Evolution and Development of Multi-Airport Systems: A Worldwide Perspective

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Abstract: This paper presents an analysis of the dynamics of evolution of multi-airport systems worldwide that can help to guide their effective development in the future. Given the capacity constraints on existing major airports, the development of multi-airport systems is going to be a key mechanism by which air transportation systems around the world will be able to meet future demand. In order to better understand how these systems will evolve, a systematic case study analysis of 59 airport systems worldwide was performed. The analysis showed significant differences in the evolution of multi-airport systems across world regions. In the United States and in Europe, the recent development of multi-airport systems primarily involved the emergence of secondary airports. This dynamic was driven by the entry of low-cost carriers seizing the opportunity of using existing airport infrastructure but also by the barriers and opposition to the construction of green field airports. In Asia, multi-airport systems have generally evolved through the construction of new high capacity airports, due to a much weaker set of available airports, high perceived benefits of strong growth of traffic and weaker opposition to the construction of airports. This study suggests that, in the United States and in Europe, protecting existing under-utilized airports will be key to meeting future demand. In Asia, where the existing under-utilized airport infrastructure is weak and where projections of high volume of demand are high, there is the need to apply a dynamic approach to develop multi-airport systems by reserving land area that can later be developed into airports.

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Introduction

The growing demand for air transportation around the world coupled with the limited ability to increase capacity at key airports in the air transportation system, pose concerns that, in the future, the system will not be able to meet demand. It appears that the development of multi-airport systems is a key mechanism by which air transportation systems will be able to meet future demand worldwide. This paper presents an analysis of the dynamics of evolution of multi-airport systems worldwide that can help to guide their effective development in the future.

Motivation

Historically, significant growth of passenger traffic was observed in North America, Europe and Asia-Pacific over the last 20 years and in the Middle East more recently (Fig. 1). Future and sustained growth of traffic in these regions assumes that the airport infrastructure capacity is also able to grow in order to meet future demand. However, in several regions of the world (mostly the United States and Europe) signs of inadequacy between demand and airport capacity that materialize in the form of delays are clearly observable. This situation of sustained delays adversely impacts passengers' quality of travel and more generally the economy. Because the air transportation system is a vital underlying infrastructure of a country's economy, there is the need to find ways by which this system remains reliable, safe and efficient while future demand is met.

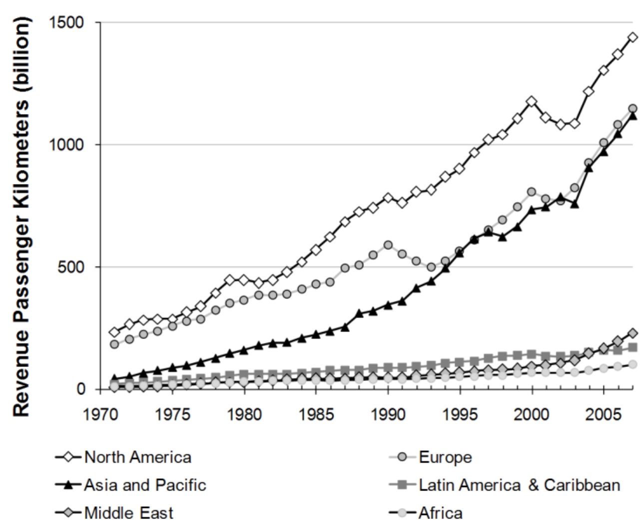

Fig. 1. Passenger traffic (Revenue Passenger Kilometers) worldwide from 1970 to 2007

Given the capacity constraints on existing major airports and the limited ability to increase their capacity, the transition and development of multi-airport systems appears to be key mechanism by which air transportation systems around the world will be able to meet future demand.

A multi-airport system is defined as a set of two or more significant airports that serve commercial traffic within a metropolitan region. Fig. 2 presents the New York multi-airport system that is composed of four airports (i.e. three primary airports; New York/Kennedy, New York/Newark, New York/LaGuardia and one secondary airport; New York/Islip on Long Island). The congestion problem at the three major airports in New York could also drive the emergence of a new secondary airport (i.e. Stewart International).

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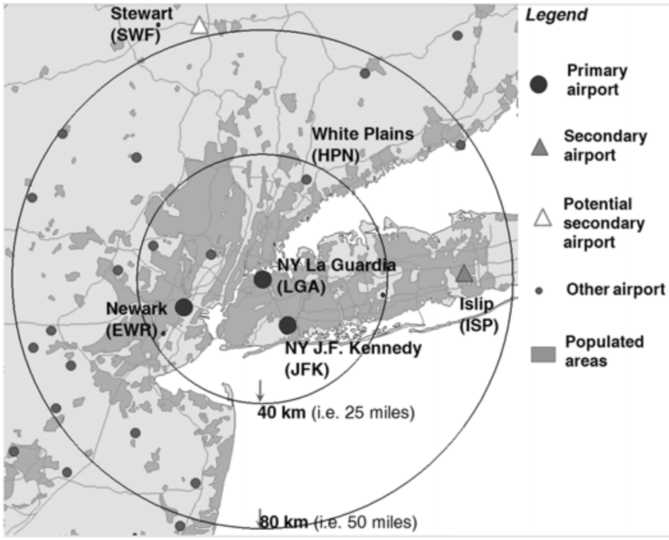

Fig. 2. Multi-airport system serving the New York metropolitan region

The importance of multi-airport systems has been demonstrated by Bonnefoy and Hansman (2007) who showed that the development of these systems is a key mechanism by which the air transportation system, in the United States, scales and accommodates increasing volumes of demand. On the basis of a network analysis, using theories of scale free and scalable networks, it was shown that the air transportation network analyzed at the airport level is not scalable. The network for which airports within multi-airport systems were aggregated into single nodes was found to be scale-free and scalable, which is an indication that the development of multi-airport systems is a key mechanism by which the system scales.

However the development of multi-airport systems poses several challenges in terms of planning and development. The evolution of these systems typically occurs over long time horizons and involves multiple stakeholders (i.e. passengers, airlines, airport developers and operators, local and national regulatory authorities, etc.).

The objective of this paper is to analyze the evolution and development of multi-airport systems worldwide, and to better understand how to develop them successfully and effectively in the future.

Approach and methodology

The development of multi-airport systems involves and is influenced by a wide range of factors, from the technical (e.g. compatibility of aircraft requirements and airport infrastructure capabilities), the political and regulatory (e.g. policies to prohibit the use of an airport to certain operators) and the social (e.g. distribution of population around airports, opposition to airport development by local communities). Given the multi-factor nature of the problem, an engineering systems approach was followed. The objective of this approach is to perform a systematic analysis of the system under investigation (i.e. multi-airport systems in this case) in order to identify the fundamental mechanisms that govern the system, the factors that influence its dynamics and from this understanding derive insights as to how to better design, operate and manage the system.

This approach involved a three step process:

- The first phase involved the identification of multi-airport systems using a worldwide airport passenger traffic database composed of data from ICAO (ICAO 2008) and FAA (FAA 2007). All airports with more than 500,000 passengers in 2005 were considered in this analysis. A geographical cluster analysis was performed to identify airports located in the vicinity of each other. These airports were then categorized into two types; *primary airports* and *secondary airports*. A *primary airport* was defined as an airport serving more than 20% of the total passenger traffic in the multi-airport system while a *secondary airport* was defined as an airport serving between 1% and 20% (and more than 500,000 passengers per year). Airports that served less than 1% of the of the total passenger traffic in the multi-airport system were not included in the analysis (e.g. White Plains in the New York airport system). Freight tonnage data was also used to identify airports at which significant freight activity was taking place, despite the fact that these airports may not exhibit significant passenger traffic.
- In the second phase, the dynamics that govern these systems were analyzed through a multiple case study analysis of all the multi-airport system identified in the first phase. The objective was to identify any differences in the way multi-airport systems evolved across different world regions. The factors that influence these dynamics were then analyzed in order to explain the observed differences.
- Finally, the implications of the results of these analyses were analyzed in order to provide recommendations for the successful and effective development of multi-airport systems in the future.

Multi-Airport Systems Worldwide

Fig. 3 presents the set of 59 multi-airport systems that resulted from the identification process. This set composed the core of the database of multi-airport systems that were used for further analysis.

As Fig. 3 shows, the number of multi-airport systems across world regions generally correlates with the maturity of these air transportation systems. Europe and North America exhibit the largest number of multi-airport systems with 25 and 18 multi-airport systems respectively. Asia-Pacific accounts for 8 systems; Latin America and Middle East account for 5 and 3 multi-airport systems respectively.

Fig. 3. Multi-airport systems worldwide

Table 1 presents the distribution of primary and secondary airports across the 59 multi-airport systems. As Table 1 shows, there are several types of multi-airport systems (i.e. number and combinations of airports).

Table 1. Multi-airport systems worldwide (sorted alphabetically by world region and ranked by decreasing number of primary and secondary airports)

World region	Metropolitan Area	Country	Number of primary airports	Number of secondary airports
Asia-Pacific	Japan	Osaka	2	1
	China	Hong Kong	2	0
	China	Shanghai	2	0
	China	Taipei	2	0
	Japan	Tokyo	2	0
	South Korea	Seoul	2	0
	Thailand	Bangkok	2	0
	Australia	Melbourne	1	1
Europe	United Kingdom	London	2	3
	Germany	Dusseldorf	2	2
	United Kingdom	Manchester	1	3
	France	Paris*	2	1
	Germany	Berlin	2	1
	Italy	Milan	2	1
	Russia	Moscow	2	1
	United Kingdom	Glasgow	2	1
	Netherlands	Amsterdam	1	2
	Spain	Barcelona	1	2
	Sweden	Stockholm	1	2
	Italy	Pisa	2	0
	United Kingdom	Belfast	2	0
	Austria	Vienna	1	1
	Belgium	Brussels*	1	1
	Danmark	Copenhagen	1	1
	Germany	Frankfurt	1	1
	Germany	Hamburg	1	1
	Germany	Stuttgart	1	1
	Italy	Bologna	1	1
	Italy	Rome	1	1
	Italy	Venice	1	1
	Norway	Oslo	1	1
	Sweden	Gothenburg	1	1
	Turkey	Istanbul	1	1
Latin America	Brazil	Sao Paulo	2	1
	Argentina	Buenos Aires	2	0
	Brazil	Belo Horizonte	2	0
	Brazil	Rio de Janeiro	2	0
	Mexico	Mexico	1	1
Middle East	Iran	Tehran	1	1
	Israel	Tel Aviv	1	1
	UAE	Dubai	1	1
North America	United States	Los Angeles	1	4
	United States	New York	3	1
	United States	Washington	3	0
	United States	San Francisco	2	1
	United States	Boston	1	2
	United States	Tampa	1	2
	United States	Miami	2	0
	United States	Norfolk	2	0
	United States	Chicago*	1	1
	United States	Cleveland	1	1
	United States	Dallas*	1	1
	United States	Detroit	1	1
	United States	Houston	1	1
	United States	Orlando	1	1
	United States	Philadelphia	1	1
	United States	San Diego	1	1
	Canada	Toronto	1	1
	Canada	Vancouver	1	1

*Note: * indicates the presence of one additional airport in the metropolitan region at which significant freight activity is taking place.*

The most frequent type is a multi-airport system composed of two airports; one primary airport and one secondary airport (e.g. Chicago, Frankfurt, and Melbourne) or in some cases two primary airports (e.g. Miami, Belfast, Shanghai). These systems become more complex as the number of primary and secondary airports increases. The most complex multi-airport systems are Los Angeles (with 1 primary airport and 4 secondary airports), London (with 2 primary airports and 3 secondary airports) and New York (with 3 primary airports and 1 secondary airport).

Mechanisms Governing the Evolution of Multi-Airport Systems

The existence of different types of multi-airport systems (i.e. combination and distribution of primary and secondary airports), motivated the need to investigate the temporal evolution of these systems and identify the mechanisms that govern their evolution. This time series analysis was performed using passenger traffic data from ICAO (ICAO 2008) and FAA (FAA 2007) for the years 1975 to 2005 and historical airport information from a wide range of sources.

This historical analysis identified two fundamental mechanisms governing the evolution of multi-airport systems; *the emergence of a secondary airport through the use of an existing airport*, and *the construction of a new airport*.

Fig. 4 shows that a single-airport system can transition to a multi-airport system through the emergence of secondary airports (e.g. Boston/Manchester, Frankfurt/Hahn, etc.). In some cases, the secondary airport can grow and become a primary airport.

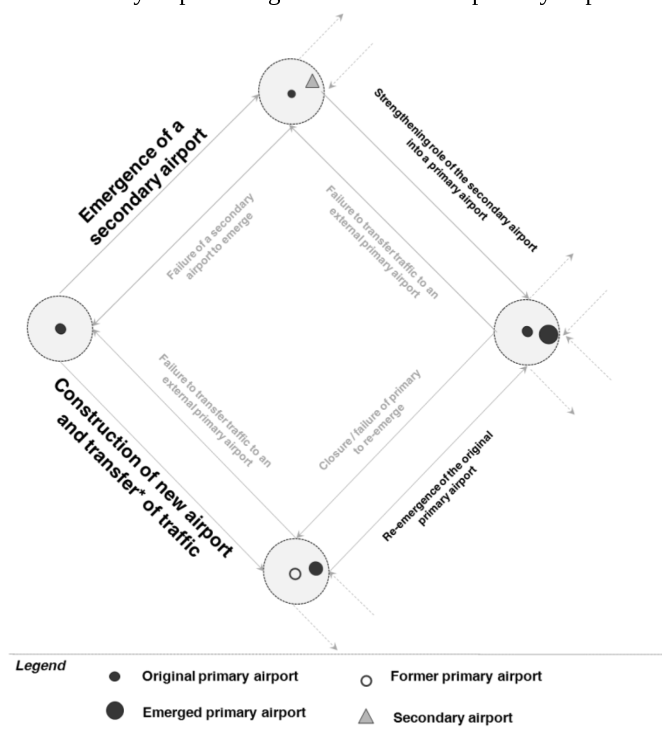

Fig. 4. Simplified Transition Diagram of Spatial Configurations of Multi-Airport Systems (i.e. transition from single-airport system to two airport multi-airport system)

*Note: *total or partial transfer of traffic. In some cases, the transfer can be total (e.g. Denver/Intl) or partial (e.g. Bangkok/Suvarnabhumi, Tokyo/ Narita, etc.)*

Another path by which an airport system can evolve is through the construction of a new airport with partial or total transfer of traffic to this new airport (e.g. Chicago/O'Hare, Tokyo/Narita, etc.). In the case of total transfer of traffic, the original airport can be closed. This was observed in several cases (e.g. Denver/Stapleton in 1995, Oslo/Fornebu in 1998). If the original primary airport remains open, it can reemerge as a secondary airport (e.g. Dallas/Love Field, Chicago/Midway, and Bangkok/Don Mueang). This reemergence dynamic also results in the creation of a multi-airport system.

From these states, the systems can continue to evolve to more complex configurations by the addition of new airports through the emergence of new secondary airports or the construction of new airports.

Based on the detailed historical analysis of the evolution patterns of the 59 cases of multi-airport systems, Table 2 shows the frequency of observation of both evolution patterns (i.e. *the emergence of a secondary airport through the use of an existing airport*, and *the construction of a new airport*) across different world regions. Table 2 shows that multi-airport systems in Europe and in North America tend to evolve predominantly through the emergence of secondary airports. Conversely, in the Middle-East, Latin America and Asia-Pacific, multi-airport systems have evolved predominantly through the construction of new high capacity airports.

Table 2. Frequency of observation of mechanisms governing the evolution of multi-airport systems across world-regions

World region	Emergence of secondary airport through the use of an existing airport	Construction of a new airport
Europe	81%	19%
North America	81%	19%
Middle East	50%	50%
Latin America	20%	80%
Asia/Pacific	10%	90%

Note: Middle-East only accounts for 3 multi-airport systems and the results are not necessarily statistically significant. However, recent trends in construction of new high capacity airports, such as the Dubai World Trade Centre (DWTC) and other projected airports in the region indicate that multi-airport systems in this region will continue to evolve according to the mechanism of construction of new airports.

Key Factors Influencing the Evolution of Multi-Airport Systems

To understand and explain the differences in the occurrence of mechanisms that govern the evolution of multi-airport systems, a detailed analysis of the factors that influence these mechanisms was performed. A wide array of factors was considered. Three types of factors have been identified as key to influencing the evolution of multi-airport systems and are presented in the following section; (1) the availability of existing airport infrastructure, (2) the entry of low-cost carriers at under-utilized airports and (3) regulatory and political factors.

Availability of existing airport infrastructure

The emergence of secondary airports assumes the availability of existing non-utilized airports in the metropolitan region. In order to evaluate the availability of airport infrastructure within metropolitan regions, regional airport system capacity coverage charts were constructed for each of the 59 airport systems. These represent the cumulative number of airports within a certain distance of the airport that is the closest to the center of the metropolitan region. This analysis was performed using a worldwide airport database (DAFIF 2005) of active civil and jointly operated airports (i.e. Category A and B airports) with at least one runway longer than 1524 m (i.e. 5000ft). To compare the availability of airports across different world regions, the results were averaged by world regions (Fig. 5).

Fig. 5 shows that North America is characterized by a high density of existing airports with an average of approximately 7 and 10 existing airports within 80 and 120 km (i.e. 50 and 75 miles) of the primary airport respectively. This high density of existing airports explains that in the presence of barriers to the construction of new greenfield airports, this available set of airports is utilized through the emergence of secondary airports. Conversely, the low density or absence of existing airports within metropolitan regions in Asia-Pacific and Latin America is a factor responsible for the observed predominant trend of construction of airports.

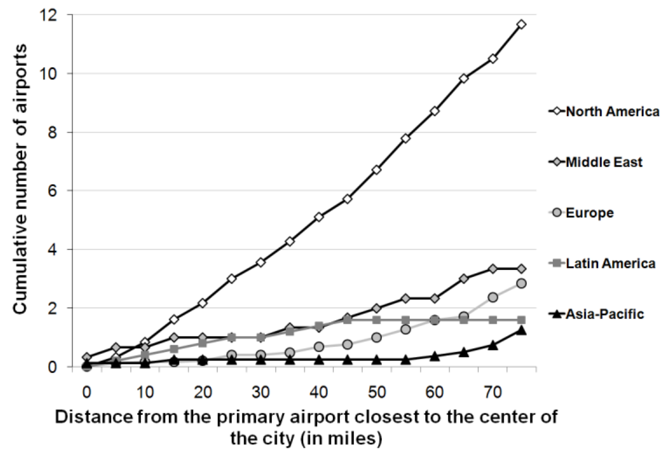

Fig. 5. Airport system capacity coverage by world region: cumulative number of existing airports by distance from the airport that is the closest to the center of the metropolitan region

Interestingly, while the density of available airports in Europe is low, the reason for the predominant dynamic of emergence of secondary airports is explained by the conversion of military airports into civil or joint-use airports. The analysis of the historical evolution of the status of airports (i.e. civil, joint-use, military) showed that, in Europe, 13 secondary airports emerged after the conversion from military airfields into civil or joint use airports. Table 3 shows the number of military airports converted into secondary airports across different world regions.

Table 3. Secondary Airports Emerged & Converted from Military Airfields across World Regions

World region	Number of secondary airports converted from military airports
Europe	13
North America	4
Asia-Pacific	1
Middle East	0
Latin America	0

Entry of low-cost carriers at under-utilized airports

In most cases investigated, it was found that the entry of an air carrier, generally a low-cost carrier, corresponded with the emergence of a secondary airport. The entry of a low-cost carrier stimulates the emergence process of an airport. In the United States, Southwest Airlines was responsible for the emergence of 13 airports. In the case of the Boston/Manchester and Boston/Providence, the impact of the entry of Southwest was substantial. At Boston/Manchester, the year-to-year growth in passenger enplanements was on average 6% from 1990 to 1997. After the entry of Southwest in 1998, this average annual growth rate increased to 45% during the two subsequent years. The same phenomenon occurred at Boston/Providence, where the traffic grew at an average of 35% per year during the three years following the entry of Southwest.

In several cases, prior to the entry of a low-cost carrier, there was almost no service at these airports. In the cases where limited service was available it was usually by network carriers that offered connecting flights to a hub airport.

The entry of a low-cost carrier changes the market dynamic and typically lowers fares which opens up new market opportunities and stimulates traffic. This phenomenon is also known as the "Southwest effect" (Bennett and Craun 1993). In the case of Boston/Manchester, the average aggregate yield at the airport level dropped by 27% between 1997 and 1999, while passenger traffic increased by 154% (Bonnefoy and Hansman 2005). In addition, after the initial entry of a low-cost carrier, several other carriers generally follow. These subsequent entries significantly increase the overall number of airlines offering service at the airport and further increase the attractiveness of the airport to both passengers and airlines.

While Southwest Airlines played a key role in the successful emergence of secondary airports in the United States, this dynamic was also observed in Europe, with the development of the low-cost carrier networks serving secondary airports (i.e. Ryanair, Wizzair). Table 4 shows the result of an analysis of the distribution of low-cost carriers versus other carriers at both primary and secondary airports. Table 4 shows low-cost carriers tend to predominate at secondary airports.

Table 4. Presence of Low-Cost Carriers (vs. Other Airlines) at Primary and Secondary Airports within Multi-Airport Systems Worldwide

World region	Percentage flights operated by Low-Cost Carriers	
	Primary airports	Secondary airports
Asia-Pacific	9%	50%
Europe	19%	44%
Latin America	9%	43%
North America	12%	21%
Middle East	7%	7%

Data source: (Official Airline Guide, OAG, 2005).

Regulatory and political factors

While the previous factor (i.e. entry of low-cost carriers at certain airports) and the resulting emergence of secondary airports was mostly driven by airlines' behaviors and therefore by market considerations, the evolution of multi-airport systems is also influenced by regulatory and political factors. These factors were identified as playing a significant role in the way traffic distributed in the case of the construction of a new airport and partial or total transfer of traffic from an original primary airport to the newly constructed airport. While in few cases the original primary airport was successfully closed (e.g. Denver/Stapleton in 1995, Oslo/Fornebu in 1998, Hong Kong/Kai Tak in 1998, Athens/Ellenikon in 2001), it is generally difficult to close an airport. Given that in all the cases in the study, the new airport was located further away from the city center than the original primary airport, keeping an original primary airport open makes the new airport less attractive for airlines and creates competition and market access problems. Regulatory solutions were often employed in these cases in order to force the distribution of traffic. In the United States, the Wright Amendment limiting Southwest Airlines' operations at Dallas/Love Field in order to ensure transfer of traffic to Dallas/Fort Worth illustrates the role and the impact of such regulatory and political factors on the evolution of multi-airport systems. These regulatory tools can be effective to preserve the original airports (i.e. by avoiding their closure) while ensuring the successful emergence of a new primary airport.

Conversely, the use of regulatory tools to influence traffic distribution within airports serving a region can limit the development of multi-airport systems. The 1997 Indian Airport Infrastructure Policy was designed to limit the construction of new airports within 150 km (i.e. 93 miles) of existing major airports. This policy put in place to attract and protect airport investments into existing airports limits the development of new multi-airport systems.

Implications for Future Development of Multi-Airport Systems

The key questions and implications for the future development of multi-airports are; (1) the location of future multi-airport systems and (2) how the lessons learned from this study can be used to better plan, operate and manage these systems.

Future airport infrastructure adequacy and long term needs

In order to predict regions of future development of multi-airport systems, there is the need to investigate where future demand for air transportation will emerge and how airport infrastructure is able to accommodate this projected demand. Fig. 6 shows Passenger-Kilometers per Capita versus Gross Domestic Product per Capita in 2005. As Gross Domestic Product (GDP) per capita increases, demand for air transportation generally increases accordingly. In Fig. 6, the size of the bubbles is proportional to the population in each country and is indicative of the future potential demand for transportation in nominal terms. From Fig. 6, it is clear that as GDP grows in China and India, significant demand for air transportation and traffic will be generated.

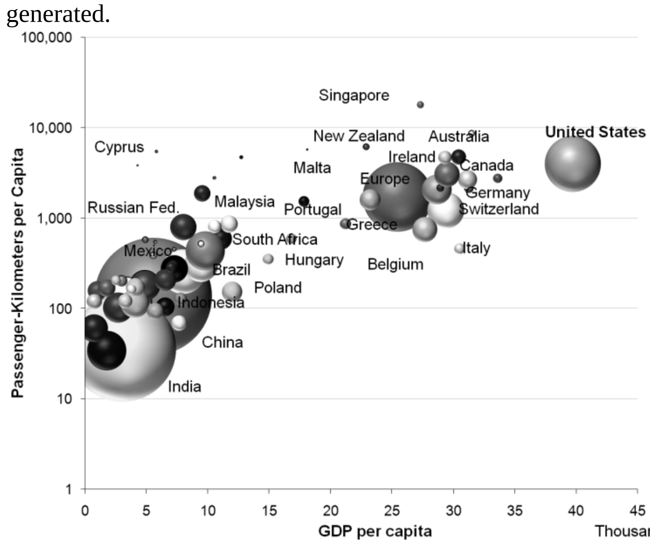

Fig. 6. Passenger-Kilometers per Capita vs. Gross Domestic Product per Capita in 2005

Data source: (CIA 2006, ICAO 2005).

However, the analysis of the adequacy of airport infrastructure and the construction of the regional airport system capacity coverage charts (Fig. 5) showed the great diversity in the ability of different world regions and different countries to accommodate future demand. Table 5 shows the list of countries (with population greater than 100 million) ranked by decreasing ratio of population over number of existing airports. With high population over airport infrastructure ratios and high population numbers, China and India will require significant future development of airport infrastructure as their GDP grows. In contrast, the United States and Europe generally have larger number of existing airports that can accommodate future growth through the emergence of new secondary airports.

Table 5. List of countries and regions ranked by decreasing ratio of population over number of existing airports with runways longer than 1524 m (i.e. 5000ft)

Country	Population (est. 2007) in millions	Airports with paved with runways longer than 5000 ft	Ratio of Population to Airports (millions)
Bangladesh	150	9	16.7
India	1,130	141	8.0
Nigeria	135	28	4.8
China	1,322	321	4.1
Indonesia	235	68	3.5
Pakistan	165	68	2.4
Japan	127	87	1.5
Brazil	190	196	1.0
Mexico	109	122	0.9
Europe (27)	490	1013	0.5
Russia	141	379	0.4
United States	301	1836	0.2

Data source: (CIA 2007).

Short to medium term development of multi-airport systems

In parallel to the identification and detailed analysis of existing multi-airport systems (Table 1), an analysis of single-airport systems in transition was also performed. Table 6 shows a set of airport systems for which a secondary airport is likely to emerge or plans to construct of a new airport exist.

Table 6 indicates that most of the single-airport systems in transition are located in Asia-Pacific, corresponding mostly to airport systems where a new high capacity airport is under construction or in future development. In addition, Table 6 shows that multi-airport systems in Europe continue to evolve through the emergence of new secondary airports, especially as European low-cost carrier expands towards Eastern Europe.

Table 6. Single-airport systems in transition

World region	Country	Metropolitan Region	Dynamics affecting these single-airport systems in transition
Africa	South Africa	Johannesburg	Potential emergence of a secondary airport (i.e. Johannesburg/Lanseria)
Asia/Pacific	China	Beijing	Construction of a second airport (i.e. expected to start in 2010).
	India	Bangalore	Construction of a new airport in 2008 (Bangalore/Intl) and the original airport (Bangalore/HAL) may remain open and become a secondary airport.
	India	Cochin	Construction of a new airport and transfer of traffic with the original serving domestic traffic
	India	Hyderabad	Construction of a new airport opened in 2008 (Rajiv Gandhi Intl) and the original airport that may become a secondary airport (Begumpet)
	India	Mumbai	Original airport (i.e. Mumbai/Intl) with the potential construction of a new high capacity airport (i.e. Mumbai/Navi)
	India	New Delhi	Original airport with the potential construction of a new high capacity airport (i.e. New Delhi/Noida in Jewar)
	Indonesia	Jakarta	Construction of a new airport and transfer of traffic with the original serving as a potential secondary airport
	Malaysia	Kuala lumpur	Construction of a new airport and transfer of traffic with the original serving domestic traffic (Subang)
	New Zealand	Auckland	Potential emergence of a secondary airport (i.e. Auckland/Whenuapai)
	Philippines	Manila	Primary airport (Manila/Aquino) with the potential emergence of two secondary airports (i.e. Manila/Subic Bay and Manila/Macapagal)
Europe	Germany	Berlin	Potential growth of traffic at a secondary airport (i.e. Berlin/Finow), despite the consolidation of the three major airports (i.e. Tegel, Tempelhof and Schoenfeld) into one single airport
	Germany	Leipzig	Potential growth of traffic at a secondary airport (i.e. Leipzig/Altenbourg)
	Poland	Warsaw	Military airfield with plans to transfer it to civil status and serve low-cost carriers (i.e. Warsaw/Modlin)
	Portugal	Lisbon	Construction of a new airport (i.e. Lisbon/Aclochete)
	Spain	Madrid	Construction of a new airport (i.e. Madrid/Don Quijote)
North America	Canada	Montreal	Unsucessfull establishment of a primary airport (i.e. Montreal/Mirabel) through the construction of a new airport and transfer of traffic. All traffic was transferred back to Montreal/Trudeau. As of 2008, Montreal/Plattsburgh located 57 miles south of Montreal is exhibiting early signs of emergence.
	United States	Las Vegas	Potential construction of a new airport in the Invanpah Valley

Implications for future planning and development of multi-airport systems

The lessons learned from the worldwide analysis of the dynamics of multi-airport systems imply that there is no single solution to the development of all multi-airport systems. There are different ways of developing multi-airport systems in different regions and countries. These differences are largely based on the conditions and dynamics that differ between world regions.

In the United States and Europe, the constraints on expanding the capacity of existing primary airports imply that there is the need to protect existing under-utilized airports that will be key to meeting future demand. These constraints arise from inherent land use issues (i.e. inability to physically expand the footprint of the airports) and growing opposition from local communities to expand airports using environmental impact justifications. These constraints coupled with the findings of the analysis of the available airport infrastructure (Fig. 5 and Table 5) imply that existing under-utilized airports will be key to accommodating future demand. However, weak streams of revenue due to low passenger traffic and competition for land use (i.e. transformation of under-utilized airports into real estate or industrial development) threaten the continuing existence of under-utilized airports. These existing airports should be seen as options for future development and future accommodation of air transportation demand.

In parts of Asia where the existing under-utilized airport infrastructure is weak and where projections of high volume of demand -with high uncertainty- are high, there is the need to apply a real option based approach (i.e. flexible and staged development approach) to develop multi-airport systems. This approach includes actions such as reserving land area for future airport development and keeping original airports open since this option has proven to be useful and successful in the United States. In addition, in some parts of Asia such as India where the military airport infrastructure is more developed, there is also the need, as in the United States and Europe, to protect these airports since they may become future secondary airports following the airport status conversion dynamics observed in Europe.

Advantages of multi-airport systems

While multi-airport systems can exhibit some disadvantages (e.g. dilution of operations at multiple airports limiting economies of scale for airlines, limited possibility for passengers to connect between flights at the different airports serving the metropolitan region) these systems provide significant advantages:

- relieve congestion at primary airports while providing additional capacity to the regional air transportation system,
- provide increased operational robustness by spatially decoupling operations and reducing the effects of disruptions,
- offer new travel alternatives for residents of the metropolitan region, which translates into reduces airport access distance and travel time,
- generate direct, indirect and induced regional economic impacts (i.e. employments, revenue sources for surrounding cities from taxes, attract new companies, etc.),
- reduce the effects of monopolistic positions that can sometime emerge in single-airport systems.

Conclusions

The development of multi-airport systems is the expression of the adaptation of the national air transportation system to capacity constraints and emergent market opportunities. As major airports around the world reach their capacity limits and become congested, new airports emerge in the vicinity either through the construction of new high capacity airports or the emergence of secondary airports from available and non-utilized airports. Given the capacity constraints on existing major airports, the development of multi-airport systems is going to be a key mechanism by which air transportation systems around the world will be able to meet future demand.

This paper presents a comprehensive analysis of the dynamics of evolution of multi-airport systems worldwide that can help to guide their effective development in the future. In order to better understand how these systems will evolve, a systematic analysis of 59 multi-airport systems worldwide was performed. It showed significant differences in the evolution of multi-airport systems across different world regions. In the United States and in Europe, the recent development of multi-airport systems involved primarily the emergence of secondary airports. This dynamic was driven by the entry of low-cost carriers seizing the opportunity of using existing airport infrastructure but also to barriers and opposition to the construction of greenfield airports. In Asia, multi-airport systems have generally evolved through the construction of new high capacity airports, due to a much weaker set of available airports, high perceived benefits of strong growth of traffic and weaker opposition to the construction of airports. This study suggests that, in the United States and in Europe, protecting existing under-utilized airports will be key to meeting future demand. In addition, particularly in Asia, there is the need to apply a real option based approach to develop multi-airport systems, by reserving land area (i.e. land banking) for future airport development.

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