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ARTICLE

Low-Cost Airports for Low-Cost Airlines: Flexible Design to Manage the Risks

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ABSTRACT Airport planning is shifting from the traditional pattern – driven by long-term point forecasts, high standards, and established clients – to that of recognizing great forecast uncertainty, many standards and changeable clients. This is a consequence of economic deregulation of aviation and the rise of low-cost airlines.

Low-cost airlines are becoming significant factors in airport planning. Their requirements differ from those of 'legacy' carriers. They drive the development of secondary airports and cheaper airport terminals. They catalyze 'low-cost airports' around the 'legacy main airports' built for the 'legacy airlines'.

This paper proposes a flexible design strategy to deal with the uncertainty of this dynamic. This differs significantly from traditional airport master planning. It builds flexibility into the design, to enable airports to adjust to changes in the type, needs and location of traffic. The case of Portugal illustrates the current risks, and indicates how flexible design could manage uncertainties and maximize expected value.

KEY WORDS: Airport planning; low-cost carriers; airport terminals; risk management; flexible design; Portugal

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Introduction

This paper argues that a paradigm shift is taking place in airport planning, away from the traditional pattern driven by long-term point forecasts, high standards, and established clients, toward one that recognizes great uncertainty in forecasts, a broad range of standards, and the potential for a rapidly changing client base.

After a brief review of the traditional airport planning process, this paper makes the case for a paradigm shift in airport planning, from a focus on traditional airlines to one that considers the needs, practices, and volatility of low-cost airlines. The new approach recognizes great uncertainty in the type, location and level of investments in airport infrastructure. This paper proposes a process of flexible design for dealing with these uncertainties. Its key element involves the use of real options that permit airport owners to adjust their facilities easily to changes in the location and needs of air transport. It illustrates this approach through a discussion of the prospective aviation future for Portugal.

Traditional Airport Planning

During the second half of the 20th century, the practice of airport planning adopted standard procedures attuned to the needs of the dominant airlines – those now known as the 'legacy carriers'. These procedures were encoded into long-lasting, slowly evolving manuals such as those of the International Air Transport Association (2004) and other entities, as de Neufville and Odoni (2003) describe.

The standard paradigm was compatible with the regulatory regimes and business models that prevailed during most of this period. It reflected the then prevailing reality that:

- organizational change occurred slowly, given the consistency and slowness of the regulatory process, and airports could count on decade-long relationships with their airline customers;
- changes in airlines, through mergers (e.g. BOAC and BEA into British Airways) or changes in route structures were of little consequence for airports, as one airline would simply substitute for another to serve the travel market;
- standards for the quantity and quality of the space in airport buildings were high, given the IATA and other definitions of appropriate practice; and
- technological changes (such as the introduction of the Boeing 747) could be easily anticipated because of their long lead times.

The traditional practice of airport planning and design reflected a fairly static view of the industry. Granted, the actual levels of traffic could be volatile, suffering slow-downs or benefiting from expansionary bursts, but airport practitioners came to understand these variations as fluctuations around long-term trends, which they could cope with by delaying or accelerating the delivery of airport facilities.

Argument for Paradigm Shift

As the basis for the change in airport planning, this paper presents and defends the hypothesis that the ascendancy of low-cost airlines entails increased expansion of the network of low-cost airports, and of low-cost airport facilities in general. The proposition is simple, and might appear obvious, but leads to a paradigm shift in the concept of airport development.

Airport planners and investors need to recognize the effect of low-cost airlines. It implies a downward shift in standards, and acceptance of the volatility of these carriers. Established airport organizations and professionals find this new order difficult to accept. To many it is degrading, beneath their standards, to deal with the low-cost carriers. The trend runs counter to the practice of the past generation that has committed to massive, multi-billion Euro investments in hub airports featuring spectacular edifices by signature architects (de Neufville, 2006).

This hypothesis involves propositions concerning the timing, location, and business proposition of low-cost airports. It implies that in general but with exceptions:

- The development of low-cost airports and airport facilities is largely catalyzed by the expansion of low-cost airlines, in the sense that the low-cost airlines come first, and the low-cost airports (and low-cost facilities) mostly come afterwards.
- Low-cost airports largely develop in competition with major airports, either as secondary airports in a metropolitan multi-airport system, or as destinations that bypass the use of a centralized metropolitan hub.
- The business model for low-cost airports is distinct from that of the traditional major airports. Mirroring the difference between low-cost and legacy airlines, low-cost airports emphasize profitability through operational efficiency and minimal frills.

Extensive worldwide data support these points.

The proposition that the growth of low-cost airlines leads to the development of low-cost airports and airport facilities has important

consequences for airport planning, and for policy and investment in airport infrastructure. To the extent that one believes that inexpensive, mass air transport is either inevitable or socially desirable, the proposition has consequences for how and where:

- governments should develop and promote airport infrastructure;
- private investors should allocate their investments in airport facilities; and
- thus for the role, objectives and criteria of success for airport planning.

In general, the implication is that policy makers and investors should focus more attention on the development of airport facilities serving low-cost carriers, both at the legacy and low-cost airports, and correspondingly be careful about the long-term future for multi-billion Euro facilities constructed along traditional lines. This thought contradicts the main line of on-going discussions, obviously dominated by the existing large airports, their spokesmen, and associated professionals who promote the development of expensive main airports.

Hypothesis in Detail

Background. Economics teaches that oligopolies enable their members to extract extraordinary profits from consumers. Furthermore, organizational studies indicate that the stakeholders in the enterprise tend to share the oligopoly benefits. Conversely, economics teaches that lower-cost producers compete away and eventually eliminate oligopolies and oligopoly profits. It also gives us to understand that the pressure on the front-line competitors to lower costs is transmitted to the providers of all their factors of production. That is, competition between 'legacy' and 'low-cost' airlines leads to competition between 'legacy' and 'low-cost' airports.

The history of airline competition after economic deregulation is an epitome of these standard economic teachings. In detail:

1. For the first half-century of the airline industry, governments protected it economically in a variety of ways. Regulatory regimes created barriers to entry into the business and particular markets. Cartels pervaded the enterprise. For example, in Australia, governmental regulation compelled the two domestic airlines (Australian and Ansett at the time) to buy the same equipment, operate the same routes on virtually the same schedules, and correspondingly divide the market. Elsewhere pooling arrangements as between Spain and France, both limited capacity in their shared markets, and divided the profits between the airlines allowed to fly the routes. In short, the

regulatory environment created a 'cost-plus' environment aimed at insuring airline success.

2. In this context, airline employees obtained extraordinary wages and working conditions compared to workers of comparable skills in other sectors. Salary levels were higher, hours of work shorter, and retirement benefits more generous than in other industries – as the subsequent history demonstrates.
3. Correspondingly, airports serving the main airlines and national hubs obtained access to large amounts of cheap capital that they used to construct monumental structures, often among the most expensive architectural expressions in a metropolitan region. The recent passenger buildings at Bangkok/Suvarnabhumi, Hong Kong/Chep Lak Kok, Madrid/Barajas, San Francisco/International, and Shanghai/Pudong illustrate this pattern. London/Heathrow Terminal 5, costing around €6.5 billion (US$9.6 billion), represents the ultimate in this kind of expense.
4. Economic deregulation has been changing this picture. In the United States, price competition since 1978 has forced the legacy airlines to cut back drastically on their costs. This phenomenon has been propagating to Australia, Canada, Europe, and Asia.
5. Pressure on the airlines has in turn forced the employees of the legacy airlines to forego their comparatively generous terms of employment. As airlines faced bankruptcy and disappearance, employees confronted the choice of losing the airline and their jobs, or lowering their pay packages. Thus, wages at North American legacy carriers have dropped by about a third in real terms, working hours have lengthened, and jobs have enlarged. For example, at Northwest Airlines (NWA) the pilots agreed to cut their pay by 15% in 2004, and a further 24% in 2006, for a total overall reduction of 35% (Fedor, 2006). Machinists and ramp workers took a 26% and then a further 11.5% pay cut, as well as foregoing about 2 weeks of annual vacation. Flight attendants likewise took an additional 21% pay cut and accepted work rule changes, such as participating in the cleaning of the aircraft cabin (Jorgenson, 2006).
6. Similarly, legacy airlines have been cutting back on airport expenses, for example, by not moving into expensive facilities built for them (Swissair did not move into the new satellite at Zürich, and Lufthansa declined to move into the €1 billion (US$ 1.5 billion) Terminal 2 at Frankfurt/Main); or by cutting back substantially on the design of facilities, as American did at New York/Kennedy (DMJM Aviation, 2005).

Hypothesis in detail. The hypothesis is that the ascendancy of low-cost airlines entails an increased importance and expansion of low-cost

airports and airport facilities. Specifically, as the low-cost airlines come to represent a sizeable fraction of the market:

- They catalyze the development of low-cost airports and airport facilities, both in the major metropolitan areas and throughout the regions.
- The low-cost airports compete with the traditional major 'legacy' airports, both locally in metropolitan areas and through a network of services connecting these facilities.
- In contrast with the traditional airports, low-cost airports will not have expensive buildings, and will focus on efficiency, and sparse commercial areas.

Low-cost airlines catalyze the development of low-cost airports. Because these carriers focus on cost competitiveness, they deliberately seek out and create opportunities for low-cost airports. This does not imply that they either build or invest heavily in these facilities. It means that they take advantage of the availability of the large number of existing under-used runways left over from an earlier technological era or obsolete military needs. The low-cost airlines then negotiate mutually beneficial arrangements with the local authorities under which the airlines create jobs and promote business and tourist opportunities for the region, and the local authorities organize the airport on advantageous terms for the low-cost airlines. These deals have often been win–win arrangements for both parties. Indeed, they follow the pattern for airport development that prevailed for most of the last century: national governments and local communities world-wide have provided capital for airport facilities at favorable interest rates or fiscal conditions. In the United States, for instance, airport facilities are largely financed by a combination of grants from the national treasury and by tax-free (i.e. subsidized) private bonds. Elsewhere, a traditional practice has been for governments to build the airports from tax resources.

Low-cost airports compete with major airports in three major ways:

1. Most obviously, as secondary airports in a metropolitan multi-airport system, they provide alternatives to the major hubs. These low-cost airports may be more convenient to some customers (as London/Stansted is to travelers from Cambridge and the Northeast of London); cheaper to users (as by lower parking charges); and provide access to a less expensive range of services.
2. In a larger sense, they compete with the larger hubs because they offer opportunities to bypass these hubs. Thus, Londoners interested in going to the South of Spain can now go on Ryanair directly to Jerez, and avoid passing through Madrid as they would ordinarily

have had to do on a legacy airline, such as Iberia. Likewise, they can get to Carcassonne directly and avoid travel through Paris or Toulouse; or reach the Algarve by flying to Faro and avoiding Portugal's premier airport at Lisbon.

3. Moreover, the low-cost airlines and airports jointly form parallel networks that compete against the routes of the legacy airlines and the major hubs. Thus, Ryanair provides service between London, Brussels, Frankfurt, and Barcelona – using the low-cost airports of Stansted, Charleroi, Hahn, and Girona. Similarly in North America, Southwest serves Boston, Washington, and Miami – using Providence, Baltimore, and Fort Lauderdale.

Finally, the business model for low-cost airports is distinct from that of the traditional major airports. Mirroring the difference between low-cost and legacy airlines, low-cost airports emphasize economy through operational efficiency and minimal frills:

1. Most obviously, they avoid grandiose buildings by signature architects and others. They favor simple designs that, as one architectural critic put it, 'have the charm of a high school gymnasium'. The contrast at Singapore between the new Terminal 3 and the low-cost terminal built around the corner illustrates this point. The low-cost terminal is a cinder block and metal truss arrangement, built at about 1/10th the cost per passenger of capacity as the resplendent Terminal 3 built concurrently.
2. The interior spaces of low-cost airport buildings reflect the performance standards of the low-cost airlines. They have lower service levels in terms of space per person, and overall higher annual capacity per square meter of space, associated with lower dwell times of passengers due to fast turnarounds of the aircraft. Because the total space required per passenger is directly related to the average time people stay in a space, that is, the dwell time, the faster an airline turns its aircraft, the faster travelers use the gate, and the less space per person is required (de Neufville & Odoni, 2003). They also emphasize common hold rooms to minimize the overall space allocated to this function. The common practice, outside of the United States, has been to build separate hold rooms for each gate. It is more economical to provide common hold rooms, so that the space provided can be used more intensively. This practice reduces the total space required by up to 50% (de Neufville & Belin, 2002).
3. Low-cost airports will not create large amounts of expensive commercial space, even though retail activities can be important sources of revenue, as Francis *et al.* (2003) document. Building and operating commercial space on airports is particularly costly.

> Security measures and general difficulty and delays of access multiply construction costs. Likewise, it is expensive to pass commercial items and staff through security – which is where they mostly have to be, to appeal to passengers. In short, the economic rationale for building airport terminals as shopping arcades is not clear. It is one thing to stuff an otherwise empty space with shops, as has been widely done in the existing terminals at main hub airports, for example, at London/Heathrow. It is quite another to spend around €6.5 billion (US$9.6 billion) on Terminal 5 at Heathrow, much of which is designed around multiple shopping floors.

As the overall hypothesis exists in a social context, its manifestations do not follow mechanically. Exceptions to the general rule occur. Moreover, the units of analysis are to some degree ambivalent. The definition of a low-cost airline is not unique. How should one classify jetBlue, for example, which acts like Southwest and easyJet in many ways, but offers amenities not found on other low-cost airlines (such as individual television screens)? The correctness of the hypothesis depends on the overall trends, and it is in this light that we should look at the evidence.

Evidence

Unit of analysis. As the hypothesis centers on low-cost airlines, it is necessary to be clear about the definition of this concept, at least in this context. As Gillen and Lall (2004) highlighted, low-cost airlines come in a variety of forms. For example, Southwest, Ryanair and easyJet each have distinct approaches to their business. However, because the argument in this paper rests on the economic reality that producers with the lowest costs ultimately define the market, the definition of 'low-cost airlines' centers on the airlines' actual costs of production, for example, per seat-mile.

Current data in the United States appear to define low-cost airlines reasonably clearly. As Figure 1 shows, there is a division between the legacy airlines that have seat-mile costs in the range of US15 cents, and the others whose costs are about 40% lower. This kind of data demarcates the low-cost airlines. Comparable data on other low-cost airlines are not available. However, from industry and other sources it is reasonably clear that easyJet, Ryanair, GOL, AirAsia, Westjet and others can confidently be placed in the low-cost category.

In thinking about this issue, it is important to recognize that an airline that offers low fares is not necessarily a low-cost airline in the sense of being a low-cost producer, which is the sense used in this paper. For a customer, low price = low cost. From that perspective, US

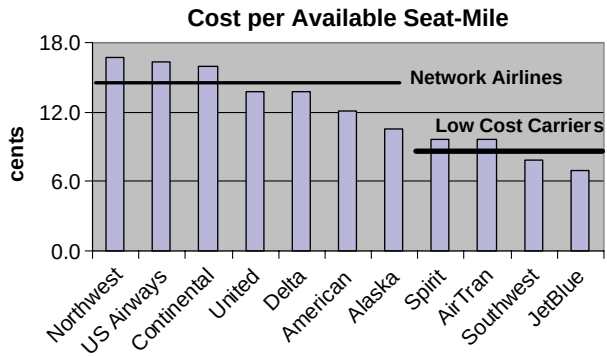

Figure 1. Comparison of airline costs in the United States in 2005. *Source*: US FAA, Bureau of Transportation Statistics (2007a)

Airways has been cited as a 'low-cost airline' (Wikipedia, 2007a), even though its costs have been among the highest, as Figure 1 indicates. However, from the perspective of an economic analysis, there is a big difference between low-cost and high-cost producers. Furthermore, from economics we know that producers in a market ultimately need to match the going price for a given quality, so that the price charged is not an appropriate way to identify low-cost producers.

Ascendancy of low-cost airlines. Low-cost carriers now drive much of the future of air travel. This fact may surprise casual observers. Most of us know that the low-cost airlines are newcomers compared to the legacy carriers, many of which have proudly commemorated their 75th anniversaries. From our travels through leading airports, we can recall the showcase terminal buildings associated with these traditional carriers. Many memories can combine to imprint us with the continuing importance of the legacy carriers. Yet, the fact is that by 2005 well over 50% of the revenue passenger-miles in the United States consisted of traffic of the low-cost carriers or traditional airlines that were matching their fares (Morrison & Winston, 2005). In particular, Southwest Airlines has been by far the largest domestic carrier in the United States since 2004. In 2006 it had 96.3 million emplanements, about 30% more than the next largest (American, at 76.3) and about 50% more than the third largest domestic carrier (Delta, at 63.4) (US Federal Aviation Administration, Bureau of Transportation Statistics, 2007a).

Similar stories are emerging elsewhere. In Canada, the low-cost Westjet has been humming along while one of the two legacy carriers went bankrupt (Canadian), merged with the other legacy carrier, Air Canada, which also went bankrupt. In Europe, Ryanair and easyJet have grown rapidly and rank among the strongest passenger airlines in

Table 1. Market capitalizations of leading airlines (US$ billion) as of 2 January 2007

Airline	Market cap	Airline type	Went bankrupt?
UPS	80.5	Integrated freight	
Fedex	33.4	Integrated freight	
Ryanair	12.6	Low-cost	
Lufthansa	12.3		
Southwest	12.1	Low-cost	
British Airways	11.8		
Air France	11.3		
Singapore	8.2		
American	6.5		
GOL	5.6	Low-cost	
EasyJet	5.1	Low-cost	
United	4.9		Yes
US Airways	4.7		Yes
Continental	3.7		Yes
Iberia	3.3		
JetBlue	2.5	Low-cost	
Virgin Blue	2.0	Low-cost	
Air Canada	1.9		Yes
Alaska	1.6		
Westjet	1.4	Low-cost	
Air Tran	1.1	Low-cost	
AirAsia	1.0	Low-cost	
Japan Airlines	0.6		
Allegiant	0.5	Low-cost	
Northwest	0.4		Yes
Delta	0.3		Yes
Hawaiian	0.2		

Source: finance.yahoo.com and industry estimates. US$10 billion:€6.8 billion.

the world, as Table 1 shows. In total, the various low-cost European airlines already account for around 1/3 of all traffic in the European Union. Likewise, in Brazil, GOL has overtaken the national flag carrier, Varig, which has collapsed economically and passed from the largest airline in South America to the number 4 in Brazil (Wikipedia, 2007b). In Asia finally, AirAsia, Lion Air, and Jetstar – each new since 2001 – already carried 6% of that traffic by 2004 (International Air Transport Association, 2005).

The rise of the integrated freight airlines, such as UPS, Fedex, and DHL, is further eclipsing the legacy carriers and the legacy hub airports with which they are associated. Fedex has more major jet aircraft than Lufthansa, British Airways or Air France, and UPS is in the same league (International Air Transport Association, 2005). Fedex and UPS have

seized the lion's share of the market for profitable air cargo. Most importantly, these innovative carriers preferentially (although not exclusively) use secondary airports in metropolitan areas. Thus in North America, beyond their main hubs at the second tier airports of Memphis and Louisville, Fedex and UPS have hubs at such airports as Chicago/Rockport, Los Angeles/Ontario, San Francisco/Oakland, and Toronto/Hamilton. The integrated freight airlines are developing their own networks of services independent of those of the legacy carriers and airports.

The market capitalizations of the low-cost and innovative carriers underscore their rise compared to the legacy carriers. The 'market cap' equals the product of the number of shares in the company times the market price per share. This standard financial measure thus takes into account the current situation and future prospects of a business. It is the investors' valuation of a company, indicating their willingness to provide it with capital (such as aircraft and terminal buildings). Equally, it represents the financial power of a company, which can use its shares to buy or otherwise acquire assets. Conversely, when an airline is bankrupt and thus has no significant market cap, it has very little financial power, even though it may have its name painted on many aircraft. Table 1 shows that the financial power of the low-cost carriers is comparable if not superior to that of the legacy carriers. Ryanair, for example, is more valuable than British Airways. Southwest has twice the value of the next US carriers, American and United.

The market capitalization is a better measure of the strength of an airline than more traditional measures, such as fleet size. The reality is that airlines largely do not own the aircraft with their logos – they lease them. The largest owner of commercial aircraft is International Lease Finance (2007) which at the end of 2006 owned 823 Boeing and Airbus aircraft – more than the combined fleets of Air France, British Airways and Lufthansa (Wayne, 2007). Table 2 illustrates this in another way: Southwest, the company with the largest market cap in the United States, is buying many new aircraft and has the youngest fleet compared with its biggest rivals.

Table 2. Southwest compared to nearest rivals for US domestic traffic

Airline	Domestic traffic (millions, 2006)	Average aircraft age (years)	Fleet size 2006	Fleet size 2007	Change (%)
Southwest	96.3	9.8	445	491	+10
American	76.3	14.1	699	672	−3
Delta	63.4	13.3	434	428	−3

Sources: Airfleets.net (2007), US FAA (2007a).

Table 3. Low-cost airports whose development was catalyzed by low-cost airlines

Metropolitan region	Secondary airport	Low-cost airline	Pre-low-cost traffic
Barcelona	Girona	Ryanair	Insignificant
Boston	Providence	Southwest	Half
Boston	Manchester, NH	Southwest	Half
Brussels	Charleroi	Ryanair	Insignificant
Budapest	Balaton	Ryanair	Insignificant
Copenhagen	Malmo, Sweden	Ryanair	Half
Dallas/Fort Worth	Love	Southwest	Insignificant
Frankfurt	Hahn	Ryanair	Insignificant
Glasgow	Prestwick	Ryanair	Insignificant
Hamburg	Lübeck	Ryanair	Half
Houston/Galveston	Hobby	Southwest	Almost all SW
London	Stansted	Ryanair	One-third
London	Luton	EasyJet	Half
Los Angeles	Long Beach	jetBlue	Half
Manchester (UK)	Liverpool	EasyJet	Insignificant
Manila	Clark	AirAsia	Insignificant
Melbourne (Australia)	Avalon	Jetstar	Insignificant
Miami	Fort Lauderdale	Southwest	Half
Milan	Orio al Serio	Ryanair	Insignificant
New York	Islip	Southwest	Insignificant
Orlando	Sanford	Allegiant	Insignificant
Oslo	Torp	Ryanair	Insignificant
Paris	Beauvais	Ryanair	Insignificant
Rome	Ciampino	easyJet, Ryanair	Insignificant
San Francisco	Oakland	Southwest	Two-Thirds
Stockholm	Skvasta Vasteras	Ryanair	Insignificant
Vancouver	Abbotsford	Westjet	Insignificant
Venice	Treviso	Ryanair	Insignificant
Vienna	Bratislava, Slovakia	Ryanair	Half

Source: de Neufville Multi-Airport Systems database.

Development of low-cost airports. The record shows that the low-cost airlines have been major drivers of the development of low-cost airports. Table 3 gives details. Ryanair has been the impetus behind the development of Barcelona/Girona, Brussels/Charleroi, Frankfurt/Hahn, London/Stansted, and others (Beck, 2007; Garriga, 2003, 2004). Likewise, easyJet has led the growth of Manchester/Liverpool and London/Luton. In the United States, the phenomenon has been known as the 'Southwest effect', as that airline has energized the doubling and tripling of traffic at airports, such as Boston/Manchester, Boston/

Providence and Miami/Fort Lauderdale. In Asia, Asia Air has been promoting Manila/Clark and Jetstar in Australia created Melbourne/Avalon from virtually nothing into an international gateway with service to Indonesia, Japan, Thailand and Vietnam (Jetstar, 2007). Overall, the low-cost airlines have catalyzed the widespread development of multi-airport systems in metropolitan areas. These used to be confined to metropolitan areas with over 10 million departing passengers a year (de Neufville, 1995), but now are a feature of many smaller areas – such as Budapest, Oslo, Stockholm, Venice, and other metropolitan regions.

Note that the cost of developing a low-cost airport is minimal – in contrast to that of a new or expanded traditional major airport (such as Madrid/Barajas, Miami/International, Paris/de Gaulle, Tokyo/Narita, etc.) that easily cost €3 billion (US$4.4 billion) or more. Low-cost airports have almost been free, due to the fact that obsolete military and other airfields are plentiful. These have provided the runways and basic facilities for many of the airports listed in Table 3. In any case, regional authorities have been glad to supply the modest supplemental facilities needed for passenger services, in exchange for the jobs the low-cost airlines create and the passengers they bring to the area. The possibilities are far from exhausted. Portugal provides a case in point: It has a sizeable military field at Beja, which the central government and local authorities wish to convert to a low-cost airport for about €30 million (US$44.4 million) (Câmara de Comercio Luso-Britânica [British-Portuguese Chamber of Commerce], 2007).

Low-cost carriers like to use low-cost, secondary airports for two reasons. Most obviously, they appreciate the low charges. Perhaps more importantly, however, they like the smaller airports because these are relatively uncongested and thus free from ground and air traffic control delays, as Table 4 indicates, and Warnock-Smith and Potter (2005) document in detail. Lack of congestion, together with work rules that permit fast turnaround times at the gate, enable low-cost airlines to increase the flying time and thus the productivity of their aircraft, and thus lower their operating costs significantly. Low-cost airlines choose secondary airports because they are generally integral to their efficiency.

The combination of quick turnaround times and use of secondary airports with low delays leads to significant cost advantages for the low-cost airlines. This fact needs to be stressed as many observers appear not to appreciate the applicable economies. The box presented in Figure 2 provides an illustration of how this works. This crude analysis does not specify many operational details such as the maintenance required after specified hours of flying. It does, however,

Table 4. Secondary airports in metropolitan areas enabling less aircraft delays

Primary airport in metropolitan region	Secondary airports	Flights with delays >15 minutes (%)
Boston/Logan		33
	Manchester, NH	25
	Providence, RI	26
Dallas/Fort Worth		30
	Love	23
Los Angeles/International		25
	Burbank	20
	Ontario	18
	Wayne/Santa Ana	21
San Francisco/International		27
	Oakland	19
	San Jose	18

Source: US FAA, Bureau of Transportation Statistics (2007b).

indicate the kind of productivity airlines can achieve by cutting their turnaround times and congestion delays.

Low-cost airlines emphasize the use of low-cost airports when these are available. Conversely, they tend to avoid legacy hub airports, even

Sample Comparison of Flight Hours/Day Achieved by Legacy and Low-Cost Carriers

Both carriers fly between cities 1.5 hours apart, over about a 17 hour day (6 am to 11 pm)

Assume 30 minutes delay at congested airports, 20 minutes at less congested airports.

Turn-around time not needed at start of day.

A) Legacy Carrier flying between congested airports, with 1 hour turn-around time

Time per leg = flight time + turn-around time + allowance for delays = 1.5 + 1 + 0.5 = 3 hours

Round trips per day = 17 / 6 => 3 (allowing for no turn-around at start and end).

B) Low-Cost Carrier flying between less congested airports, with 0.5 hour turn-around

Time per leg = 1 + 0.5 + 0.33 = 1.83 hours

Round Trips per day = 17 / 3.67 => 5 (allowing for no turn-around at start and end.)

Comparative Advantage of Low-Cost Carrier:\

Productivity increase of Aircraft (Capital employed) = + 67 %

Decrease in Capital Cost per Passenger = 40%

Figure 2. Comparison of flight hours/day achieved by legacy and low-cost carriers

though they serve some of them. Thus Southwest, by far the larger carrier of passengers in the United States (US Federal Aviation Administration, Bureau of Transportation Statistics, 2007a), as of 2007 does not provide service to half the top 10 busiest US airports (Atlanta, Chicago/O'Hare, Houston/Bush, Minneapolis/St.Paul, and New York/Kennedy) nor to obvious destinations such as Boston/Logan, New York/Newark-Liberty and Miami/International.

Competition with hub airports. Low-cost secondary airports in a metropolitan area compete with the traditional main ports. As the low-cost carriers expand along with these low-cost airports, they contribute to reducing the market share of the legacy airports as Table 5 illustrates. The impact of this competition on specific routes (such as Dublin–Brussels served by Ryanair), can be very strong, as Barrett (2004) showed. Of course, other factors contribute to the changes in market share, such as changing demographics and congestion at the legacy airport. These particular two factors cannot, however, be considered important for the examples in Table 5, as each of the cited primary airports has ample capacity to absorb the traffic at the emerging low-cost airport, and as their demographics have not changed substantially in the decade under consideration.

The point is that competition now exists between the low-cost and the legacy airports, in a way it did not when the low-cost carriers were marginal. Many legacy airports have lost their previous virtual monopolies. This fact has to motivate their management – more than they would otherwise be inclined – to build facilities that will be more competitive with low-cost airports.

More subtly, the low-cost airlines and innovative freight carriers are establishing parallel networks that bypass the traditional main airports (de Neufville, 2005). This is strikingly evident in Europe, where many low-cost carriers make a point of serving major metropolitan areas through secondary airports. Thus, the Ryanair network comprises

Table 5. Example market share drops for primary airports associated with rise of low-cost carriers

		Market share (%) in	
Metropolitan region	Primary airport	1994	2004
Boston	Logan	90	72
Brussels	Zaventam	99	90
Miami	International	69	56
San Francisco	International	68	58

Source: de Neufville Multi-Airport Systems database drawn from various reports.

London/Stansted, Barcelona/Girona, Brussels/Charleroi, Frankfurt/Hahn, Rome/Ciampino, Stockholm/Skvasta, and so on. The situation in the United States is similar as Southwest serves Boston/Providence, Dallas/Love, Houston/Hobby, Miami/Fort Lauderdale, and Washington/Baltimore.

Moreover, the low-cost carriers compete with the main airports when they fly directly from major metropolitan areas (such as London) to secondary airports, thus bypassing the hub airports that have traditionally provided connections to secondary areas. Thus when Ryanair serves Carcassonne direct from London/Stansted, it not only competes with flights that might go direct from London/Heathrow, but also those that might provide service through Paris.

Overall, we are witnessing the development of parallel air transport networks. On the one hand there are the legacy carriers, largely attached to their hub or legacy airports. On the other hand, there are the low-cost carriers, which have been promoting the definition of low-cost airports. This low-cost network is complemented in North America by a network of Fedex and UPS low-cost airports, such as Chicago/Rockford, Los Angeles/Ontario, and San Francisco/Oakland.

Business model for low-cost airports. Low-cost airlines generally aim to cut frills. They do not intend to pay for architectural showcases and gateway projects, and the associated high airport charges, it they can avoid them. According to the head of Ryanair, their top three airport requirements are: low airport charges, fast turnaround times, and single-story airport terminals (Barrett, 2004). Thus the Ryanair wing of the London/Stansted airport is a one-story structure that passengers walk to – in sharp contrast to the expensive multi-level buildings, designed by a signature architect (Sir Norman Foster), that travelers on other airlines have to access using an expensive special-purpose train.

When low-cost carriers have the opportunity to define their passenger facilities, they make them simple and sparse, with a minimum of commercial facilities. They do not use the traditional industry design standards. The terminals for Ryanair at Frankfurt/Hahn (Beck, 2007); easyJet at Manchester/Liverpool; jetBlue at Los Angeles/Long Beach, Jetstar at Melbourne/Avalon, and AirAsia at Kuala Lumpur all demonstrate this fact. At Singapore, an airport known for its excellent retail opportunities, it is remarkable that their low-cost terminal has few shops.

Low-cost airlines often apply design standards deeply different from those generally used in traditional passenger facilities, such as those of the International Air Transport Association (2004) and de Neufville and Odoni (2003). They use space more intensively, planning on higher densities of passengers per unit of area, and using shared hold rooms

instead individual gate lounges. They also process passengers quicker, with turnaround times of around 30 minutes instead of the more standard hour. For example, at Boston/Logan jetBlue manages to process about 0.5 million passengers/gate, compared to its competitor Delta which manages only about half as many. This means that jetBlue needs fewer gates for a given number of flights. The net result is that low-cost airlines often require around half the space per passenger as the legacy airlines (de Neufville, 2006).

Their approach gives the low-cost carriers a tremendous financial advantage compared to the legacy carriers that must operate out of, and consequently pay for, grandiose monuments. The airlines operating out of Terminal 5 at London/Heathrow will be carrying a substantial handicap, compared to their low-cost competitors. The cost of this building (by the signature architect Lord Richard Rogers) is already over €6.5 billion (US$9.6 billion). Its annual cost for amortization and operation will be on the order of about €20 (US$30) per passenger. This kind of burden is difficult for low-cost airlines, and they generally avoid such costs. As low-cost airlines continue to expand at the expense of the legacy carriers, so will the low-cost airports at the expense of the legacy airports.

Greater Forecast Uncertainty

The economic deregulation of the air transport industry has driven both the rise of the low-cost carriers and a significant increase in the forecast uncertainty. The collapse of limiting regulatory regimes and bi-lateral conventions has removed the bureaucratic brakes to rapid changes. The concurrent rise of the low-cost carriers, with new visions of how and where to operate airlines, has changed the nature of the business. The situation now is that:

- Changes occur quickly once the regulatory brakes are off, as de Neufville and Barber (1991) demonstrated.
- Changes in airlines can matter tremendously – when one company's business model fails, its services may not be replaced – witness the cases of TWA, US Airways, Sabena, and Swissair, with the collapse of traffic at St. Louis, Pittsburgh, Brussels and Zürich.
- Alternative service standards are appearing, so that what was designed for one airline may be incompatible with the business needs of replacements, as happened at Baltimore (de Neufville & Odoni, 2003) and more recently at Boston/Logan where the facilities built for the legacy airline Delta are not being taken up by the competitor (jetBlue) that has taken much of their traffic.

- Low-cost carriers routinely experiment with alternative, non-traditional destinations.

Airport planners thus now have to confront far greater uncertainty than ever before. Previously, they mainly worried about how fast traffic might grow, and when to time the development of facilities. Now they have to also pay attention to three key questions:

- where might the traffic grow, at main, secondary or regional airports?
- will there be abrupt and long-lasting breaks in traffic, as can occur when an airline fails? and
- what kind of facilities might future customers need? Airport developers can no longer assume that a facility can be re-branded for another airline. Low-cost carriers have repeatedly demonstrated their reluctance to use facilities designed for legacy airlines (as at Boston, Brussels, Hamburg, London/Stansted, San Francisco/International, and Zürich).

Consequences for Airport Planning, Design, and Management

The traditional paradigm of airport planning is threatened. The established pattern has been driven by long-term forecasts, based on established long-term clients, and aimed at a common appreciation and desire for high standards. These premises are no longer an obvious basis for investing and developing in airports.

Demand forecasts for any airport must be considered to be much more uncertain than before. In addition to the accustomed variability in the rates of growth due to economic cycles, we first add the market volatility associated with absence of the dampening effects of economic regulation, and further add on the great uncertainties of an industry in the midst of extensive change:

- Major airport users may disappear. As has happened extensively in North America, many legacy carriers will merge with others or go out of business. In Europe, the national airlines of Belgium and Switzerland (Sabena and Swissair) have vanished – causing great traffic decreases at Brussels and Zürich. The Dutch national airline merged with Air France. The national carrier of Brazil, Varig, has practically disappeared. Many more can be expected to vanish, with consequent impacts on their current airport bases.
- The distribution and patterns of traffic may change. Low-cost carriers may divert traffic to secondary metropolitan airports, as they have done in most of the airports listed in Table 3, or in a nation – as they have done in Portugal by building traffic at Faro and Porto.

- Different design standards may apply. The airline clientele may reject facilities provided, leaving them underutilized and possibly unprofitable, as Ryanair has done in Porto.

Airport developers thus face much greater risks of investing in the wrong place, in the wrong way, at the wrong time. They now need a planning and development process that allows them to recognize explicitly the uncertainties that threaten the planned developments and investments, and develop ways to respond easily to the many different scenarios that might develop. This is the essence of the paradigmatic shift in airport planning.

The change in paradigm has physical consequences. It is shifting the concepts about appropriate investments in airport infrastructure away from monumental airport facilities and main ports, built according to the conventional space and other standards, toward increased use of simpler facilities located at secondary airports with facilities using much less generous standards for space and expense.

What experience and practice has taught airport planners over the past half-century may no longer be fully acceptable. A new class of clients has arisen, and they are demanding and obtaining different kinds of facilities and locations. Political and business leaders concerned with airport planning and development need to think carefully and cautiously about future investments. Good airport planning, design, and management are not what they used to be.

Process for Flexible Design

The essence of a flexible design process is to put in place arrangements that enable the airport owners to respond easily and effectively to the range of scenarios that might occur. From a design perspective, flexibility consists of technical features that enable the owners to change, easily and inexpensively, the configuration of their facility to meet new needs.

Vancouver airport provides a good example of flexible design. To cope with the shifting numbers of travelers who require different processing procedures (Canadian, transborder to the United States, and other International traffic), the Vancouver terminal is basically a large open hall divided by interior glass panels into spaces that can be connected in different ways by escalators and passages. The airport can thus easily adjust to short- and long-term shifts of traffic through the building. In the short run, operators open and close doors between various sectors. In the long run, they can displace panels.

Because of the way traditional airport planning practice has focused on fixed, point forecasts of traffic, flexible designs for airports have not

been common. If you believe you know what the future requires, there is no need to plan for any adaptation to future conditions. The experience of Baltimore provides an example of how this traditional lack of recognition of uncertainty can lead to difficulties. In that case, the airport created an international terminal for US Airways based on long-term forecasts of its need. However, when the low-cost carrier Southwest drove US Airways to abandon its Baltimore hub, the airport could not transform the terminal to serve domestic passengers. The airport had to spend over US$100 million (€68 million) to create a new facility to fulfill the needs of Southwest (de Neufville & Odoni, 2003). If the airport had not relied on long-term forecasts and had instead recognized the possible scenarios, they could have avoided this loss.

Flexible designs incorporate capabilities to adjust easily to different scenarios. They create 'real options', similar to financial options (such as puts and calls) that give their owners the 'right, but not an obligation, to take an action, now or in the future.' Specifically, flexible designs involve real options 'in' projects, that is, capabilities to adjust that are due to technical elements built into the design itself (Wang & de Neufville, 2006). These require careful crafting and preparation. For example, a real option to convert a terminal from international to domestic use involves both technical foresight (such as that implemented in Vancouver) and political steps, to gain governmental and airline acceptance. In this sense, flexible designs involve 'complex options' (McConnell, 2007).

Design for flexibility is usefully compared to playing chess. The skillful practitioner will think through many scenarios, anticipate possible responses, and make moves that both deal with different threats and exploit opportunities. This is the kind of thinking involved in the new paradigm of airport planning, which is developing in response to the changes in the nature of the air transport system being brought about by the rise of low-cost airlines and the concurrent emergence of low-cost airports and airport facilities. In a nutshell, planners and investors need to adopt a flexible, evolutionary approach to the development of their airport infrastructure.

Steps of Process

A flexible design process consists of three basic elements:

- *Recognition of the range of uncertainty*. The reality of a wide variation of possible outcomes, from the least favorable to the most advantageous, is what motivates the development of plans both to mitigate downside difficulties, and to take advantage of the upside opportunities;

- *Definition of flexible design opportunities*. These enable the system owners to adjust their facilities easily to the actual future situations. Flexible design involves the ability to reconfigure the facilities to meet different technical or market developments; and
- *Analysis of the development strategies*. Identifies the strategies that could be used to exploit these design opportunities, and the selection of the initial, the 'inaugural' airport plan that provides the best starting basis for future expansions and reconfigurations.

A detailed worked-out example of this process, with supporting spreadsheets, is available on the web from de Neufville *et al*. (2006).

The flexible design process is deeply different from traditional airport planning and design (de Neufville & Odoni, 2003). The traditional process starts with the definition of the most likely forecast – and as a practical matter ignores the considerable uncertainties that lie ahead for the following decades, then defines a single Master Plan for the development of the airport facilities (and does not contemplate any substantial deviations to adapt to industry changes) and finally commits to this Master Plan, both conceptually and physically.

The traditional design process has led to many embarrassments for airport owners, where they lacked the flexibility to adapt the design to actual conditions, and thus suffered severe financial and operational difficulties, as at:

- Bangkok, where the inability to adjust to low-cost and other industry developments stalled the opening of the new airport for 2 years, thus increasing the capitalized cost of the facility by 25% or more. The author has been a consultant to the Bangkok airport project for over a decade, and has observed that the widespread explanations that attribute the situation to technical difficulties mask the deep-seated conflicts over transport policy and the airline–airport competition, and are designed to save face and avoid embarrassment, rather than portray the root causes;
- Frankfurt, where the €1 billion (US$1.5 billion) Terminal 2 is under-used because it could not be adapted to the hubbing needs of Lufthansa (for which the building had been intended);
- Kansas City, whose design likewise could not adapt to needs of its main client, TWA, which thus subsequently moved its corporate base to another city (St. Louis), thus creating huge financial difficulties for Kansas City; and
- Pittsburgh, where the design failed to account for the possibility that hubbing operations might disappear, and thus placed the airport and its owners under great financial stress when US Airways shifted its hub operations to Philadelphia.

Such failures of the traditional design motivate the use of a flexible design process that can adapt to the situations that could exist.

Recognition of uncertainty. Forecasts are 'always wrong', in that the actual level of traffic that occurs in 5, 10 or 20 years is routinely far from what is predicted, both as to the level and type of traffic. This has been extensively documented (de Neufville & Odoni, 2003). The differences between actual and forecast traffic occur because 'trend-breakers' inevitably worsen the usual swings in economic cycles. These sudden shifts in traffic patterns may be:

- Economic/Financial (airline bankruptcy, such as Sabena, Swissair, Northwest Airlines, or Air Canada);
- Industrial (airline merger, such as American and TWA, or Air France and KLM);
- Political (the opening of China to world trade and the boom of cheap tourism in Asia);
- Technical (such as the Geographic Positioning Systems (GPS) that reduce the cost of air traffic control and ground radars); and
- Other, as with terrorism, war, and the price of fuel.

The major long-term reconfiguration of the air transport industry, associated with the development of low-cost carriers, is now added to this standard list of classes of uncertainties. As many industry observers stress, the future of low-cost carriers is uncertain (Dennis, 2004; Williams, 2007). Many ventures have disappeared, such as Peoples Express, Canada 3000, and Buzz. Investors and planners need to confront and deal proactively with these risks.

In the deregulated era of low-cost airlines, leaders also need to recognize that any airport investment may be strongly affected by competitive forces far beyond their control. They should now, as never before, anticipate the possibility of large and sudden changes in traffic, as when a low-cost carrier decides to develop a market and triples traffic in a few years (the 'Southwest effect', widely experienced in the United States) or when a legacy carrier closes a hub and traffic drops dramatically in a year (as happened in Brussels with Sabena, in Zürich with Swissair, St. Louis with TWA and American, and in Pittsburgh with US Airways). Airports now need to be considered as part of a system. Any airport planning exercise that focuses only on the local situation, and fails to confront the role of the airport in its larger context, must be considered to be deficient. As Graham (2004) indicates, airport owners and managers need to consider and develop strategies to gain and maintain competitive advantage.

Definition of flexible design opportunities. Managers of airport systems need to be careful about committing to single major projects conceived along traditional lines. Given the great uncertainty about the future of air transport, they could easily find themselves spending billions on projects that turn out to have been misguided. Thus, Thailand decided to build Bangkok/Suvarnabhumi airport without thinking through the role of Bangkok in the market for low-cost tourism, and the needs of low-cost carriers. Yet now the low-fare airlines want to stay at the old (but inexpensive and convenient) Bangkok/Don Muang, and the international carriers serving that market need to be near their partners. Thus, they have been reluctant to move. This conflict contributed to the delayed opening of the new airport, and continues to be a major political and economic embarrassment to the owners. It is not an experience anyone wants to repeat.

A flexible approach to the development of major infrastructure is needed in these circumstances. Flexible designs can take many forms. For example, political leaders and investors can:

- commit to a site for a major airport, think through how they could implement it, and yet only decide to invest in a small 'Inaugural airport'. Such a facility would establish the political and technical reality of the airport, without committing it to be a supplemental or replacement hub, or a secondary or low-cost facility.
- simultaneously create both traditional and low-cost facilities at a new airport, to appeal to the range of possible customers. Doing this is very different – in concept and in cost – from a commitment to a traditional design around a single architectural statement (as originally at Bangkok/Suvarnabhumi, Kansas/City, Kuala Lumpur, London/Stansted, Paris/de Gaulle and elsewhere).
- select an airport layout that easily enables different futures. They would learn from London/Stansted and Munich Terminal 1, whose designs locked in on configurations that were both difficult to alter and ill-suited to current traffic. They would not commit to a development that could not easily morph into the range of configurations that future traffic might need.
- insist that architects develop flexible spaces that can easily accommodate both short- and long-term fluctuations in traffic, as they did attractively and effectively at Vancouver.

Leaders should also anticipate the possibility that low-cost carriers and others will stimulate the demand for distributed airport infrastructure consisting of many smaller airports in contrast to one or more national facilities. They should thus manage the development of their portfolio of airports, retaining the option to develop facilities according to the

type of traffic that actually emerges. Investments in smaller airports that have not yet fully established themselves can be risky – but investments in large airports have also proven themselves to be risky, and involve far greater amounts of capital. Efforts should, for example, go into establishing and preserving sites and traffic corridors, the preparation of low-cost passenger facilities, and investments in technical support facilities for air traffic control, refueling, etc. Compared to the billions required to establish a major new hub, such investments are cheap, and might provide good provision against future needs. For example, in Portugal the adaptation of the Beja military field into a possible civilian airport is projected to cost about 1% of the anticipated totally new airport for Lisbon. This might be regarded as cheap insurance.

Overall, a key part of the flexible design process lies in the identification of design solutions that minimize irrevocable commitments that may be premature, and that simultaneously provide easy pathways to the development of the range of facilities that might actually be needed in the future.

Analysis of development strategies. The final part of the design for flexibility is to think through how alternative initial designs could adapt to future circumstances. Managers need to consider what they could do, how the future might turn out, and how they might correspondingly respond. This process is conceptually similar to how chess or bridge players think through their moves.

Professionally, this process plays on two major planes: the physical and the financial. The airport owners and managers need to know that they will be able to accommodate the buildings, aircraft, access modes and other facilities in a reasonable sequence. Equally, they need to know the financial consequences in terms of costs and revenues.

Standard analytic tools can help designers think through the possible combinations of possible outcomes and responses. Most are computerized and can be quickly learned and used. Two deserve particular attention:

- Decision Analysis, which is a process for systematically organizing the sequences of possible design decisions, the range of possible developments, and subsequent further decisions. This process was central to the original strategy for the development of Sydney's airport facilities as it entered privatization (de Neufville, 1991).
- Simulation of spreadsheet *pro forma* financial statements, a well-used process for developing useful measures such as the Expected Net Present Value (ENPV), the Value at Risk and Gain, the Minimum and Maximum results, the Initial Capital Expenditures, and Return on Investment (Hassan *et al.*, 2005).

The outcome of the process is a decision concerning the initial development, together with a strategy of how the facility will be further developed as circumstances unfold and the nature of the air transportation market becomes clear. Conceptually, this is similar to what a good chess player has in mind when making each move.

Portugal as an Example

The on-going situation in Portugal illustrates the issues discussed. The push to develop a new major airport for the capital, accelerating since 2005, gives local color to the planning, policy, and investment questions indicated above.

Background. Portugal has traditionally been served by national airlines, TAP and Portugalia (merged in 2006), and international airlines focused on the main hub at Lisbon/Portela. This facility, situated close to central Lisbon with flight paths directly over densely inhabited areas, is clearly limited in its potential expansion. Since around 1990, there has correspondingly been pressure to define a site for a major new airport. In the late 1990s, the Government selected the Ota site and commissioned the Aéroports de Paris to prepare a Master Plan for the development of this old military air base. Their conventional result featured a multi-level terminal building with air bridges to all aircraft according to the highest traditional standards. It had no obvious provision for low-cost carriers or flexibility in the overall configuration or the interior arrangements, and no strategy for alternative developments according to how air transport traffic might evolve in Portugal or Europe. The preliminary cost estimates of this fixed plan exceed €3 billion (US$4.4.billion) (ACI World and Momberger Airport Information, 2005).

In January 2007, the Government of Portugal reaffirmed its intention of developing a second airport (AFX News, 2007). It also confirmed its plan to privatize the national airport company, Aeroportos de Portugal (ANA), and to require the successful consortium to develop the new airport.

Recognition of uncertainty. Since the plans for the €3 billion airport for Lisbon emerged a decade ago, the air transport situation has changed dramatically – both in Europe and Portugal. The low-cost airlines have developed strongly. The mid-size national airlines (such as Olympic, Sabena, Swissair, and TAP, the Portuguese flag airline) have struggled financially and required substantial subsidies to stay alive (European Commission 2000). Their future is unclear. Experience in North America, Brazil, and Europe indicates that some of them may disappear through merger or bankruptcy.

Meanwhile, the low-cost carriers have become important participants in Portuguese air transport. For example, easyJet is competing vigorously with TAP at its hub in Lisbon and Ryanair is undermining the position of TAP at Porto. Both airlines provide frequent direct service to the popular Portuguese tourist destination of Faro in the Algarve – which TAP mostly serves with indirect flights via Lisbon. The outcome of this competitive struggle is not clear. From experience elsewhere, it is possible that the low-cost carriers may come to dominate intra-European air traffic for Portugal.

The low-cost airlines have not developed a secondary low-cost airport around Lisbon – in any case there have been no airfield opportunities to do so. However, this might change if local military airfields were opened for civilian use, and as additional airport capacity is inaugurated in the Lisbon area. In this connection, the Portuguese Government announced in early 2007 that it was promoting the use of the Beja military base for commercial purposes (Câmara de Comercio Luso-Britânica [British-Portuguese Chamber of Commerce], 2007). As this site is around 200 km from Lisbon, it does not appear to offer realistic prospects for a second airport for Lisbon. Other opportunities exist, however.

In any case, the low-cost airlines are demonstrating their desire and need for low-cost airport facilities. Thus at the Porto airport, which features elegant facilities up to the best standards, Ryanair avoids the air bridges and has its passengers walk to their flights. Its business model demands inexpensive efficient service, and it would look for similar facilities at a new airport.

Prospective investors in the new airport thus face considerable risk. While air traffic to Portugal has been growing steadily so there appears to be an evident need for additional airport facilities, there is considerable uncertainly about the future of the airline industry for Portugal. Thus:

- The national airline, TAP, which would appear to be the obvious main tenant of a new airport, is in a difficult financial situation, and may not be able to afford expensive new facilities when they are provided. Toronto faced with a similar situation when its national carrier, Air Canada, went bankrupt at the time of the move into the new elegant facilities conceived by the signature architect Moshe Safdie.
- The rapidly rising low-cost carriers have demonstrated their reluctance to serve expensive facilities, either avoiding the area entirely, or insisting on using low-cost facilities at the airport, as Ryanair does at Porto.

- The future of the low-cost airlines is volatile, not only in terms of their overall health, but most particularly in terms of what areas they will choose to serve. They have no intrinsic loyalty to Portugal, and can easily redeploy their services if regulations or economic conditions become unfavorable. They might also bankrupt TAP and become the dominant European carriers for the country, as Southwest is for the United States.
- The long-term growth in air traffic is subject to many unknowns such as fuel prices, carbon taxes, general economic conditions, and the effect of low-cost airlines.

In short, future traffic and revenues from a major new airport are highly uncertain.

For the sake of specificity, the example analysis uses numbers to illustrate the process for analyzing a flexible design. These numbers are entirely speculative, and are not intended as a realistic investigation. Thus the analysis assumes

- a 50:50 possibility that low-cost carriers become dominant for Portugal over the coming decade. This scenario would parallel the situation that has occurred in the United States, Canada, and Brazil, where Southwest, Westjet, and GOL have become major domestic transporters;
- three alternate scenarios for traffic growth over the following decade, that it could be High (7%/year), Medium (4%/year) or Low (2%/year). Roughly, this represents the spread from traffic doubling every decade, to merely about 50% growth in 20 years. This range approximates long-term trends at airports worldwide comparable to Lisbon.

Definition of flexible design opportunities. Flexible designs could be created for the new airport along many of the lines identified in the previous corresponding section. The case example focuses on three ways to design the passenger terminal buildings, the standard inflexible Master Plan and two alternatives. Of course, many more configurations could be investigated, indeed should be before investing €1 billion (US$1.5 billion) or more in a modern new terminal.

A conventional Master Plan design, as suggested by the Aéroports de Paris, involves a high-standard structure built along traditional lines. It would feature multiple levels, ample spaces, superior finishes, and loading bridges for all aircraft – and would cost in the range of €1.2 billion (US$1.8 billion). As indicated by experience in Toronto, London/Stansted and elsewhere, such a building would not easily serve low-cost carriers. It may be considered an inflexible alternative.

At the other end of the spectrum, a low-cost passenger building could be built, along the lines that are now being implemented at Frankfurt/Hahn. It would be a one-level building with tight spaces, adequate finishes and no loading bridges. It would cost about 10 to 20% of the standard structure; say a nominal €200 million (US$300 million). In the short run, it would not easily be organized to serve traditional airlines. In the longer run, however, conventional facilities could be implemented. This may also be considered an inflexible design.

As a compromise, one could design a half-sized standard building supplemented by low-cost facilities and featuring bus services to remotely parked aircraft. This solution could fulfill the immediate needs of both standard and low-cost airlines. It would also be suitable, with proper disposition of the first phase, for easy expansion emphasizing either traditional or low-cost carriers, depending on how traffic evolved. The cost of this flexible facility might be €700 million (US$1036 million).

Analysis of development strategies. A Decision Analysis is an appropriate first-cut way to consider the best strategy for a situation in which there are several distinct uncertainties. Numerous textbooks describe the mechanics of Decision Analysis, for example, de Neufville (1990).

The illustrative analysis is inspired by Chambers (2007). His thesis considers two stages. The first covers the short-term future during the expansion of the low-cost carriers, and second the long-term growth of air transport in Portugal. The two-stage analysis is complex, because it considers the many ways the airport could be developed for each of the outcomes of the first phase. To illustrate the approach, this case presents only a first stage analysis.

The analysis requires estimates of the outcomes from the decisions, for example, in terms of ENPV of the investments. A *pro forma* spreadsheet showing traffic, revenues, and expenses conveniently develops these numbers. The case uses the data shown in Table 6. Given three possible configurations and two possible developments (in terms of which airlines dominate after the next 10 years), there are six possible outcomes.

The following justifies the relative numbers used to calculate the Net Present Values (NPV):

- If the standard expensive terminal were built, and if the traditional airlines continue to dominate, it is assumed that the revenues after 10 years will recover the cost of the building (NPV = 1200). However, if low-cost carriers dominate and do not choose to use the expensive building, the revenues are much lower, as experienced in past years by Kansas City, Kuala Lumpur, Manila, Osaka/Kansai, and Washington/Dulles (NPV = 300).

Table 6. Decision Analysis for hypothetical first stage of airport development

	Terminal type	Dominant airlines	Revenues (NPV €M)	Expected value (EV €M)
Build which terminal?	**Standard**	Traditional	1200	
	Cost = 1200 €M			−450
		Low-cost	300	
	All low-cost	Traditional	150	
	Cost = 200 €M			−25
		Low-cost	300	
	Flexible mixed	Traditional	1000	
	Cost = 700 €M			50
		Low-cost	500	

Note: Assumes 50:50 probability of whether traditional or low-cost airlines dominate at end of period. Revenues assumed for example purposes and do not represent any specific design.

- If the all low-cost terminal were implemented, it would recover its costs if the low-cost carriers dominate (NPV = 300). Conversely, it would not make much if they did not (NPV = 150). However, its overall losses could not be great, as its costs are low.
- If the flexible terminal is designed, it would perform adequately in either case. It would not do as well as the standard design if the traditional airlines dominate (NPV = 1000), but would perform better than the low-cost terminal even if they dominate, since it would provide good service to the traditional airlines (NPV = 500).

These data are illustrative, not based on detailed analysis of the situation or of specific designs.

The Decision Analysis calculates the average of each of the possible choices, and recommends the design with the higher expected value (EV). In this case, the preferred choice would be the flexible design (EV = 50), as Table 6 indicates. Note also that the flexible design, by providing 'insurance' by being adaptable to the circumstances that develop, provides superior performance across many important criteria (Hassan *et al.*, 2005). The flexible design reduces both the 'value at risk', that is, the maximum loss, and the original investment or 'CAPEX' (Table 7).

This recommendation of a flexible solution is fairly standard, since flexible designs have the advantage of performing reasonably well over a range of situations – in contrast to inflexible designs that work well for the situations for which they were designed, but poorly when other scenarios prevail. As a general rule, a Decision Analysis recognizes the

Table 7. Comparison of hypothetical flexible and standard designs

	Design choice		
Criterion	Standard	Flexible mixed	Which better?
Expected value	−450	50	Flexible
Capital invested	1200	700	Flexible
Maximum loss	−900	−200	Flexible
Range of risk	900	500	Flexible

merit of an adaptable strategy of development that proceeds according to what the future brings – instead of a Master Plan that designs for a fixed concept of the future and does not allow for alternative possibilities. Walker *et al.* (2001) provide an extended general description of adaptive policies.

The best strategy over the two stages would depend on both the future structure of the airline industry (does TAP flourish or not?) but also on the rate of growth. The overall recommendation strategy would then be of the form:

- If TAP flourishes and traffic growth is high, build high-standard extensions to the flexible terminal as needed. However, if growth is low, only invest marginally.
- If the low-cost carriers dominate, develop the site to their requirements.

Note that the strategy recommended involves the use of designs that easily accommodate alternative developments. A properly flexible approach requires more than staging a plan over time. If an inflexible design is chosen at the beginning, it is difficult – if not financially impossible – to 'stage' into a completely different arrangement. The history of Kansas City and Munich Terminal 1 provide two of many examples of this. Both facilities were designed around the 'gate arrival concept' suitable for origin–destination traffic. These proved inappropriate for the hubbing traffic that developed. As these designs could not be re-configured to what was needed, the airports suffered. Kansas City lost its prime tenant, TWA. Munich had to commission a brand new facility to serve the traffic of their prime tenant, Lufthansa.

Conclusions

The paradigm of airport planning and design is changing. It is shifting from the traditional pattern driven by long-term point forecasts, high

standards, and established clients; to one that recognizes great uncertainty in forecasts, a broad range of standards, and the potential for a rapidly changing client base. This is an extended consequence of economic deregulation of air transport, and of the rise of low-cost airlines.

Low-cost airlines are becoming significant drivers of airport planning. Their requirements differ from those of the 'legacy' carriers. They focus on cost and handle passengers differently. Now that they are sizeable participants in the air transport industry, they influence airport design. They are central to the proliferation of secondary airports and are propelling the development of cheaper airport terminals. They are thus catalyzing 'low-cost airports' for low-cost carriers around the 'legacy main airports' built to serve the 'legacy airlines'. Consistent with economic theory, the competition between the legacy and low-cost airlines is extending to their major factors of production, that is, the airports and airport facilities.

The uncertain outcome of this dynamic poses substantial strategic issues. Airport planners, investors, and managers need to develop strategies that will enable them to avoid over commitments that are financially risky, and position them to take advantage of opportunities as they develop. They thus need to adopt a flexible approach to airport analysis and design.

The proposed flexible design strategy deals with this reality. It differs significantly from traditional airport Master Planning. Its core element is to build flexibility into the design, to enable airport owners to adjust facilities easily to changes in the type, needs, and location of traffic. The case of Portugal illustrates the current risks in airport development, and suggests how a flexible design process could develop a strategy that manages uncertainties and maximizes Expected Value.

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