for all Mexican airports, and then use those values in the lattice model for the specific case of AICM[17].

Based on historical trends, we calculate the annual growth rates (v), average growth rate for all years ($v_{average}$), and standard deviation of growth rate (σ), using the following:

(Passengers in year Y_i) = (Passengers in year Y_{i-1}) . $\exp(v_i)$

(Passengers in year Y_i) = (Passengers in year Y_{i-T}) . $\exp(T.v_i)$

With T being the number of years between Y_i and Y_{i-T}. Calculating v_i for each consecutive pair of years,

$v_i = \ln$ (Passengers in year Y_i / Passengers in year Y_{i-1})

allows calculation of the average v:

$v_{average} = \sum v_i / (N-1)$

With N equal to the number of years for which we have valid data (in our case, N=18, from 1989 to 2006). Also, variance (σ^2) and standard deviation (σ) are calculated by comparison on actual growth rates with average rate.

$$\text{Variance} = \sigma^2 = \sum (v - v_{average})^2 / (N-1)$$

With the data for our case shown in table 1.

Year	Passengers	v	$(v-v_{ave})^2$
1989	18.576.000		
1990	20.490.000	9,81%	0,00171
1991	24.142.000	16,40%	0,01151
1992	26.943.000	10,98%	0,00281
1993	28.574.000	5,88%	0,00000
1994	32.767.000	13,69%	0,00643
1995	28.620.000	-13,53%	0,03688
1996	30.296.000	5,69%	0,00000
1997	32.855.000	8,11%	0,00059
1998	35.237.000	7,00%	0,00018
1999	37.834.000	7,11%	0,00021
2000	39.412.000	4,09%	0,00025
2001	38.282.000	-2,91%	0,00736
2002	37.256.000	-2,72%	0,00704
2003	39.276.000	5,28%	0,00002
2004	43.523.000	10,27%	0,00211
2005	46.110.000	5,77%	0,00000
2006	48.725.000	5,52%	0,00000
	Average v:	5,67%	
		Variance:	0,454%
		Stand. deviation:	6,73%

Table 1: Number of passengers per year in all Mexican airports.

Source: US Department of Commerce.

So, for the purpose of our calculations, $v_{average}$ = 5.67% and σ =6.73%.Actual data and growth based on average growth can be represented as in figure 8.
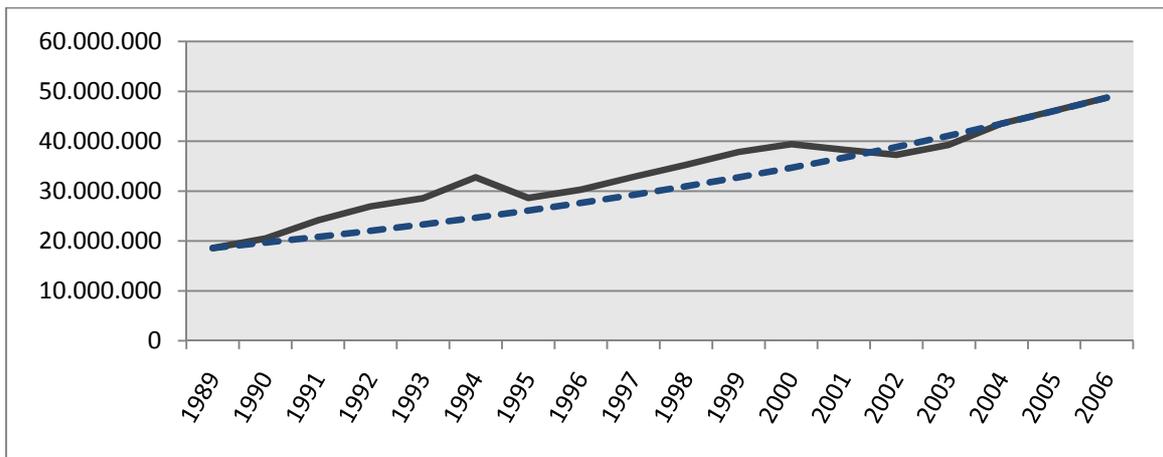

Figure 8: Number of passengers in all Mexican airports: actual data (source: US Department of Commerce) and exponential growth based on average yearly growth.

For the lattice model, we will use the above history trend parameters and determine the

controlling parameters, using the expressions (Chambers, 2007, Neiva et al, 2010a and 2010b):

$u = \exp [\sigma.(\Delta T)^{0.5}]$

$d = 1 / u$

$p = 0.5 + 0.5 . (v/ \sigma) . (\Delta T)^{0.5}$

with ΔT being the interval between two consecutive moments in time where v occurs, so in our case ΔT=1 year. Applying the above, we obtain u=1.0697, d=0.9349 and p=0.9211. Replacing in the lattice model, we obtain the probability density function (PDF) on the 20th year (that is in 2030) shown in table 2 and figure 9.

Passengers (millions)	Prob.	Pass . Prob
92,86	0,193	17,94
81,15	0,331	26,87
70,93	0,269	19,11
61,99	0,138	8,58
54,18	0,050	2,73
47,35	0,014	0,65
41,38	0,003	0,12
36,17	0,001	0,02
31,61	0,000	0,00
27,63	0,000	0,00
24,15	0,000	0,00
21,10	0,000	0,00
18,44	0,000	0,00
16,12	0,000	0,00
14,09	0,000	0,00
12,31	0,000	0,00
10,76	0,000	0,00
9,41	0,000	0,00
8,22	0,000	0,00
7,18	0,000	0,00
6,28	0,000	0,00
	Exp.Value:	**76,03**

Table 2: Probability density function in year 2030

With the expected number of passengers being given by (de Neufville and Odoni, 2003, pp 811):

$$E(V) = \sum [\text{(probability of event I)}.\text{(value of resulting outcome I)}]$$

So just by assuming that uncertainty is inherent to the process, the expected number of passengers after 20 years rose from 73 million to 76,03 million (explained because probability of upshifts are higher than downshifts).
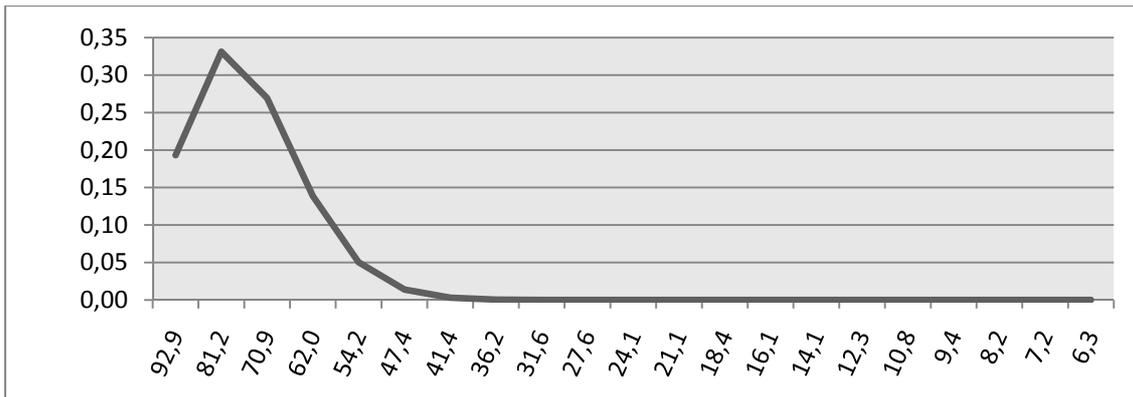
Figure 9: Probability vs. Million of passengers per year (in year 2030)

We can see in advance that there is a great potential for incorporating options in the project, mainly for taking advantage of increasing demand growth.

Calculation of revenue per passenger

The project will generate sources of revenue from basically two different infrastructures: new runways; new Terminal 3. As for the runways it is considered that dividends will immediately start to be collected by the current entrepreneurship as soon as construction is complete; however, as for Terminal 3, it is assumed that only when demand reaches 36.5 million (maximum capacity of both Terminals T1 and T2), will all exceeding passengers start to be allocated to T3.

To determine revenue, we will have to consider the sources of airport revenue that will be allocated to the expansion: commercial revenue; operational revenue.

Commercial revenue

Commercial revenue includes retail (duty free, bureau de change, food and beverage and other), car parking, car rental, property, advertising and other. We will consider US$ 3.13 per passenger for AICM as for typical airport revenue in Latin America and Caribbean (Graham, 2009), worldwide average being US$8.06. This is valid for 2007, but that we will use for our base year of 2010.

Operational revenue

Operational revenue is related to fees charged by the airport, both on airside (charged for aircraft use of runways, taxiways and aprons, like landing, embarking and disembarking, overnight and parking, shuttle bus and jet bridges fees), and terminals (charged for individual passengers use of security services and general airport handling fees). While the latter is directly defined per passenger, for the former we need to convert the fee per aircraft operation into a fee per passenger, in order to calculate overall revenue. For such conversion, we

determined the standard aircraft movement in ACMI, based on statistical data (table 3) and some assumptions (table 4) as follows:[18]

	Total pax	% intern.	Total ops	Pax/ops
2005	24.115.552	35,6%	332.623	72,5
2006	24.727.296	35,9%	355.593	69,5
2007	25.881.662	35,9%	378.161	68,4
2008	26.210.217	36,0%	366.561	71,5
2009	24.243.056	33,4%	348.306	69,6
	Average:	35,4%		70,3

Table 3: Average No. of passengers per operation and % of international vs. domestic.

Source: AICM

Assumptions	
Average number of minutes per operation embark/disemb:	80
Average number of minutes per operation on overnight/ext parking:	30
Average % of flights that use shuttle bus / jet bridges / walking	45% / 45% / 10%
Average number of half-hour when shuttle bus required:	1,0
Average number of shuttle buses per requiring flight:	2,0
Average number of minutes used on jet bridge when required:	75
Average aircraft (type/MTOW tones):	A319 / 75 ton

Table 4: Assumptions to be used for the calculation of fee per passenger and revenue

For the exchange rate, we used the said 1 US\$ = 12.55 \$MXN for the conversion of all initial values, then worked with US\$ for all remaining years of study, thus eliminating the need to account for devaluation, and assuming that prices will be remain constant in terms of its value in US\$. This may be a rough approximation (mainly for all domestic operations and passengers), however it does not compromise the objective of the current paper.

Landing fees

We refer in table 5 to the prices valid in 2010 for AICM[19].

Time	Flight	MXN\$/ton (MTOW)
Normal	Domestic	13,342
	International	34,443
Critical	Domestic	16,981
	International	43,898

Table 5: Landing fees for AICM

Assuming that total number of flights are equally split between normal and critical periods (less and more congested), and using the calculated statistical average of 35,4% international flights, we determine the weighted average landing fee of 23,661 MXN\$/ton. For the average aircraft, with MTOW equal to 75 tones, the weighted average landing fee is 1774.55 MXN\$ or 141.40 US\$. Since the average landing (or operation) corresponds to 70.3 passengers, we

obtain the value of the weighted average landing fee per passenger of 1.006US\$/pax (with total passengers being the double of landing passengers).

Embarking and disembarking fees

With the same assumptions as for landing fees, and referring to the prices valid in 2010 for AICM shown in table 6, we determine the weighted average embarking and disembarking fee of 14,281 MXN\$/ton/60min.

Time	Flight	MXN\$/ton/60min.
Normal	Domestic	9,180
	International	18,726
Critical	Domestic	11,698
	International	23,857

Table 6: Embarking & Disembarking fees for AICM

With the assumption that each aircraft will stay, on average, 80 minutes on ground for normal *turn-around*, the weighted average fee is 1428.08 MXN\$ or 113.79 US\$ per operation. With the average operation being made with 70.3 passengers, that fee turns into 1.62 US\$ per passenger.

Overnight and parking fees

Again, we refer to the prices valid in 2010 for AICM (see table 7).

Flight	MXN\$/ton/60min.
Domestic	1,300
International	2,558

Table 7: Overnight & Parking fees for AICM

With the same ratios for domestic and international flights, we determine the weighted average overnight and parking fee of 1,745 MXN\$/ton/60min. Assuming that each aircraft will use on average 30 minutes of this ground service (most of the aircraft will not use it, but some will pay overnight or parking for some hours, so this is the value that, on average, each one will stay overnight per day), then the weighted average fee is 65.45 MXN\$ or 5.22 US\$ per operation, which turns into 0.07 US\$ per passenger.

Shuttle bus fee

We refer to the prices valid in 2010 for AICM: 573 MXN\$/bus/half-hour (independent of flight origin or time). Assuming that each aircraft requires two buses (which seems adequate for the average number of people for operation), for half-hour, and assuming that only 45% of flights require access by shuttle bus (all others use either jet bridges or walking) we obtain an average bus fee of 515.70 MXN\$ or 41.09 US\$ per operation, which turns into 0.58 US\$ per passenger.

Jet bridges fee

We refer to the prices valid in 2010 for AICM (see table 8), considering values from both terminals T1 and T2 (operated by AICM and Fumisa, respectively).

Terminal	Operator	Flight	MXN$/service/hour
T1	AICM	Domestic	704,00
		International	1.254,00
T2	Fumisa	Domestic	708,00
		International	1.259,00

Table 8: Jet bridges fees for AICM

With the same ratios for domestic and international flights, and assuming passengers equally distributed by T1 and T2, we determine the weighted average jet bridges fee of 900.88 MXN$/service/hour. Assuming that this service will be used by 45% of all aircraft, and that, when required, each aircraft will use the bridge on average for 75 minutes, then the weighted average fee is 506.74 MXN$ or 40.38 US$ per operation, which turns into 0.57 US$ per passenger.

Security screening fee

We refer to the prices valid in 2010 for AICM (see table 9):

Flight	MXN$/passenger
Domestic	2,695
International	3,408

Table 9: Security screening fees for AICM

With the same ratios for domestic and international flights, we determine the weighted average security fee of 2,947 MXN$/pax, which turns into 0.117 US$ per passenger (with total passengers being the double of passengers going through security and screening at departures).

Airport fee

We refer to the prices valid in 2010 for AICM (see table 10):

Flight	US$/pax
Domestic	14,73
International	18,13

Table 10: Airport passenger departure fees for AICM

With the same ratios for domestic and international flights, we determine the weighted average airport fee of 15.93 US$/pax, which turns into 7.97 US$ per passenger, since this fee is only applied at departures.

Summary of all fees (operational revenue)

The above calculations are summarized in table 11:

Fee description	Fee US$/pax	%
Landing	1,01	8%
Embarking & disembarking	1,62	13%
Overnight & parking	0,07	1%
Shuttle bus	0,58	5%
Jet bridges	0,57	5%
Security	0,12	1%
Airport pax fee	7,97	67%
Total	11,94	100%

Table 11: Fees paid to the airport per passenger at AICM

Some of the above are considered related to runways (about 30%), the rest allocated to terminals (about 70%), as shown in table 12.

Description	US$/pax
Operational revenues - associated with Runways (fees) ≈ 30%	3,58
Operational revenues - associated with Terminal (fees) ≈ 70%	8,36
Total operational revenue per passenger	11,94

Table 12: Operational revenue per passenger at AICM

Total revenue

Total revenue is the simple sum of the two previous values (see table 13):

Description	US$/pax
Commercial revenue	3,13
Operational revenues (fees)	11,94
Total revenue per passenger	15,07

Table 13: Total revenue per passenger at AICM

Calculation of expected NPV and IRR

Allocation of revenue to airport expansion

For the purpose of allocation of revenue to the airport expansion, we will consider the following rules:

- All new operational revenue associated with runways will be allocated to the airport expansion (since this is related to the increased capacity caused by the two runways);

- As for revenue associated with terminals, it is assumed that passengers allocation per terminal is the following, as per government decision[20]:

  - One third of all passengers is allocated to each terminal T1, T2 and T3, till maximum capacity of T1 is reached (16,5 million passengers) – note that in year 0 (2010) actual number of passengers are allocated to T1 and T2 (which are very similar to each other, 12.41 and 11.72 million respectively), with T3 having no passengers.

  - After T1 is exhausted, one third of total demand continues to be allocated to T2 till

maximum capacity of T2 is reached (20,0 million passengers), the remaining going to T3;

- The excess demand after T1 and T2 are exhausted will be allocated fully to T3.

Although the lattice model allows multiple scenarios of total number of passengers for the period 2011 to 2030, a visualization of the above is made in figure 10, where number of passengers is allowed to grow at the average growth rate.
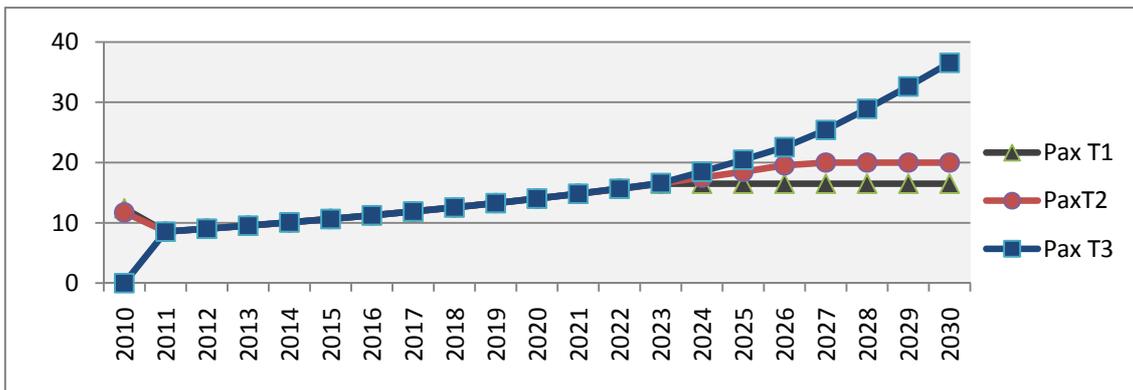

Figure 10: Example of visualization of allocation of passengers between terminals T1, T2 and T3 (case of constant growth based on average growth).

Variable and fixed costs

As for the variable and fixed costs, we assume the values shown in table 14.:

Operation cost	
New runways - marginal cost per pax (US$)	0,80
New runways - fixed cost (million US$)	3,00
New terminal T3 - marginal cost per pax (US$)	2,20
New terminal T3 - fixed cost (million US$)	3,00

Table 14: Assumptions for costs with new runways and terminal T3

Lattice model (revenue)

As for the revenue calculation, we refer to the values already presented (commercial and operation revenue), as well as the schedule for allocation of passengers between T1, T2 and T3. The obtained probability density function for revenue associated with the new runways and the new terminal T3 in year 2030 is shown in figure 11.
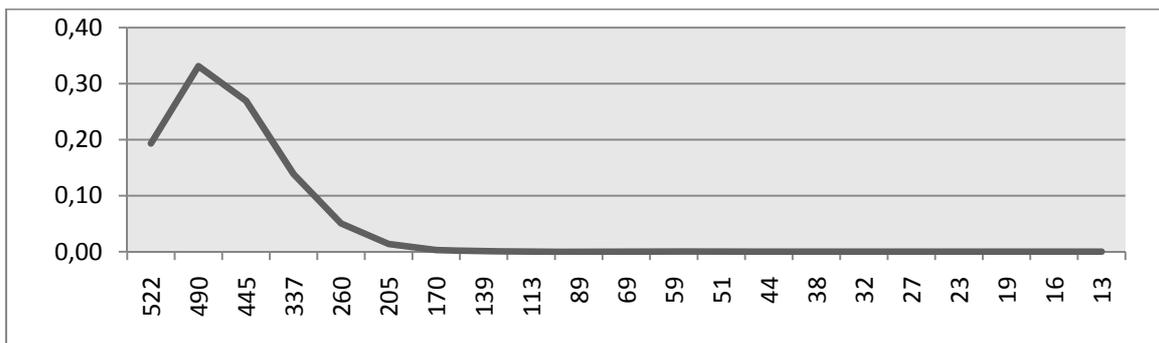

Figure 11: Probability density function of revenue (million $US) associated with new runways and T3 (in 2030)

Investment analysis (CAPEX)

The US$1.5 billion is assumed to be spent as follows: US$1000 million on year 0; US$500 million on following 20 years related to maintenance and renewal, as depicted in figure 12.
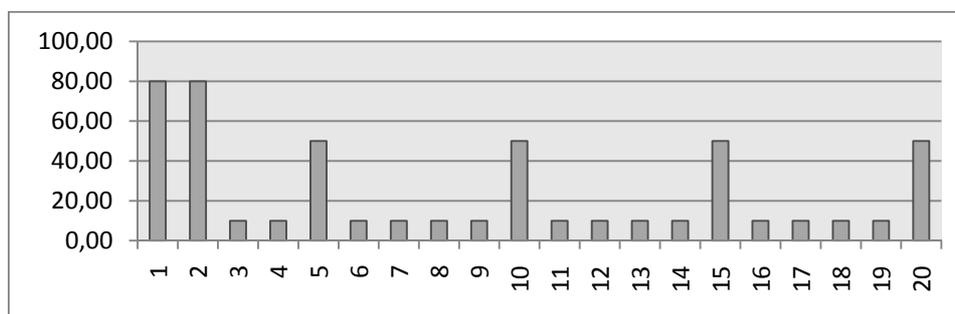

Figure 12: Remaining CAPEX (in million $US) to be spent over 20 years

Net Present Value (NPV) and Internal rate of Return (IRR)

With the expected costs, revenues and CAPEX, and with a discount rate of 12%, we obtain:

NPV = -71.15 US$ million, IRR = 11.3%

This is equivalent to say that the project is not interesting (NPV is negative and IRR is less than discount rate).

Sensitivity analysis

We analyzed the effect on NPV and IRR of some key variables.

With the base yearly average growth of 5,67%, we determined the influence of increase or reduction in growth in demand, by direct influence on the probability (p) of yearly upshifts (we assume that standard deviation is not changed) (see table 15).

v	p	NPV (US$ million)	IRR
3,67%	0,7727	-360,64	7,5%
4,67%	0,847	-227,7889	9,4%
5,67%	**0,9211**	**-71,15**	**11,3%**
6,67%	0,9955	105,43	13,0%

Table 15: Sensitivity analysis: NPV and IRR vs. average yearly growth

As for the discount rate influence, results can be seen in table 16.

Discount rate	NPV (US$ million)
6%	788,65
8%	419,00
10%	140,78
12%	**-71,15**
14%	-234,50

Table 16: Sensitivity analysis: NPV vs. discount rate

As for the influence of the revenue (operational and commercial):

Revenue per pax	NPV (US$ million)	IRR
-10%	-222,71	9,60%
-5%	-146,93	10,50%
615,07 US$/pax	**-71,15**	**11,30%**
+5%	4,62	12,00%
+10%	80,40	12,80%

Table 17: Sensitivity analysis: NPV and IRR vs. revenue per passenger

Flexible design

We will use the concept of 'real options' for provision of flexibility (de Neufville and Odoni, 2003, pp 812-817) in order to have the project flexible and adaptable to certain situations, both in favorable and unfavorable situations. *" 'Real' options concern the actual development of physical entities, in distinction to financial options on the price of an asset. Real options are 'in' the design, because they are embedded in physical features that designers have created. For example, designing a bridge with sufficient strength so that it can be double-decked if necessary (as was done for the George Washington Bridge in New York and the Ponte de 25 Abril in Lisbon) is a way of embedding a real call option on the opportunity to expand the system"* (de Neufville, 2008). For our specific case, we will consider the following:

Flexibility in Runways (option to build 2nd runway later)

- It is considered that the project will have two new runways, however we considered the option of building the second runway only when demand approaches 1.5 times the current capacity (24,13 million in 2010), that is when passenger demand reaches 36.5 million passengers, and not before; construction of one runway has and assumed cost of 100 US$ million, so postponing means allocation of capital from year 0 to year of construction of 2nd runway;

- When the two new runways are operating, we took the option of closing one of the runways, again if passengers demand is less than 36.5 million. In this situation we considered that fixed costs for runways are reduced from +3 million US$ per year regarding the planned yearly CAPEX, to +0.5 million US$.

- By analysis of the lattice model we determined that 2nd runway should be built no sooner than the 7th year. Also, construction of the 2nd runway can be delayed in many scenarios, however being practically certain that it will have to be built somewhere between year 7 and year 20 (for example, probabilities for requirement of 2nd runway are 56%, 85%, 95% and 99.9% in years 7, 9, 11 and 20).

- As for the revised CAPEX, the same value of US$1.5 billion was assumed to be spent as follows: US$900 million on year 0; US$600 million on following 20 years (see figure 13).
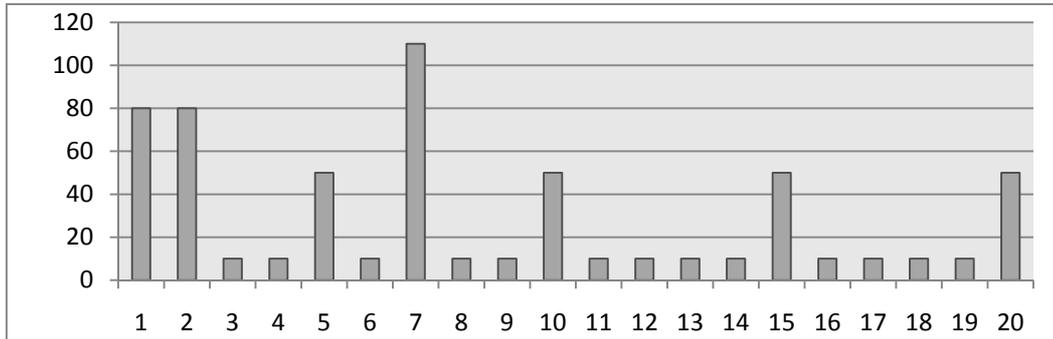

Figure 13: Remaining CAPEX (in million $US) to be spent over 20 years (with flexibility in runways)

With this option, the revised NPV was -6.96 million $US, which by comparison with the base NPV of -71.15 million $US, reveals an option value of 64.20 million $US.

Flexibility in Runways and in Terminal T3 (increasing capacity as needed)

- Additionally to the flexibility in runways, options were also incorporated in the new terminal T3 in order to have reduced capacity and fixed costs in case of smaller demand; and to have increased capacity in case demand grows to values higher than planned (T3 maximum capacity planned for 36,5 million passengers). From the lattice model we observed scenarios where demand is higher than 36,5 million for T3 if capacity constraints are not imposed;

- It was considered that the new Terminal 3 will not need to have full capacity built on base year. Instead, we considered that base capacity will be 15 million passengers, then 150 US$ million expansions of 10 million passengers each, will be added when capacity is required above 15, 25 and 35 million passengers. For this possibility we considered that up to 35 million passengers (initial capacity was planned for 36.5 million) CAPEX will be increased by 50 US$ million (cost of incorporating options), so overall CAPEX will be 1.55 US$ billion, plus the last expansion cost (if required) of 150 US$ million, for a total maximum of 1.70 US$ billion (only in certain scenarios).

- We considered that fixed costs for allowing expansion above 35 million will be increased by 10% (from 3 to 3,3 US$ million), while also considered that by closing unnecessary space in T3 (if demand is lower than expected) it is possible to save in fixed costs.

- By analysis of the lattice model we saw that investments on T3 expansion can be delayed in time, and that reduced costs can be incurred by operating at reduced capacity of T3 or before expansions.

- Capacity was allowed to 45 million passengers for T3 alone, however it is quite possible

that expansions only to 25 or 35 million will occur (it is unlikely, with only 1.7% probability that, after 20 years, capacity did not require any expansion at all and stayed at 15 million). As per the lattice model, demand requirements for expansion to 25, 35 and 45 million may occur in years 10, 14 and 17, with probabilities on those years of 44%, 32% and 25% respectively.

- As for the revised CAPEX, the new value of US$1.7 billion was assumed to be spent as follows: US$600 million on year 0; US$1100 million on following 20 years (figure 14).
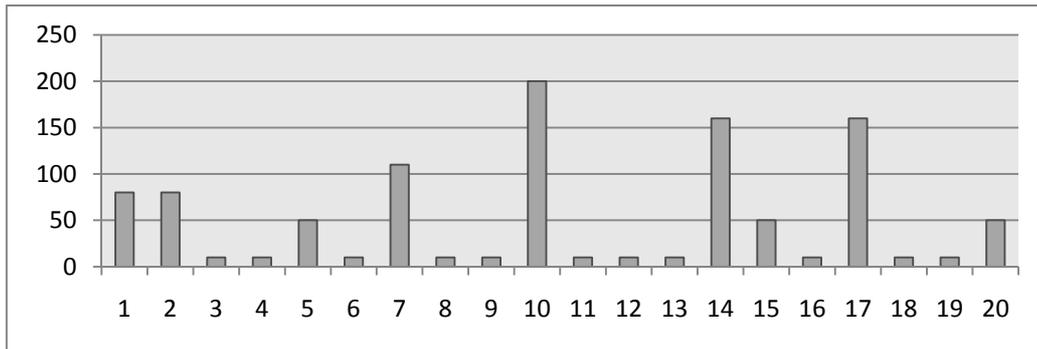

Figure 14: Remaining CAPEX (million $US) to be spent over 20 years (with flexibility in runways and T3)

With options on runways and terminal T3, NPV was positive 170.46 million $US and IRR was 17.2%, which by comparison with the base NPV of -71.15 million $US, reveals an option value of 241.62 million $US.

Conclusion

Analysis of uncertainty and flexibility in design is a key issue in a process that aims at increasing the project value, and eventually change the expected NPV substantially. In this paper, we used a binomial lattice model and applied it to AICM. It was shown that there a number of uncertainty factors that apply to Mexico and AICM that definitely make this kind of rationale very much recommended for our example airport.

In case of airport expansion, where revenue already exists due to the existing infrastructure, it may not be obvious how the new revenue will be allocated, mainly if existing capacity is not yet fully attained at the time of expansion. If the ownership of the existing infrastructure and expansion is not the same, this may become a crucial matter for new investors and influence calculations of NPV substantially. The specific case of AICM has all these aspects: ownership of most of current infrastructure belongs to AICM, however the most recent Terminal 2 belongs to Fumisa, that has a securitization financing process in place.

The current paper highlighted these aspects and presented calculations of the value of flexible design and real options that were considered both for new runways and new Terminal 3. Even

if some of the variables had to be assumed (mainly regarding costs), we consider that the purpose of the paper was achieved: to motivate designers, planners, investors and politicians to abandon the traditional deterministic way of deciding, and to introduce uncertainty, flexibility and real options value calculations in their decision processes, with the help of available tools and simple methodology.

From the overall study, we may state that AICM expansion may turn into a very interesting investment opportunity under the proposed model, with higher than anticipated internal return rates of capital invested. We should emphasize that conclusion is strongly based on expected demand growth, however supported by good statistical data from that region of the world. Again, real options and flexibility in design and construction may be the determinant factor of success.

References

Chambers, R.-D. (2007), *Tackling Uncertainty in Airport Design: A Real Options Approach*, MSc thesis, Engineering Systems Division, Massachusetts Institute of Technology, USA. Available at: http://ardent.mit.edu/real_options/Common_course_materials/papers.html

de Neufville, R. (2008), *Building Airport Systems for the Next Generation*, The Bridge, Journal of the National Academy of Engineering, Special Issue on Transportation Infrastructure, Summer 2008, pp.41-46. Available at: http://ardent.mit.edu/real_options/ and http://www.nae.edu/File.aspx?id=7420

de Neufville, R. and Odoni, A. (2003), *Airport Systems – Planning, Design, and Management*, McGraw-Hill, New York, NY

Graham, A. (2009), *How important are commercial revenues to today's airports?*, Journal of Air Transport Management 15, pp 106-111.

Huber, H. (2010), *Strategic Flexible Planning and Real Options for Airport Development in India*, paper #3210, WCTR – World Conference of Transport Research, 12th WCTR, Lisbon, Portugal.

Keeney, R. and de Neufville, R. (1973), Multiattribute Preference Analysis for Transportation Systems *Evaluation: Mexico City Airport as a Case Study*, Transportation Research, 7, No. 1, pp. 63-76.

Neiva, R., Costa, A., Coutinho dos Santos, M., Cruz, C. (2010a), *Airport Investment Analysis in Unstable Markets*, paper #322, ATRS – Air Transport Research Society, 14th ATRS Conference, Porto, Portugal.

Neiva, R., Costa, A., Coutinho dos Santos, M., Cruz, C. (2010b), *Valuation Techniques for*

Airport Investments: Maximizing Value Through Flexibility, paper #2897, WCTR – World Conference of Transport Research, 12th WCTR, Lisbon, Portugal.

Savage, S. (2000), *The Flaw of Averages,* published October 8, in the San Jose Mercury News. Available at: http://www.stanford.edu/~savage/flaw/Article.htm

Savage, S. (2009), The Flaw of Averages: Why We Underestimate Risk in the Face of Uncertainty, John Wiley & Sons.

Endnotes

[1] Airport news, Momberger Airport Information, http://www.mombergerairport.info/

[2] Wikimapia, http://wikimapia.org/10820461/es/Aeropuerto-del-Lago-Nuevo-Proyecto

[3] Wikipedia, http://en.wikipedia.org/wiki/Popular_Revolutionary_Army and http://en.wikipedia.org/wiki/Zapatista_Army_of_National_Liberation

[4] Mexico City mayor environment, http://www.citymayors.com/environment/mexico-bordo-boniente.html

[5] US EIA, Energy Information Administration http://www.eia.doe.gov/

[6] Wikipedia, http://en.wikipedia.org/wiki/File:Brent_Spot_monthly.svg

[7] Wikipedia, http://en.wikipedia.org/wiki/Price_of_petroleum

[8] Cisco, http://www.musion.co.uk/Cisco_TelePresence.html

[9] Council on Foreign Relations, http://www.cfr.org/publication/13448/airports_on_guard.html

[10] Tourism Mexico, http://www.spanish-mexico.com/tourism-mexico/

[11] Wikipedia AICM, http://en.wikipedia.org/wiki/Mexico_City_International_Airport#cite_note-2

[12] OECD GDP, http://stats.oecd.org/Index.aspx?DatasetCode=CSP2009

[13] http://www.exchange-rates.org/history/MXN/USD/T

[14] Wikipedia AICM, http://en.wikipedia.org/wiki/Mexico_City_International_Airport#cite_note-2

[15] AICM website, http://www.aicm.com.mx/acercadelaicm_en/Estadisticas/

[16] US Commercial Service, Department of Commerce, *Mexico: Aviation Industries Opportunities*, August 2007, http://www.buyusainfo.net/docs/x_4697919.pdf

[17] This is a simplification that we will use due to lack of equivalent data for AICM.

[18] AICM web site, http://www.aicm.com.mx/ClienteseInversionistas_en/Tarifas/

[19] AICM prices valid from 1st March 2010 onwards, after a 3.8% increase over prices charged from 2007 to 2010.

[20] The reason why this is basically a political decision is because different terminals may have different ownership. In the specific case of AICM, terminal T2 is clearly owned and run by a private group (Fumisa) under securitization financing, thus very much sensible to interferences in the outcome of their own revenue.