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**MATERIAL AVAILABILITY AND THE SUPPLY CHAIN:**  
**RISKS, EFFECTS, AND RESPONSES**

Paper Prepared for Special Issue of *Journal of Transportation Planning and Technology*  
Warren Walker and Vincent Marchau, editors

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**LOW-COST AIRPORTS FOR LOW-COST AIRLINES:  
FLEXIBLE DESIGN TO MANAGE THE RISKS**

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**ABSTRACT**

The paradigm of airport planning and design is changing fundamentally. Low-cost airlines have become significant drivers of airport planning, along with aircraft size and other technical factors. They have different requirements than the “legacy” carriers. They focus on cost and on alternative ways to handle passengers. Now being sizeable participants in the air transport industry, they are influencing airport design. They are central to the proliferation of secondary airports and metropolitan multi-airport systems. They are catalyzing the development of cheaper airport terminals configured internally much differently than traditional designs. These factors lead to the creation of “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. This competitive reality creates great uncertainty and poses substantial strategic issues for airport and airline managers and planners.

The paradigm shift introduces great risks into practice. The paper proposes a flexible design strategy to deal with such uncertainties. This is significantly different from traditional airport master planning. The core element is to build “real options” into the design, which allow the airport owners to match the development to the way the traffic demands unfold in the decades ahead. A review of developments in Portugal illustrates the current risks in airport development, and suggests how airport owners and investors could apply flexible design process to develop a strategy that would manage these uncertainties to maximize expected value.

Keywords: Airport Planning; Low Cost Carriers; Multi-Airport Systems; Airport Terminals; Technology Choice; Airport Competition, Risk Management, Flexible Design, Risk Management, Portugal

**LOW-COST AIRPORTS FOR LOW-COST AIRLINES:  
FLEXIBLE DESIGN TO MANAGE THE RISKS**

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This paper has two elements. It first makes the case that for a paradigm shift in airport planning, from a focus on traditional airlines to the situation that demands a strong consideration of the needs and practices of low-cost airlines. This paradigm shift creates great uncertainty for investments in airport infrastructure. Thus the paper secondly proposes a process of flexible design for dealing with these risks. It illustrates this approach through a discussion of the prospective aviation future for Portugal.

## **1 ARGUMENT FOR PARADIGM SHIFT**

This paper presents and defends the hypothesis that the ascendancy of low-cost airlines entails an increased importance and expansion of the distributed network of low-cost airports, together with the increase in metropolitan multi-airport systems. The proposition is simple, and might appear obvious, but it represents a paradigm shift in the concept of airport development that established airport organizations and professionals are finding difficult to accept. This thesis runs counter to the dominant trend of the past generation that has committed to massive, multi-billion Euro investments in centralized hub airports (de Neufville, 2006).

This hypothesis involves a range of testable propositions concerning the timing, location, and business proposition of low-cost airports. Specifically, the basic proposition leads to the corollaries 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 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 distributed destinations that by-pass the use of a centralized metropolitan hub.

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- 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.

The extensive worldwide data available so far support these points.

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

- regional and national governments should develop and promote airport infrastructure, and
- private investors should allocate their investments in airport facilities.

In general, the implication is that policy-makers and investors should focus more attention on the development of secondary metropolitan airports and the distributed network of low-cost airports, and correspondingly be careful about the long-term future of existing or future multi-billion Euro facilities constructed along traditional lines. This thought runs counter to the main current of the existing discussions, obviously dominated by the existing large airports, their spokesmen, and associated professionals who promote the development of expensive main airports. As discussed in detail later in the paper, a number of subtleties are associated with this theme.

### **HYPOTHESIS IN DETAIL**

Background: Economics teaches us that oligopolies enable their members to extract extraordinary profits from consumers. Further, organizational studies help us understand that the stakeholders in the enterprise tend to share the oligopoly benefits. Conversely, economics teaches us that lower-cost producers compete away and eventually eliminate oligopolies and oligopoly profits. It also gives us to understand that the pressure to lower costs on the principal competitors is transmitted to the providers of all their factors of production. Thus, competition among major participants in a market leads to competition among their suppliers. These general concepts lead to the conclusion that the 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 the economic teachings outlined in the previous paragraph. In detail:

1. For the first half century of the airline industry, governments protected it economically in a variety of ways according to the country and context. These regulatory regimes created barriers to entry, both into the business and into particular markets. Various degrees of

- cartels existed, to a degree not encountered in other economic enterprises in the 20<sup>th</sup> century. 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. In a different way but to the same effect, the pooling arrangements between Spain and other countries such as France not only limited capacity in their markets, but also divided the profits between the two 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 in comparison to other workers of comparable skills. Salary levels were high, hours of work relatively short, and retirement benefits generous compared to other industries – as the subsequent history demonstrates clearly.
  3. Correspondingly, airports serving the main airlines and national hubs obtained access to extraordinary amounts of 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, Paris/de Gaulle, San Francisco/International, and Shanghai/Pudong illustrate this pattern. London/Heathrow Terminal 5 costing around 6.5 Billion Euros may represent the ultimate in this kind of lavish 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 were faced with the alternative of losing the airline and their jobs, or lowering their pay packages. Thus wages at North American legacy carriers have dropped by a third or more in real terms, working hours have been extended, and jobs have been enlarged.<sup>1</sup>
  6. Similarly, legacy airlines have been cutting back on airport expenses by not moving into facilities built for them (as Swissair reneged on using the new satellite at Zürich, and Lufthansa did at Frankfurt/Main); by cutting back substantially on the design of facilities (as American did at New York/Kennedy (DMJM 2005)), or simply by squeezing more flights into an existing number of gates.

The Hypothesis in Detail: The hypothesis is that the ascendancy of low-cost airlines entails an increased importance and expansion of the distributed network of low-cost airports. Specifically, as the low-cost airlines come to represent a sizeable fraction of the market, such as 1/3 or more:

- They will cause the creation or expansion of individual low-cost airports, both in the major metropolitan areas and throughout the regions;
- These airports will compete with the traditional major – “legacy” airports, both locally in metropolitan areas and through a network of services focused on and connecting these facilities;
- In contrast with the traditional airports, these low-cost airports will be characterized by an absence of expensive buildings, a focus on efficiency, and sparse commercial facilities.

The first thought is that the low-cost airlines catalyze the development of low-cost airports. That is, because the low-cost airlines are focused on cost competitiveness, they deliberately seek out and in effect create opportunities for low-cost airports. This does not imply that they either build the airports or invest heavily in them. It means that they take advantage of the availability of the large number of existing under-used, and often not used, runways left over from an earlier technological era or from obsolete military needs. The low-cost airlines then come to terms with the local authorities in mutually beneficial arrangements whereby 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. This has often proven to be a win-win arrangement for both parties. Indeed, it has been the pattern for airport development for the last century: national governments and local communities have provided capital for airport facilities at favorable interest rates or fiscal conditions.

Secondly, low-cost airports compete with major airports. They do this in three major ways:

1. Most obviously, as secondary airports in a metropolitan multi-airport system, they provide alternatives to the major hubs. In this immediate sense, the low-cost airports may be more convenient to some users (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 by-pass these hubs. Thus Londoners interested in going to the South of Spain can go on Ryanair directly to Jerez, and avoid passing through Madrid as they would ordinarily have 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. Perhaps most deeply, the low-cost airlines and the low-cost 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 flies between 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 profitability through operational efficiency and minimal frills:

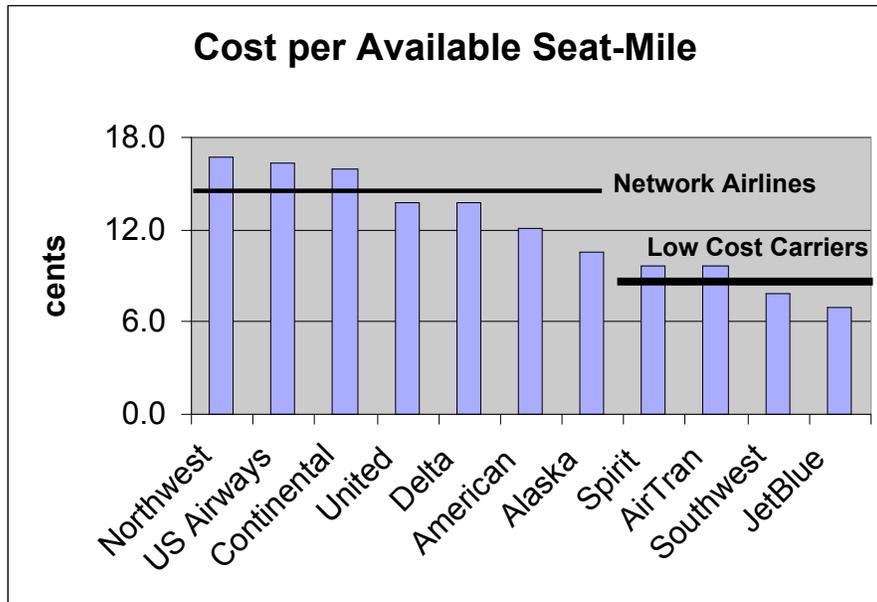
1. Most obviously, they avoid grandiose buildings by signature architects and others. They favor simple designs that, as one architectural critic put it, may “have the charm of a high school gymnasium”. The comparison at Singapore between its new Terminal 3 and the low-cost terminal it built around the corner illustrates this point. The low-cost terminal is a cinder-block and metal truss arrangement, built at about 1/10<sup>th</sup> the cost per passenger of capacity as the resplendent Terminal 3 opened concurrently in 2006.<sup>2</sup>
2. The interior spaces of low-cost airport buildings will reflect the performance standards of the low-cost airlines. They will have lower service levels in terms of space per person at any time, and overall higher annual capacity per square meter of space, associated with lower dwell times of passengers due to fast turn-arounds of the aircraft. They will also emphasize common hold rooms to minimize the overall space allocated to this function.
3. Finally, even though retail activities can be important sources of revenue for low-cost airports, as Francis et al (2003) indicate, they will not create large amounts of expensive commercial space. Building and operating commercial space on airports can be particularly expensive. 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 4.3 billion (around €6.5 billion or US\$ 8.5 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 will 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) have high-lighted, low-cost airlines come in a variety of forms: 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” here centers on their actual costs of production, for example for each seat-mile.<sup>3</sup>

Current data in the United States appear to define low-cost airlines reasonably clearly. As Table 1 shows, there continues to be a division between the legacy airlines that have seat-mile costs in the range of 15 cents US, and the others whose costs are about 60% as large. This kind of data conveniently demarcates the low-cost airlines. Comparable data on other putative low-cost airlines are not available. However, from industry and other sources it is reasonably clear that easyJet, Ryanair, GOL, Air Asia, Westjet and a range of others can confidently be placed in the low-cost category.



Source: US FAA, Bureau of Transportation Statistics, 2005

**Figure 1: Comparison of Airline Costs in the United States in 2005**

In thinking about this issue, we must carefully recognize that an airline that offers low fares is not necessarily a low-cost airline in the sense used in this paper. From the perspective of the customer, low price = low cost. However, from the perspective of an economic analysis, there is

a big difference between low-cost and high-cost producers, as Figure 1 illustrates. 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 can remember that the low cost airlines are newcomers compared to the legacy carriers, many of which have proudly commemorated their 75<sup>th</sup> anniversaries. From our travels through leading airports, we can remember 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 and Winston, 2005).

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 company also went bankrupt. In Europe, Ryanair and easyJet have grown rapidly and rank among the strongest passenger airlines in 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, 2007). In Asia finally, AirAsia, Lion Air, and Jetstar – each new since 2001– already carried 6% of that traffic by 2004 (IATA, 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. Contrary to possible appearances that Fedex is a trucking company, it has more major jet aircraft than Lufthansa, British Airways or Air France, and UPS is in the same league (IATA, 2005). Fedex and UPS have seized the lion's share of the market for profitable air cargo. Most importantly, these innovative carriers preferentially 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" is the investors' valuation of a company. It equals the product of the number of shares in the company times the market price per share. It reflects the

financial power of a company, taking into account both its current situation and future prospects. Table 1 thus shows that the financial power of the low-cost carriers is comparable to that of the legacy carriers. Ryanair for example has more financial power than British Airways. Southwest has twice the value of the next largest US carriers, American and United.

**Table 1: Market Capitalizations of Leading Airlines (Billions of US \$) as of January 2, 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	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

Development of Low-Cost Airports: The record is clear that the low-cost airlines have been major drivers of the development of low-cost airports. Ryanair has prominently been the impetus behind the development of Barcelona/Girona, Brussels/Charleroi, Frankfurt/Hahn, London/Stansted and others. Likewise, easyJet has led the business development of Manchester/Liverpool and the growth of 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 has created Melbourne/Avalon from virtually nothing. Table 2 provides details. 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 these are a feature of many smaller areas – such as Budapest, Oslo, Stockholm and other metropolitan regions.

**Table 2: Low-cost Carriers Preferentially Serve Secondary Airports in a Metropolitan Region.**

Metropolitan Region	Secondary Airport	Low-cost Airline
Barcelona	Girona	Ryanair
Boston	Providence	Southwest
Boston	Manchester, NH	Southwest
Brussels	Charleroi	Ryanair
Budapest	Balaton	Ryanair
Copenhagen	Malmo, Sweden	Ryanair
Dallas/Fort Worth	Love	Southwest
Frankfurt	Hahn	Ryanair
Glasgow	Prestwick	Ryanair
Hamburg	Lübeck	Ryanair
Houston/Galveston	Hobby	Southwest
London	Stansted	Ryanair
London	Luton	easyJet
Los Angeles	Long Beach	jetBlue
Manchester (UK)	Liverpool	easyJet
Manila	Clark	Air Asia
Melbourne (Australia)	Avalon	Jetstar
Miami	Fort Lauderdale	Southwest
Milan	Orio al Serio	Ryanair
New York	Islip	Southwest
Orlando	Sanford	Allegiant
Oslo	Torp	Ryanair
Paris	Beauvais	Ryanair
Rome	Ciampino	easyJet, Ryanair
San Francisco	Oakland	Southwest
Stockholm	Skvasta	Ryanair
Vancouver	Abbotsford	Westjet
Venice	Treviso	Ryanair

Source: de Neufville Multi-Airport Systems data base

It is worth noting that the cost of developing low-cost airports has been 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 cost several billions of dollars, euros or pounds. Low-cost airports have almost been free, due to the fact that obsolete or abandoned military and other airfields are plentiful. These have provided the runways and basic facilities for almost all the airports listed in Table 2. In any case, regional authorities have been glad to supply the modest supplemental facilities needed for passenger services, in exchange for the jobs created by the

low-cost airlines and the passengers they bring to the locality. And the possibilities are far from exhausted. Portugal provides a case in point: It has a substantial military field at Beja, which the central government and local authorities apparently wish to convert to a low-cost airport.

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 3 indicates, and Warnock-Smith and Potter (2005) have documented. This lack of congestion, together with work rules that permit fast turn-around times at the gate, enables 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 promote secondary airports because they are generally integral to their efficiency.

**Table 3: Examples of Secondary Airports in a Metropolitan Area that incur significantly less Aircraft Delays**

<b>Primary Airport in Metropolitan Region</b>	<b>Secondary Airports</b>	<b>% of Flights with Delays &gt; 15 min.</b>
Boston/Logan		27
	Manchester, NH	19
	Providence, RI	18
San Francisco/Internatl		27
	Oakland	19
	San Jose	18

Source: US FAA, Bureau of Transportation Statistics (2006)

**Table 4: Example Market Share Drops for Primary Airports Associated with Rise of Low-Cost Carriers**

<b>Metropolitan Region</b>	<b>Primary Airport</b>	<b>Market Share (%) in</b>	
		1994	2004
Boston	Logan	90	72
Brussels	Zaventam	99	90
London (UK)	Heathrow	65	53
Miami	International	69	56
Rome	Fiumicino	99	91
San Francisco	International	68	58

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

Competition with Hub Airports: Most obviously, 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 reduce the market share of these legacy airports. Table 4 illustrates this obvious point. The impact of this competition on the specific routes served by low-cost carriers can be much stronger (such as Dublin-Brussels served by Ryanair), as Barrett (2004) showed.

More subtly, the low-cost airlines and innovative freight carriers are establishing parallel networks that by-pass the traditional main airports. (de Neufville, 2005) This is strikingly evident in Europe, where both Ryanair and easyJet make a point of serving major metropolitan areas through secondary airports. Thus the Ryanair network comprises 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, 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, 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 has been complemented in North America by a network of Fedex and UPS low-cost, secondary airports such as Chicago/Rockford, Los Angeles/Ontario, and San Francisco/Oakland.

Business Model for Low-cost Airports: The business model of the low-cost airlines generally aims to cut frills. Low-cost airlines simply do not intend to pay for architectural showcases and gateway projects, and the associated high airport charges, to the extent that they can avoid them. According to an interview with the head of Ryanair, their top three airport requirements are: low airport charges, fast turn-around times, and single-story airport terminals (Barrett, 2004). Thus the Ryanair wing of the London/Stansted airport is a one-storey 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 a special-purpose train.

When the low-cost carriers have the opportunity to define the passenger facilities they are simple and sparse, with a minimum of commercial facilities. This is thus the pattern, for example, at the Ryanair terminal at Frankfurt/Hahn; the easyJet facility at Manchester/Liverpool; the jetBlue terminal at Los Angeles/Long Beach, the Jetstar sheds at Melbourne/Avalon, and the Air Asia low-cost terminal at Kuala Lumpur. At Singapore, an airport known for its excellent shopping opportunities, it is remarkable that the design of the low-cost terminal has essentially no shops.

Specifically, the low-cost airlines apply design standards that can be deeply different from those that have been and are generally applied to traditional passenger facilities, such as those of the International Air Transport Association (IATA, 2004 and de Neufville and Odoni, 2003). They use space more intensively, by planning on higher densities of passengers per unit of area, and by using shared hold rooms instead individual gate lounges. Additionally, they process passengers more quickly, with turn-around times of around 30 minutes instead of the more standard hour, which means that they need fewer gate positions for a given number of daily flights. The net result is that low-cost airlines often require around half the space per passenger as the legacy airlines (de Neufville, 2006).

This 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. In effect, the cost of this grandiose building (by the signature architect Lord Richard Rogers) is already over £4.2 billion (US\$ 8 billion, € 6.5 billion). Its annual cost for amortization and operation will be on the order of £10 to 15 (about US\$ 25 or € 20) per passenger. This kind of burden is one that low-cost airlines will not tolerate, and such expenses are avoided wherever possible by going to the low-cost airports. 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.

### **CONCLUSION ABOUT PARADIGM SHIFT**

The expansion of low-cost airlines and airports has significant implications for public and private investors in airports. At the most basic level, the lesson is that the air transport industry is in the midst of a paradigm shift, and that previous assumptions and conventional wisdom should be questioned. The increasingly important role of low-cost airlines is reshaping not only the airline industry, but concepts about appropriate investments in airport infrastructure. What experience has taught us over the past 30 years may no longer fully apply. 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 is not what it used to be.

## 2 FLEXIBLE DESIGN PROCESS

The reality of possible fundamental changes in the nature of the air transport system, and consequently of its infrastructure requirements, has specific implications for where and how public and private leaders should plan airport investments. These concern the:

- Increased uncertainty and thus risk in the outcome of investments;
- Recognition that infrastructure investments are part of a system, and need to be coherent with how the system will eventually evolve – in short, a region should invest low-cost facilities to the extent and when these will be suitable;
- Need for caution before focusing funds on a single course of action, and most especially on a single massive airport project built according to traditional specifications for legacy airlines; and
- Complementarily, the need to provide the basis for a distributed network of airports in the region and nation.

In a nutshell, planners and investors need to adopt a flexible, evolutionary approach to the development of their airport infrastructure system.

### STEPS OF PROCESS

A flexible design process consists of three basic elements<sup>4</sup>, the:

- 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 get out of the downside bad situations, and to take advantage of the upside good opportunities.
- Definition of flexible design opportunities: these will enable the system owners to adjust their designs easily to the situations as they actually will evolve. These may involve staging of development, so that the right facilities can be created for the prevailing circumstances; or the ability to reconfigure the facilities easily, to meet different technical or market developments.
- Analysis of the development strategies: identifies the steps could be used to exploit these design opportunities, and the selection of the initial, the “inaugural” airport plan that will provide 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 process for defining the best flexible design strategy is similar to that of playing chess. The good player recognizes that developments on the board are not known, thinks ahead through various moves and their possible consequences, and chooses an individual move on the grounds that it will provide the best basis for continued successful development.

The flexible design process is deeply different from traditional airport planning and design (de Neufville and 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;
- Defines a single Master Plan for the development of the airport facilities – and does not contemplate any substantial changes to adapt to industry changes; and
- 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;
- Frankfurt, where the billion Euro terminal 2 is largely unused because it could not be adopted to hubbing needs of Lufthansa and the Star Alliance;
- Kansas City, whose design likewise could not adapt to hubbing needs of its main client, TWA, that subsequently moved its base to another city entirely, thus creating huge financial difficulties for the airport owner; and
- Pittsburgh, where the designers 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 Air shifted its hub operations to Philadelphia.

This track record motivates 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. This has been extensively documented (see for example, de Neufville and Odoni, 2003). The differences between actual and forecast traffic occurs because a range of “trend-breakers” inevitably worsen the usual swings in economic cycles. These sudden shifts in traffic patterns may be:

- Technical (such as Geographic Positioning Systems (GPS) navigation systems that reduce the cost of air traffic control and ground radars);
- Economic/Financial (the bankruptcy of major airlines such as Sabena, Swiss Air, Northwest Airlines, or Air Canada);
- Industrial (the merger of major airlines, such as American and TWA, or Air France and KLM);

- Political (such as the opening of China into world trade and the boom of inexpensive tourism in Asia); and
- Other, as with terrorism, war, and the price of fuel.

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

Leaders also need to recognize that any airport investment can now be strongly affected by competitive forces far beyond their control. Airports can 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”, so commonly 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 Air). Airports now need to be considered as part of a system, if not as part of competing networks of traffic. 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 now need to consider and develop strategies to gain and maintain competitive advantage.

Definition of Flexible Design Opportunities: Managers of airport systems therefore need to be careful about committing to single major projects conceived along traditional lines. In the context of the great uncertainty about the future nature of air transport, they could easily find themselves irretrievably spending billions on projects which in retrospect turn out to have been misguided. Thailand’s decision to build its massive new airport at Bangkok/Suvarnabhumi, without thinking through the role of Bangkok in the market for low-cost tourism, and the needs of low-cost carriers, created a situation in which the low-fare airlines wanted to stay at the old (but inexpensive and convenient) Bangkok/Don Muang, so the international carriers serving that market also wanted to be near their partners. This stress was a major contributor to the delays opening of the new airport, has continued to be a major difficulty for the airlines and in general is a major political and economic embarrassment to the owners. It is not the kind of experience anyone wants to repeat.

A flexible approach to the development of major infrastructure is needed in these circumstances. The alternatives for flexible designs can take many forms:

- Political leaders and investors can, for example, commit to a site for a major airport, think through how a major airport might be implemented, and yet only decide to invest in a fraction of the possible airport – in an “Inaugural airport”.
- They can also create both traditional and low-cost facilities, to appeal to the range of possible customers. Proceeding along these lines is very different -- in concept and in cost -- from a commitment to a major second airport to replace an existing facility.
- When confronted by major uncertainties as they are now, airport investors should stage the development of major hub airports, giving them the possibility to end up with a secondary airport, while keeping the option open to expand aggressively if this eventually seems advisable.
- Correspondingly, they can stage the implementation of various elements of a major airport, for example by opening with a single runway, and expanding to two as traffic develops. Such deferrals of investments by several years dramatically reduce the financial exposure and risk of the investment, as well as reducing the effective present values of the costs.
- Architects can develop flexible spaces, using glass partitions for example, that can easily be moved to accommodate both short and longer term fluctuations in traffic, as has been done attractively and effectively at Vancouver.

Conversely, leaders should 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. Investments in smaller airports that have not yet fully established themselves can be risky – but many of the investments in large airports have proven themselves to be equally risky – and involve far greater amounts of capital! Given the uncertainties, investments in low-cost airports and airport facilities should also be staged. 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 provide a good insurance against the need to have such a system should it occur.

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 develop according to the circumstances. This needs to be done considering both what the airport operators could do, how the future might turn out, and how they might correspondingly respond. This process is conceptually similar to what chess or bridge players do as they 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.

Various standard analytic tools exist to assist the designers in thinking through the possible combinations of possible outcomes and responses. Most of these have been computerized and can be quickly learnt and used. Two of these 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, for example key to the original strategy for the development of Sydney's airport facilities as it entered privatization (de Neufville, 1991).
- Simulation of Spreadsheet financial pro forma financial statements, which is a well-used process for the development such useful measures as the Expected Net Present Value, the Value at Risk and Gain, the Minimum and Maximum results, and the Initial Capital expenditures (See Hassan et al, 2005 for an example).

The outcome of the process is a decision concerning the initial development -- for the country, region, airport or facility -- together with a strategy of how the plan 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 in this paper. 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 a national airline, TAP, and international airlines focused on the main hub at Lisbon. This facility, situated close to central Lisbon and involving flight paths directly over densely inhabited areas, is clearly limited in its potential expansion. Since around 1990, there has correspondingly been increasing pressure to define a

site for a major new airport. Indeed, in the late 1990s the Government selected the Ota site, which involved a long-time military air base. Around the same time, the Aéroports de Paris was commissioned to prepare a master plan for the development of the site. This conventional master plan for the new airport at Ota features a massive multi-level terminal building, complete with air bridges to all aircraft according to the highest traditional standards. The preliminary costs estimates have exceeded 3 billion euros (ACI, 2005).

As of the end of January 2007, the Government of Portugal announced that it was definitely going ahead with its intention to develop a second airport at Ota (AFX News, 2007). Moreover, in early 2007, it announced its intention to privatize the national airport company, Aeroportos do Portugal (ANA), and to require the successful consortium to develop the new facilities at Ota.

Recognition of Uncertainty: Since the plans for the development of the 3 billion Euro new airport for Lisbon emerged in 1990s, the air transport situation has changed dramatically -- in Europe in general, and Portugal in particular. Along with trends across the continent, the low-cost airlines have developed strongly, and the mid-size national airlines (such as Olympic, Sabena, Swissair – and including TAP) have struggled financially and required substantial subsidies to stay alive. In short, the low-cost carriers have become important participants in Portuguese air transport, and need to be considered seriously.

Meanwhile, the low-cost airlines have acted in Portugal as indicated by this article. They have developed operations that by-pass the main hub at Lisbon. Ryanair specifically has been promoting Faro and appears to have become the dominant airline at this airport on the Algarve, providing a service to passengers that had made obsolete much of the “legacy” service offered by the national airline centered on the traditional hub airport. Likewise, their services to the UK, Italy and the like are part of a larger parallel network of service between low-cost airports.

The low-cost airlines have not so far developed a secondary low-cost airport around Lisbon – in any case there seems to have been no airfield opportunities to do so to date. However, this might change as additional military airfields are open 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 airport for commercial purposes (Câmara de Comercio, 2007). As this site is around 200 km. from Lisbon, it does not appear to offer realistic prospects for a second airport for Lisbon.

In detail, the low-cost airlines are demonstrating their desire and need for low-cost airport facilities. Thus at the Oporto airport, which features elegantly renovated 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.

The prospective private investors in the new airport at Ota face considerable risk. On the one side, air traffic to Portugal has been growing steadily so there appears to be an evident need for additional airport facilities. On the other side, there is considerable uncertainty along the following lines:

- 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 was faced with a similar situation when its bankrupt national carrier, Air Canada, could not afford to move fully into the 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 Oporto.
- 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.

In short, the future revenues from an investment in a major new airport are unpredictable. Similarly, the potential for underused secondary airports in Portugal may have interesting upside potential.

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. Specifically, it could be worth investigating:

- Scaled development of the site, for example by delaying the construction of the intended second runway for a while, or by building the passenger buildings to meet the immediate needs with the flexibility to continue development as required;
- Provision of a range of facilities, both along conventional lines and for low-cost carriers, so as to enable the airport to serve appropriately the range of clientele that might wish to use the airport; and
- Design of flexible facilities organized to permit reconfiguration of spaces between transcontinental and Schengen flights whose proportions may change radically in the future (as they already have done in the past decade).

Analysis of development strategies: The appropriate development strategy is likely to involve two parallel tracks:

- Deferring investments until their need has been fully demonstrated. Thus for example the development of the new airport for Lisbon might first focus on an “inaugural airport” with one major runway, leaving the investment in the second runway for a later time when the traffic in the area had been fully justified.
- Making investments that enable the development of different kinds of traffic. Thus the plan for the new airport might specifically offer low-cost facilities to the prospective low-cost airlines, thus attracting these customers.

The precise strategy that would be best overall will need careful thought and analysis, which neither the Government of Portugal nor prospective private investors have yet had the opportunity to do.

In general, appropriate investments in the presence of uncertainty involve options – real options enabled through the design. Correspondingly, the appropriate development strategy will be flexible, investing as the market develops.

The result of using a flexibility design process will be, as it has been in many other cases, some cited already, to increase the expected value of the airport developments both to the owners and the nation. Resources will be spent when and where needed, in the facilities required at that time. Conversely resources will not be committed prematurely to facilities that will be inappropriate to future air transportation needs.

## **CODA**

The competition between the legacy and low cost airlines is extending to their major factors of production, that is, the airports. This reality poses substantial strategic and research questions for managers of both the “legacy airlines” and their associated “legacy” hub airports.

No definitive claims about how the situation will unfold should be trusted. The future is always unpredictable, and the recent history of air transport has been especially volatile. That said, it is clear that we are in a period of transition, and that the pattern of the past is in flux.

It is also apparent that low-cost airlines will have low-cost airport facilities. This seems inescapable. What is unclear is whether these low-cost airport facilities will continue to be distinct from the legacy airports. Indeed, it is possible that to the extent that low-cost carriers drive the legacy carriers out of business, they will supplant them at major airports, much as Southwest has

taken over Chicago/Midway, replaced US Air at Baltimore/Washington, and is moving aggressively on Pittsburgh and Philadelphia International airports.

In face of these facts, airport planners, investors, and managers need to develop strategies that will enable them both to avoid over commitments that are financially risky, and position them to take advantage of opportunities as they may develop. To achieve this, they need to adopt a new, flexible approach to airport analysis and design, possibly along the lines indicated.

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### 4 REFERENCES

- ACI World and Momberger Airport Information (2005) "Airport Development News"  
<http://www.airports.org/aci/aci/file/ADN%20-%20Momberger/ACI-ADN%20Dec%202005.pdf>
- AFX News (2007) "Portugal Government to fully privatise ANA airports authority," 30 Jan.,  
<http://www.finanznachrichten.de/nachrichten-2007-01/artikel-7661191.asp>
- Barrett, S. (2004) "How do the demands for airport services differ between full-service carriers and low-cost carriers?" *J. of Air Transport Management*, 10, pp. 33-39.
- Câmara de Comercio Luso-Britânica [British-Portuguese Chamber of Commerce], (2007) "Beja Airport", <http://www.bpcc.pt/airports.asp#ancora13>
- Chambers, R.-D. (2007), Master of Science Thesis, MIT Technology and Policy Program, Cambridge, MA.
- de Neufville, R. (2006) "Accommodating Low Cost Airlines at Main Airports," Transportation Research Board presentation, summarized in *International Airport Review*, No. 1, pp. 62-65.  
[http://ardent.mit.edu/airports/ASP\\_papers/](http://ardent.mit.edu/airports/ASP_papers/)

- de Neufville, R., Scholtes, S. and Wang, T. (2006) "Valuing Options by Spreadsheet: Parking Garage Case Example," *ASCE Journal of Infrastructure Systems*, 12(2), pp. 107-111.  
[http://ardent.mit.edu/real\\_options/Common\\_course\\_materials/papers.html](http://ardent.mit.edu/real_options/Common_course_materials/papers.html)
- de Neufville, R. (2005) "The Future of Secondary Airports: Nodes in a Parallel Air Transport Network?" [http://ardent.mit.edu/airports/ASP\\_Papers/](http://ardent.mit.edu/airports/ASP_Papers/) English version of "Le devenir des aéroports secondaires: bases d'un réseau parallèle de transport aérien?" *Cahiers Scientifiques du Transport*, Issue 47, pp.11-38.
- de Neufville, R. (2004) "Multi-Airport Systems in the Era of No-Frills Airlines," *Transportation Research Board*, Washington, DC, Jan.  
[http://ardent.mit.edu/airports/ASP\\_papers/no-frillstrbtext.pdf](http://ardent.mit.edu/airports/ASP_papers/no-frillstrbtext.pdf)
- de Neufville, R. and Odoni, A. (2003) *Airport Systems Planning, Design, and Management*, McGraw-Hill, New York, NY.
- de Neufville, R. (1995) "Management of Multi-Airport Systems: A Development Strategy," *J. of Air Transport Management*, 2(2), June, 99-110.  
[http://ardent.mit.edu/airports/ASP\\_papers/mas.atm1.pdf](http://ardent.mit.edu/airports/ASP_papers/mas.atm1.pdf)
- de Neufville, R. (1991) "Strategic Planning for Airport Capacity: An Appreciation of Australia's Process for Sydney," *Australian Planner*, 29(4), Dec., pp.174-180.
- Dennis, P. (2004) "Can the European Low-Cost Airline Boom Continue? Implications for Regional Airports", *European Regional Science Association (ERSA) conference paper ersa04p571*,  
<http://ideas.repec.org/p/wiw/wiwr/ersa04p571.html>
- DMJM Aviation (2005) *American Airlines Terminal, John F. Kennedy International Airport*,  
<http://www.dmjmhm.aecom.com/MarketsandServices/4028/index.jsp>
- Fedor, L. (2006) "NWA pilots seek to sell bankruptcy claim early," *LexisNexis*, 26 Nov.,  
<http://airportbusiness.com/article/article.jsp?siteSection=1&id=9034>
- Francis, G., Fidato, A., and Humphreys, I. (2003) "Airport-Airline Interaction: the Impact of Low-Cost Carriers on Two European Airports," *J of Air Transport Management*, 9, pp 267-273.
- Gillen, D. and Lall, A. (2004) "Competitive advantage of Low-Cost Carriers: Some Implications for Airports," *J of Air Transport Management*, 10, pp. 41-50.
- Graham, A. (2004) "Airport Strategies to Gain Competitive Advantage,"  
<http://www.garsonline.de/Downloads/Slots%20Competition%20Benchmarking/04119-graham.pdf>
- Hassan, R., de Weck, O., Hastings, D., de Neufville, R. and McKinnon, D. (2005) *Value-at-Risk Analysis for Real Options in Complex Engineered Systems*, IEEE Conference on Large Scale Infrastructures, Hawaii, Oct., in Volume 4, pp. 3697-3704, Digital Object Identifier 10.1109/ICSMC.2005.1571721.  
[http://ardent.mit.edu/real\\_options/Real\\_opts\\_papers/Hassan\\_deN\\_IEEE\\_SMC\\_2005\\_final1.pdf](http://ardent.mit.edu/real_options/Real_opts_papers/Hassan_deN_IEEE_SMC_2005_final1.pdf)
- International Air Transport Association (2005) *World Air Transport Statistics*. Montreal.
- International Air Transport Association (2004) *Airport Development Reference Manual*, 9<sup>th</sup> edition, Montreal.
- Jorgenson, R. (2006) "Machinists Union reaches tentative agreement with Northwest Airlines," 25 May <http://www.wsws.org/articles.2006.may2006/nwa-m25.shtml>

Morrison, S. Winston, C. (2005) "What's Wrong with the Airline Industry? Diagnosis and Possible Cures," Statement to the US Congress Subcommittee on Aviation, Sept. 28.  
<http://www.economics.neu.edu/morrison/research/>

United States, Federal Aviation Administration, Bureau of Transportation Statistics (2005)  
Third Quarter 2005 Airline Financial Data  
[http://www.bts.gov/press\\_releases/2005/bts058\\_05/html/bts058\\_05.html](http://www.bts.gov/press_releases/2005/bts058_05/html/bts058_05.html)

United States, Federal Aviation Administration, Bureau of Transportation Statistics (2006)  
Airline On-Time Statistics and Delays Causes, [http://www.transtats.bts.gov/OT\\_Delay/](http://www.transtats.bts.gov/OT_Delay/)

Warnock-Smith, D. and Potter, A. (2005) "An Exploratory Study into Airport Choice Factors for European Low-cost Airlines," *J of Air Transport Management*, 11, pp. 388-392.

Wikipedia (2007) "Varig" <http://en.wikipedia.org/wiki/Varig>

Williams, A. (2007) "Competitive Volatility and Structural Change in the International Low Cost Carrier Markets: a discussion on the basic causes and probable outcomes," *Singapore Journal of Aviation Management* (in press)

## FOOTNOTES

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<sup>1</sup> 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 similarly took a 26% and then a further 11.5% pay cuts, 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 now participating in the cleaning of the aircraft cabin. (Jorgenson, 2006) Workers at other legacy carriers have similarly brought their pay scale in line with the going market rates.

<sup>2</sup> As reported to the author while on site in 2006.

<sup>3</sup> The cost per seat-mile is the total cost of displacing one passenger-seat one mile. It does not consider whether this unit of production is actually sold. Statistics on this factor strive to exclude airline costs that are not associated with this production – for example the costs associated with hotel operations the airline might run.

<sup>4</sup> A syllabus for a course on this, Engineering Systems Analysis for Design, is available at [http://ardent.mit.edu/real\\_options/ROCse\\_MIT\\_latest/index.html](http://ardent.mit.edu/real_options/ROCse_MIT_latest/index.html)