

Dynamic evolution of European airport systems in the context of Low-Cost Carriers growth

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Abstract

Airport systems adapted to the influx of Low-Cost Carriers (LCC) as the segment grew to prominence in the European market during the last decades. The generalised perspective that LCCs are attached to remote secondary airports is being increasingly challenged by recent moves of the largest European LCC. The reality is that the impact of LCCs has spread to most commercial airports in Europe, primary and secondary alike. Yet, despite valuable insights on the evolution of airline networks, existing literatures lacks a clear understanding of why this has occurred. This paper explains the dynamics in the evolution of airports systems that resulted in significant growth for the low-cost segment in Europe. A multiple case study involving 42 European airports provides evidence to identify the mechanisms that trigger the traffic patterns leading to the ascendancy of LCCs in their respective airport systems. Understanding these mechanisms may probe valuable for airport strategic planning.

Highlights

- LCCs in Europe have significantly impacted both major and secondary airports
- New infrastructure encourages the growth of LCCs, even if not directly aimed at LCCs
- Market dynamics led many European airports to focus on LCC traffic

Keywords: airport evolution, multi-airport systems, low-cost carriers, low-cost airport

1 Introduction

Liberalisation of the air transport market around the world has profoundly changed the evolution trends of the aviation industry. A liberalised market created a proper environment for Low-Cost Carriers (LCC) to emerge and favoured their rapid expansion. Yet after decades of liberalisation the academic literature is not conclusive on the long-term impact of this trend for airports (A. Graham, 2013). There is concern about the growing market power of LCCs and its implications for airports, and there is uncertainty about the future evolution of the business models, not only for LCCs but for traditional airlines too (European Parliament, 2007).

An important body of literature links the emergence of LCCs to the availability of 'secondary' airports where they could thrive avoiding direct competition with other airlines (Barbot, 2006; de Neufville, 2008; Dobruszkes, 2006, 2013; Francis, Fidato, & Humphreys, 2003; Francis, Humphreys, & Ison, 2004; Franke, 2004; Zhang, Hanaoka, Inamura, & Ishikura, 2008). This aspect has been studied as a trigger for competition between airports (Jimenez, Claro, & Pinho de Sousa, 2013; Pels, Njegovan, & Behrens, 2009) a factor for airport efficiency (Martini, Manello, & Scotti, 2013), and as a potential asset to increase network connectivity (Malighetti, Paleari, & Redondi, 2008). Yet recent developments in Europe show that primary airports are in the core of LCC expansion and that the implication of this trend for smaller secondary airports remain unclear (Dobruszkes, Givoni, & Vowles, 2017).

In order to understand such implications, it is necessary to understand first how LCCs start, expand or abandon service at a given airport and how other airlines and airports react. And that needs to be assessed over time to gain a clearer picture of foreseeable trends. To the best of our knowledge, existing literature (covered in the next section) describes extensively what has happened to the low-cost segment over time, but still lacks a clear understanding on how the current landscape formed. Gaining insights on such details may be valuable for airport planners and policy makers to discern possible outcomes of the current trends.

In that sense, this paper proposes a dynamic perspective to study the evolution of European airport systems regarding LCC influence. Given that 16 of the top 20 European airports with the largest amount of seats provided by LCCs in 2013 belonged to a Multi-Airport System (MAS), we examined the evolution at 42 airports (all the airports in each MAS plus the four single-airport systems) between 2004 and 2013. Over this period LCCs became major players at both primary and secondary airports in Europe, contrary to the generalised notion that LCCs are attached to remote secondary airports.

We considered two types of dynamics in the evolution of the airport systems: infrastructure-related and market-related dynamics. The interaction of different dynamics result in particular traffic patterns with commonalities that are recognisable among diverse airport systems. By understanding such dynamics, airport managers may improve their planning processes considering both infrastructure development and strategy formulation simultaneously.

The paper is structured in six sections. After this introduction, the second section reviews relevant literature and defines the gaps that this research addresses. Section 3 describes the methodology used for the research. Section 4 summarises the most relevant findings from the traffic evolution at the airports selected for the study. Section 5 introduces the mechanisms that produce generic traffic patterns extracted from the multiple case studies. And section 6 presents the main findings and implications for policy making.

2 The impact of LCCs on airport systems

Airports are systems in the sense that they do not operate independently (de Neufville & Odoni, 2003); they are part of networks in which decisions made in one airport can affect others. This is more evident when different airports serve the same region, i.e., when they are part of Multi-Airport Systems (MAS). In an MAS airports compete with each other for traffic and services (Copenhagen Economics, 2012; de Neufville & Odoni, 2003; Jimenez et al., 2013; Pels et al., 2009) generating complex dynamics for planning and operations (de Neufville, 1995a, 1995b). Bonnefoy (2008) studied some of those dynamics to determine how airport systems can be scaled by developing into an MAS along time.

Over the last decades LCCs have disrupted airport systems, particularly in North America and Europe (de Neufville, 2008). The impact that LCCs have on airports have been ample matter of research, yet “the academic literature is far less clear and conclusive about the overall impacts of LCC operations at airports and the extent to which airports benefit from LCCs, particularly in the long-term, and this suggests that more studies are needed” (A. Graham, 2013). Indeed, many studies have focused on specific airports within a limited time frame, or on the airlines (Barret, 2004; European Parliament, 2007; Francis et al., 2003, 2004; Gillen & Lall, 2004; B. Graham & Shaw, 2008; Malighetti, Paleari, & Redondi, 2009; Malighetti, Redondi, Martini, & Paleari, 2007; Martini et al., 2013).

Consequently, it is commonly agreed that LCCs prefer 'secondary' airports (Barbot, 2006; de Neufville, 2008; Dobruszkes, 2006, 2013; Zhang et al., 2008). However Abda et al. (2012) found that, in the USA, the market shares of LCCs were bigger at the largest primary airports, “contrary to the common perception that LCCs avoid primary airports and direct competition with the [Full Service Carriers]” (A. Graham, 2013). This indicates that LCCs are becoming increasingly dominant in some markets (in particular the intra-USA and intra-European markets) and, as they keep growing, they move to the primary airports. In fact, the recent evolution of the networks of LCCs in Europe (Dobruszkes, 2006, 2009, 2013; Dobruszkes et al., 2017) suggests similar developments as the business models of the airlines evolve.

The expansion of LCCs at larger primary airports poses interesting questions for practitioners and researchers. How do these airports respond if their infrastructure has been normally developed for the use of traditional airlines? What factors favour or hinder LCC growth at primary and secondary airports? Are LCCs abandoning secondary airports altogether? What are the implications of these issues for policy

making?

In order to contribute towards filling such gaps, this paper proposes a dynamic perspective to study how LCCs have affected the evolution of European airport systems. The main factors that guided particular paths of evolution in the airport systems may suggest insights for the future development as LCCs keep growing and legacy airlines compete more strongly. Understanding the dynamics of such evolution is paramount to cope with the inherent volatility and uncertainty in airport systems, increased by trends associated to LCCs.

3 Methodology

In order to study the evolution of airport systems with special consideration for the low-cost segment, we selected the 20 European airports with the largest offer of low-cost seats in 2013, as per Innovata data (IATA, n.d.). As most of them (16) belong to Multi-Airport Systems (MAS), we also included all the other airports in every relevant MAS to analyse their evolution and mutual influences. Hence, we performed a multiple-case study comprising an extensive document review coupled with an analysis of traffic trends for each of the 42 resulting airports (see Table) during the period between 2004 and 2013.

The analysis of traffic trends is primarily based on airline capacity (available seats) data, from the Innovata database (IATA, n.d.) aggregated for the years 2004, 2008, 2012 and 2013. In the case of Spanish airports we have also used data provided by AENA Aeropuertos, the airport operator, in terms of passengers per airline for every year between 2005 to 2013 (AENA, 2014). In the case of British airports, we complemented capacity information with passenger traffic data, aggregated at the airport level (i.e. not by carrier) between 1998 and 2013 (CAA, 2014).

The document review included public documents in different languages, mainly the periodic reports of airport operators and civil aviation authorities, as well as their websites, aviation industry news and analyses, and mainstream and local journals. Traffic trends were assessed using non-hierarchical cluster analysis to group airports according to the relevance of low-cost traffic at the start (2004) and end (2013) of the analysis period. A non-hierarchical approach using k-means clustering (Forgy, 1965; Lloyd, 1982) based on euclidean quadratic distances was selected due to the relatively small sample (the 42 airports were grouped in their respective 17 airport systems) and the insights gained from the case studies that preliminarily hinted the possible number of clusters. Results of the cluster analysis were evaluated using Dunn (Dunn, 1974; Rousseeuw, 1987) and silhouette indexes. To select the appropriate number of clusters Dunn and silhouette indexes should be high.

Table 1: Airports selected for detailed dynamic analysis by MAS (the 20 airports with the largest amount of LCC seats in 2013 are highlighted bold).

IATA Code	Airport	MAS	Rank by LCC seats (2013)	IATA Code	Airport	MAS	Rank by LCC seats (2013)
ALC	Alicante (Elche)	Alicante	16	SEN	Southend	London	116
MJV	Murcia San Javier	Alicante	111	STN	Stansted	London	3
AMS	Schiphol	Amsterdam	11	LBA	Leeds Bradford	Manchester	49
EIN	Eindhoven	Amsterdam	42	LPL	Liverpool	Manchester	30
RTM	Rotterdam	Amsterdam	108	MAN	Manchester (Ringway)	Manchester	6
BCN	El Prat	Barcelona	1	BGY	Bergamo	Milan	8
GRO	Gerona	Barcelona	48	LIN	Linate	Milan	134
REU	Reus	Barcelona	139	MLP	Malpensa	Milan	12
BRU	Brussels Zaventem	Brussels	85	OSL	Oslo (Gardermoen)	Oslo	5
CRL	Charleroi	Brussels	20	RYG	Rygge	Oslo	62
CPH	Copenhagen (Kastrup)	Copenhagen	17	TRF	Torp (Sandefjord)	Oslo	92
MMX	Malmo	Copenhagen	120	BVA	Beauvais	Paris	33
EDI	Edinburgh	Glasgow	18	CDG	Charles de Gaulle	Paris	26
GLA	Glasgow Intl	Glasgow	36	ORY	Orly	Paris	15
PIK	Prestwick	Glasgow	101	XCR	Vatry	Paris	292
IST	Ataturk	Istanbul	158	CIA	Ciampino	Rome	27
SAW	Sabiha Gokcen	Istanbul	4	FCO	Fiumicino	Rome	19
LCY	London City	London	-	AGP	Malaga (Costa del Sol)	-	10
LGW	Gatwick	London	2	DUB	Dublin	-	9
LHR	Heathrow	London	135	MAD	Madrid Barajas	-	14
LTN	Luton	London	7	PMI	Palma de Mallorca	-	13

In the document review we collected information regarding two types of dynamics in the evolution of every airport: infrastructure-related and market-related dynamics. Infrastructure-related dynamics mostly focus on capacity expansion in the passenger buildings and the air-side facilities (runway system and aprons); as well as in the redevelopment of existing airports or construction of new greenfield airports. Market-related dynamics refer to external events affecting the aviation industry in a global or local context (such as the 2008 economic recession, or the opening of the Madrid – Barcelona High-Speed Rail line for airports in or near Madrid and Barcelona); management strategies (Malighetti et al., 2007) from the airports or airlines that affect their competitive position or their operations (such as mergers or acquisitions, change of strategic focus, creation of spin-off or start-up companies, opening or closing of bases or hubs); and vicissitudes that affect airline or airport operations (such as bankruptcies and legal disputes).

The 42 airports were studied by MAS in order to allow for an analysis of the impacts that events in one airport may have on the other airports of the MAS. Given the extent of the exercise, Annex A summarises the most relevant findings of the multiple-case study according to the type of dynamics examined for every airport system. Likewise, the next section highlights the outcomes of the analysis of traffic

evolution at the airports under study. Traffic evolution, besides the analysis shown in the next section, was examined on a carrier-by-carrier basis for each airport system over the period of analysis. Such details, however, are too extensive to be reproduced in this paper. Interested readers are referred to (Jimenez, 2015) for more information.

4 Traffic evolution at European airport systems

Table 2 shows traffic evolution at the 42 airports by MAS and type of airline (Non-LCC and LCC) between 2004 and 2013. Cell colours show the trends in growing or declining traffic for every segment in each MAS: Dark green backgrounds signal a large number of Non-LCC traffic (relative to the MAS) whilst dark orange signals a large number of LCC seats (also relative to the MAS). In every airport system low-cost traffic grew considerably from the levels of 2004. Yet in most cases of Multi-Airport Systems, low-cost traffic grew more significantly at the primary airports, to the point that the primary¹ airports had the largest share of LCC traffic in every MAS by 2013 as Table illustrates. Moreover, the prominent growth of LCCs made Brussels Charleroi (CRL) and Milan Bergamo (BGY) airports transition from secondary to primary airports in their respective MAS according to the definition set by Bonnefoy (2008).

Some airports had a clear change in focus as low-cost traffic filled the void of fewer legacy traffic, whether as an intended strategy where LCCs were actively promoted by airport management, as in the case of London Gatwick (LGW); or unintended as a result of the interaction of the different dynamics summarised in Annex A and described in more detail in the next section, as in the cases of Barcelona El Prat (BCN), Malaga (AGP), Alicante (ALC), Milan Malpensa (MXP), Edinburgh (EDI), and to a lesser extent Madrid (MAD), Palma de Mayorca (PMI), Rome Fiumicino (FCO), Copenhagen (CPH) and Paris Orly (ORY).

In Multi-Airport Systems the smaller airports usually provide less room for expansion, hence it was more common that low-cost traffic moved from secondary to primary airports in the MAS. This happened especially when there was capacity available at the primary airport even when such capacity was not intentionally built for LCCs. Table and Table show this evolution clearly for the MAS in Alicante and Barcelona. There were also cases in which primary airports provided sufficient capacity for LCCs to capture demand growth that was more difficult for FSCs to stimulate, as in Amsterdam (AMS), Paris Charles de Gaulle (CDG), Oslo (OSL) and Glasgow (GLA).

Secondary airports have played an important role in fostering the growth of LCCs, particularly in the initial phases that made the low-cost business model viable at large scale. Although in most cases secondary airports cannot provide the same levels of capacity than primary airports, some secondary airports were able to secure prime positions for low-cost traffic within their MAS. As pointed out above Milan Bergamo (BGY) and Brussels Charleroi (CRL) stand out in this regard, along with Paris Beauvais

¹ Bonnefoy (2008) considers primary airports those that handle over 20% of total traffic in a Multi-Airport System (secondary airports thus handle 20% or less). In the case of systems with a single airport that is naturally considered a primary one.

Table 2: Traffic evolution (available seats) by type of airline in the sampled airports. Source: Innovata.

IATA Code	MAS	Available seats (thousands)								Airport type
		Non-LCC				LCC				
		2004	2008	2012	2013	2004	2008	2012	2013	
ALC	Alicante	2.167	2.525	1.316	1.391	1.525	3.241	3.701	4.265	P
MJV		92	146	76	59	403	1.012	606	618	S
AMS	Amsterdam	24.183	25.505	25.080	25.583	1.707	3.586	4.772	4.935	P
EIN		174	41	25	6	161	844	1.777	2.029	S
RTM		664	200	123	304	0	475	573	666	S
BCN	Barcelona	15.830	13.599	9.424	8.113	1.703	8.051	13.745	13.815	P
GRO		66	116	40	33	1.501	3.337	1.813	1.807	S
REU		20	197	159	134	242	428	375	445	S
BRU	Brussels	9.087	11.816	11.126	11.199	1.302	1.072	1.073	1.041	P
CRL		25	24	328	396	1.258	1.750	3.765	3.832	P
CPH	Copenhagen	13.370	14.253	11.929	11.904	922	701	3.183	3.961	P
MMX		731	813	696	769	161	129	537	561	S
EDI	Glasgow	3.108	2.655	2.228	2.434	2.106	3.351	3.686	3.890	P
GLA		2.975	2.704	2.250	2.318	1.370	2.412	2.207	2.325	P
PIK		11	12	0	0	1.110	1.654	703	756	S
IST	Istanbul	9.394	16.543	29.235	32.353	35	111	321	342	P
SAW		0	1.059	1.805	3.288	43	1.336	6.232	7.938	P
LCY	London	1.619	3.320	2.508	2.673	119	0	0	0	S
LGW		10.245	12.509	9.005	8.726	3.366	7.662	11.151	11.944	P
LHR		46.024	46.634	45.570	46.847	106	146	421	473	P
LTN		170	351	308	323	4.042	5.944	5.492	5.470	S
SEN		1	0	64	48	0	3	371	582	S
STN		1.029	1.408	428	360	11.239	12.913	10.266	10.528	S
LBA	Manchester	582	535	303	361	761	1.420	1.626	1.802	S
LPL		209	28	17	0	1.623	3.436	2.904	2.749	S
MAN		7.388	8.512	7.126	7.160	1.389	3.609	5.013	5.635	P
BGY	Milan	362	362	142	139	1.519	3.752	5.237	5.238	P
LIN		5.184	6.376	6.112	5.817	579	277	617	479	P
MXP		11.679	9.793	6.449	6.262	333	2.850	5.288	4.882	P
OSL	Oslo	9.054	10.041	9.277	9.645	1.830	3.791	5.748	6.319	P
RYG		0	13	45	35	0	292	1.243	1.384	S
TRF		458	388	451	476	299	700	788	916	S
BVA	Paris	7	66	8	51	853	1.637	2.455	2.476	S
CDG		34.609	36.888	35.113	34.784	1.228	3.024	3.007	2.928	P
ORY		14.938	14.633	13.634	13.841	1.527	3.094	3.982	4.267	P
XCR		0	0	11	10	0	0	49	56	S
CIA	Rome	146	23	0	0	1.482	2.926	2.868	2.926	S
FCO		18.756	23.086	20.089	19.242	972	1.839	4.138	3.841	P
AGP	Malaga*	3.970	4.123	2.451	2.445	1.925	3.568	4.723	4.973	P
DUB	Dublin*	6.434	8.204	7.381	7.809	3.576	6.954	4.965	5.083	P
MAD	Madrid*	27.009	30.209	24.166	21.335	527	4.251	6.364	4.550	P
PMI	Palma*	6.569	10.236	7.723	7.588	1.107	2.297	4.588	4.824	P

Notes: * Single-airport system. Dark green indicates large number of Non-LCC seats in relation to the MAS. Dark orange indicates large number of LCC seats in relation to the MAS. Airport type according to Bonnefoy (2008) based on 2013 traffic: P = Primary (>

(BVA) and Rome Ciampino (CIA) to a lesser extent. Ciampino, however, is in fact a former primary airport that was able to attract low-cost traffic when all airlines moved to the then new primary airport in the MAS (Fiumicino – FCO).

Table 3. Evolution of LCC market shares in each airport and MAS. Source: Innovata.

IATA Code	MAS	Proportion of Available seats								Airport type
		Share of LCC traffic in the airport				Share of LCC traffic in the MAS				
		2004	2008	2012	2013	2004	2008	2012	2013	
ALC	Alicante	41,3%	56,2%	73,8%	75,4%	79,1%	76,2%	85,9%	87,3%	P
MJV		81,4%	87,4%	88,9%	91,3%	20,9%	23,8%	14,1%	12,7%	S
AMS	Amsterdam	6,6%	12,3%	16,0%	16,2%	91,4%	73,1%	67,0%	64,7%	P
EIN		48,1%	95,4%	98,6%	99,7%	8,6%	17,2%	25,0%	26,6%	S
RTM		0,0%	70,4%	82,3%	68,7%	0,0%	9,7%	8,0%	8,7%	S
BCN	Barcelona	9,7%	37,2%	59,3%	63,0%	49,4%	68,1%	86,3%	86,0%	P
GRO		95,8%	96,6%	97,8%	98,2%	43,6%	28,2%	11,4%	11,2%	S
REU		92,4%	68,5%	70,2%	76,9%	7,0%	3,6%	2,4%	2,8%	S
BRU	Brussels	12,5%	8,3%	8,8%	8,5%	50,9%	38,0%	22,2%	21,4%	P
CRL		98,1%	98,6%	92,0%	90,6%	49,1%	62,0%	77,8%	78,6%	P
CPH	Copenhagen	6,5%	4,7%	21,1%	25,0%	85,1%	84,5%	85,6%	87,6%	P
MMX		18,0%	13,7%	43,6%	42,2%	14,9%	15,5%	14,4%	12,4%	S
EDI	Glasgow	40,4%	55,8%	62,3%	61,5%	45,9%	45,2%	55,9%	55,8%	P
GLA		31,5%	47,1%	49,5%	50,1%	29,9%	32,5%	33,5%	33,4%	P
PIK		99,0%	99,3%	100,0%	100,0%	24,2%	22,3%	10,7%	10,8%	S
IST	Istanbul	0,4%	0,7%	1,1%	1,0%	44,9%	7,7%	4,9%	4,1%	P
SAW		100,0%	55,8%	77,5%	70,7%	55,1%	92,3%	95,1%	95,9%	P
LCY	London	6,8%	0,0%	0,0%	0,0%	0,6%	0,0%	0,0%	0,0%	S
LGW		24,7%	38,0%	55,3%	57,8%	17,8%	28,7%	40,3%	41,2%	P
LHR		0,2%	0,3%	0,9%	1,0%	0,6%	0,5%	1,5%	1,6%	P
LTN		96,0%	94,4%	94,7%	94,4%	21,4%	22,3%	19,8%	18,9%	S
SEN		0,0%	100,0%	85,3%	92,4%	0,0%	0,0%	1,3%	2,0%	S
STN		91,6%	90,2%	96,0%	96,7%	59,6%	48,4%	37,1%	36,3%	S
LBA	Manchester	56,7%	72,6%	84,3%	83,3%	20,2%	16,8%	17,0%	17,7%	S
LPL		88,6%	99,2%	99,4%	100,0%	43,0%	40,6%	30,4%	27,0%	S
MAN		15,8%	29,8%	41,3%	44,0%	36,8%	42,6%	52,5%	55,3%	P
BGY	Milan	80,8%	91,2%	97,4%	97,4%	62,5%	54,5%	47,0%	49,4%	P
LIN		10,0%	4,2%	9,2%	7,6%	23,8%	4,0%	5,5%	4,5%	P
MXP		2,8%	22,5%	45,1%	43,8%	13,7%	41,4%	47,5%	46,1%	P
OSL	Oslo	16,8%	27,4%	38,3%	39,6%	86,0%	79,3%	73,9%	73,3%	P
RYG		-	95,7%	96,5%	97,5%	-	6,1%	16,0%	16,1%	S
TRF		39,5%	64,3%	63,6%	65,8%	14,0%	14,6%	10,1%	10,6%	S
BVA	Paris	99,2%	96,1%	99,7%	98,0%	23,6%	21,1%	25,9%	25,5%	S
CDG		3,4%	7,6%	7,9%	7,8%	34,0%	39,0%	31,7%	30,1%	P
ORY		9,3%	17,5%	22,6%	23,6%	42,3%	39,9%	41,9%	43,9%	P
XCR		-	-	81,7%	84,8%	0,0%	0,0%	0,5%	0,6%	S
CIA	Rome	91,0%	99,2%	100,0%	100,0%	60,4%	61,4%	40,9%	43,2%	S
FCO		4,9%	7,4%	17,1%	16,6%	39,6%	38,6%	59,1%	56,8%	P
AGP	Malaga*	32,7%	46,4%	65,8%	67,0%	100,0%	100,0%	100,0%	100,0%	P
DUB	Dublin*	35,7%	45,9%	40,2%	39,4%	100,0%	100,0%	100,0%	100,0%	P
MAD	Madrid*	1,9%	12,3%	20,8%	17,6%	100,0%	100,0%	100,0%	100,0%	P
PMI	Palma*	14,4%	18,3%	37,3%	38,9%	100,0%	100,0%	100,0%	100,0%	P

Notes: * Single-airport system. Dark orange indicates a high share of LCC seats in relation to the airport or the MAS. Airport type according to Bonney (2008) based on 2013 traffic: P = Primary (> 20% of MAS traffic), S = Secondary (<= 20% of MAS traffic).

Interestingly, other airports that are usually considered as secondary within their MAS were actually intended to replace or extend capacity for legacy traffic in the cities they serve (London Stansted – STN – and Istanbul Sabiha Gokcen – SAW, for instance). As the expected traffic did not materialise, LCCs were better fit to use these facilities.

These developments were contrasted with the results of the cluster analysis. In order to be able to replicate the data available (Table) and focus on the relative position of LCCs in each airport, we produced seven input variables. Three of them were the same but on two different periods (2004 and 2013): the market share of primary airports in the MAS, the market share of LCCs at primary airports in the MAS, and the market share of LCCs at secondary airports in the MAS. The other variable was the traffic (available seats) growth rate in each MAS between 2004 and 2013.

Given that traffic growth at Istanbul MAS was extraordinary during the period of analysis (364%), compared to the rest of MAS, different combinations were tested for the cluster analysis. Several clusters were produced considering all airports and not considering the growth variable, whilst varying the number of clusters; and again considering all variables and considering Istanbul as an outlier. The significance of the results was first contrasted against the findings in the multiple-case study for all the airports and it was more satisfactory when Istanbul MAS was included. Then validity indexes to select the appropriate number of clusters were calculated for every alternative. As Table shows, four clusters deliver the best performance for Dunn and silhouette indexes.

Table 4. Values of Dunn and Silhouette indexes to select number of clusters.

Number of clusters	Dunn index	Silhouette index
3	0,686	0,605
4	1,669	0,738
5	1,289	0,408

Table shows the airport systems included in each of the clusters selected. Based on the findings of the multiple-case study summarised in Annex A, Table also presents a qualitative description of each cluster, as well as the mechanisms of low-cost traffic evolution that were deduced from the mixed quantitative/qualitative approach. The mechanisms are further detailed in the next section.

Table 5: Clusters of airport systems according to low-cost traffic evolution.

Cluster	MAS	Description	Mechanisms
1	Alicante	MAS where primary airport(s) reacted to LCC growth in secondary airport(s) and developed a stronger position in the MAS due to fostering low-cost growth mainly through infrastructure expansion that was not intended for LCCs	I1,M1
1	Barcelona		I1,M1
1	Glasgow		I1,M1
1	Manchester		M1,I1
2	Brussels	MAS where where secondary airport(s) gained and sustained a strong position in the MAS due to fostering low-cost growth. Primary airport(s) reacted by allowing LCCs and secondary airport(s) remained strong in the MAS	I3
2	Istanbul		I2
2	London		I3,M1
2	Milan		I3,M1
2	Paris		I3
2	Rome		I2,M1
3	Amsterdam		I2
3	Copenhagen	MAS where primary airport allowed (but not straightforward fostered) LCC growth focused on more hybrid LCCs. Secondary airport(s) captured ultra-LCCs	I2,M1
3	Oslo		I2,M1
4	Malaga		I1,M1
4	Dublin	Single-Airport Systems subject to strong market dynamics that jeopardised the position of the major FSC users and LCCs replaced legacy carriers and captured growth using infrastructure expansion not intended for LCCs	I1,M1
4	Madrid		I1,M1
4	Palma		M1,I1

Mechanisms:

I1 – Capacity expansion at primary airports

I2 – New/emerged primary airport

I3 – New/emerged secondary airport

M1 – Market dynamics

5 Mechanisms of low-cost traffic evolution at European airports

Despite the particular characteristics that make every case unique, we used the 42 case studies to identify four generic mechanisms that trigger distinctive patterns of traffic evolution. Three of them relate to infrastructure dynamics: i) Capacity expansion at primary airports, ii) new/emerged primary airports, and iii) new/emerged secondary airports². The fourth mechanism is directly related to the market dynamics occurring in the airport system. The mechanisms normally occurred in a combination of infrastructure plus market dynamics to produce a given outcome or traffic pattern.

5.1 Capacity expansion at primary airports (I1)

The first mechanism relates to the implementation of a major capacity expansion at a primary (or at the only) airport in the system. In this case low-cost traffic is typically promoted because the airport is unable to attract the foreseen growth in non-LCC traffic that had justified the expansion (see Fig. 1). Given that additional capacity is deployed in discrete amounts, some airports invest in large expansions, based on long-term forecasts that are highly uncertain.

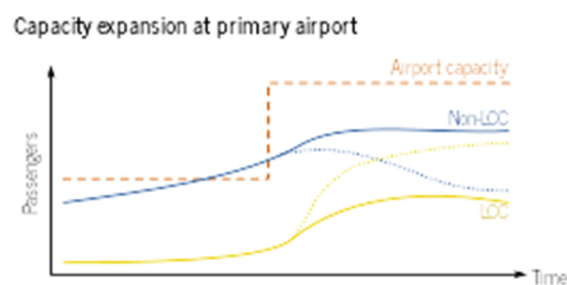


Fig. 1. Typical traffic patterns at a primary airport before and after considerable capacity expansion.

When investments are realised (typically 2 to 6 years after construction started depending on the scale of the project, and 5 to 15 years after planning – i.e. forecasting – started) external conditions that affect demand are different (as in the case of Spanish airports in which most major expansions opened amid economic recession). If expected demand does not occur, unused facilities with high fixed costs become a burden for the airport operator. LCCs (and in particular the largest European LCCs) have large fleets that can be deployed quickly and flexibly to stimulate demand with low fares and occupy the new space. This pattern is more visible when capacity was added by building new separate passenger buildings. The old ones either close or attract LCCs.

If demand for traditional airlines effectively grow but not at the expected rate, the marginal cost of providing capacity for LCCs is much lower than before the expansion, when the airport was more congested. In this case LCCs can also thrive at the airport by exploring new markets with higher yields.

² New secondary airports may become primary (as per Bonnefoy, 2008) if they concentrate enough traffic growth, as in the case of Brussels Charleroi (CRL) and Milan Bergamo (BGY).

5.2 New/emerged primary airports (I2)

The second mechanism involves the emergence of a new primary airport in the region, not necessarily a greenfield project as major redevelopment of former facilities can also be considered. When, in a given airport system, a new primary airport is built (or an existing airport is extensively redeveloped to become a primary airport), there are typically two patterns of evolution according to whether the new/emerged airport is able to capture traffic or not (see Fig. 2).

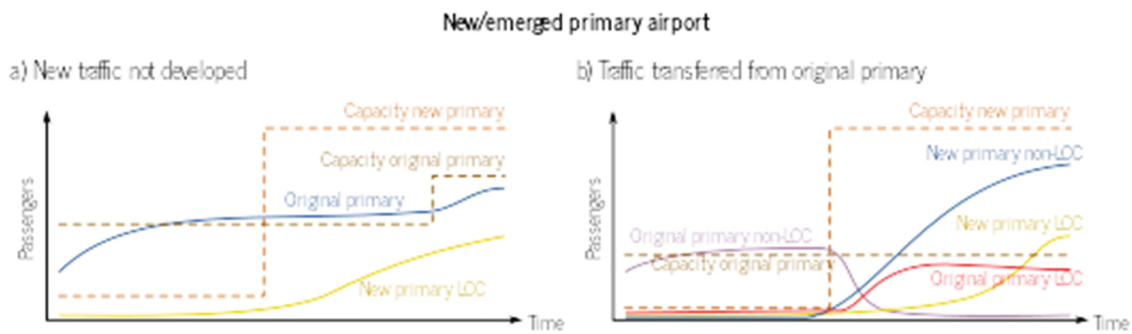


Fig. 2. Typical traffic patterns when a new or redeveloped primary airport emerge.

In the first case (Fig. 2 left) the new airport opens, the old one is not closed, and its traffic is not forced to transfer to the new location. As traffic does not materialise in the new facilities, the airport operator needs to increase revenues to balance high fixed costs and LCCs become a natural option for the airport to foster growth. In the meantime, capacity at the original primary airport may be increased to cope with congestion. Eventually, some LCCs may operate from the original primary airport as well, especially through acquisitions or mergers, whilst some non-LCC carriers may also use the new/emerged airport, especially foreign FSCs or charters.

London Stansted (STN) and Istanbul Sabiha Gokcen (SAW) are the best examples of this pattern. Built to alleviate congestion in other primary airports, STN and SAW only grew to prominence when LCCs started regular services.

In the second case (Fig. 2 right) traffic is transferred from the original primary airport to the new development, but the old airport is not dismantled. Eventually, low-cost traffic may develop almost exclusively in the original primary airport (which can become a secondary one if traffic at the new primary grows considerably) but limited to the available capacity. When capacity is reached, the airport is not expanded (usually there is no space to do it, this being the reason for the new development) and some LCCs can go to the new/emerged primary airport to continue growing. The Rome MAS illustrates this case very well. Fiumicino (FCO) was built to replace Ciampino (CIA) as the main airport, after some years empty CIA turned a secondary airport for LCCs but then most LCCs started expanding at FCO when capacity limits were reached at CIA.

It may also happen that the original primary airport gets closed and dismantled (as in Oslo or as it is planned for Berlin). The new airport can be designed with different types of traffic in mind and thus allow space for the growth of LCCs. Or, especially when the new location becomes inconvenient for some

travellers (as in the case of Oslo), the new primary airport can foster the (re)development of secondary airports that mainly target LCCs.

Sometimes the new primary airport does not capture any traffic at all. Montreal Mirabel Airport is perhaps the most renowned case. Examples in Europe are not uncommon though: the 1.1 billion Euro Ciudad Real Airport (intended to be South Madrid Airport) opened in December 2008 and closed in 2012 with less than 100 000 passengers over that period; the Region de Murcia International Airport, also in Spain, has not seen its first passenger despite construction ended in 2012; opening of Berlin Brandenburg has been severely delayed and it is not expected to happen soon.

5.3 New/emerged secondary airports (I3)

The third mechanism relates to the emergence of a new, or existing but underused, secondary airport in the region served by an existing primary airport. In this case the emerging airport typically attracts mostly low-cost traffic (see Fig. 3). In many cases, secondary airports accompanied the initial expansion of LCCs and their developers provided incentives or better opportunities to capture that market (as in Charleroi, Luton, Liverpool, Bergamo, Beauvais, for instance). For start-up LCCs, these airports offered a lower cost but also lacked congestion and had simple layouts that favoured streamlined efficient operations.

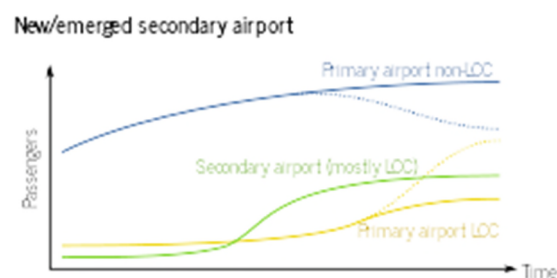


Fig. 3. Typical traffic patterns when a new or redeveloped secondary airport emerge.

Emerged secondary airports can also foster the growth of LCCs at the primary airport mainly by raising awareness of competition between airlines and between airports. Thus, as Fig. shows, low-cost traffic at the primary airport may become more important than at the secondary airport, particularly when LCCs with a more hybrid proposition come to the primary airport. In addition, if non-LCC carriers cannot sustain competition from their low-cost counterpart, the significance of LCC traffic at the primary airport can also increase as these airlines downsize their operations.

Secondary airports may also fail to attract traffic, thus facing closure or downscaling, transferring part of their LCC traffic to primary airports (or to other secondary airports). Paris Vatry (XCR), for instance, has not been able to establish significant operations since its redevelopment. Forli Airport, in Italy, went bankrupt in 2013 and most flights moved to Rimini and Bologna nearby. Hamburg Lubeck, filed for bankruptcy in early 2014 and ended commercial services by 2016. Beja Airport, located in between Lisbon and the Algarve in Portugal, opened in 2011 aiming at attracting LCCs but has not attracted any regular scheduled operator to date.

5.4 Market dynamics (M1)

The fourth mechanism involves the occurrence of market dynamics at a given primary or secondary airport affecting either the airlines that use the airports or the airports themselves. Market dynamics imply changes in the traffic mix of the airport system that are not directly related to changes in the infrastructure. These include new LCC start-ups, changes in the commercial focus of a major airline (from FSC or charter to LCC, or vice versa, for instance) at the airport, or of the airport itself (due to change in ownership or management); bankruptcy or downscaling of a major airline (de-hubbing, for instance); and mergers or acquisitions.

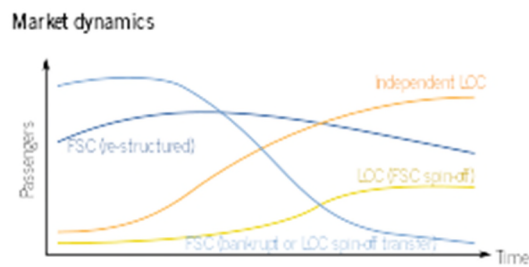


Fig. 4. Typical traffic patterns after market disruptions.

Fig. 4 shows the typical traffic pattern that leads to strengthened position of LCCs at an airport following market-related dynamics. The overall growth of LCCs in Europe increased competition with traditional 'legacy' and charter carriers, and this in turn added pressure for these airlines to control their costs and, in many cases, to restructure and concentrate their operations. For many small regional airports this meant that LCCs were the only viable alternative to sustain traffic. Other major airports changed their attitude towards LCCs as the airlines they were used to serve gradually (or suddenly in some cases) vanished or transformed themselves.

As Fig. 4 illustrates, typically LCCs are keen to substitute the void left by 'legacy' carriers that went bankrupt. Moreover, 'legacy' carriers may replace themselves with their in-house LCC subsidiaries to focus on their hubs for long-haul traffic. The major independent LCCs (Ryanair, easyJet, Norwegian, Vueling before IAG acquisition, or Wizz Air, for instance) usually gain larger market shares because they have larger fleets and better financial positions to fund expansion.

5.5 Stages of dynamic airport evolution in relation to low-cost traffic

The different mechanisms described above normally occur in combination accelerating or increasing the impact of low-cost traffic evolution at the airports that belong to the same airport system. Fig. illustrates the possible stages of the dynamic evolution of airport systems as a result of the identified mechanisms occurring in the airports.

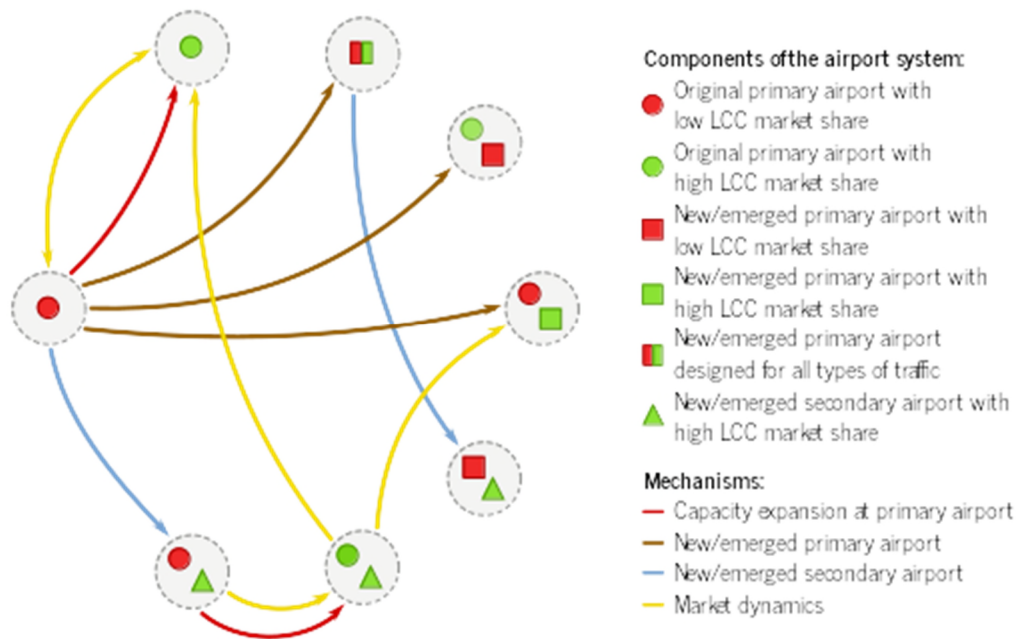


Fig. 5. Conceptualisation of the dynamic evolution for airport systems in relation to low-cost traffic.

Considering an initial state in which the airport system is composed of an original primary airport where low-cost traffic is not relevant (not necessarily a single airport. London, for instance, had Heathrow and Gatwick before the development of Luton, Stansted, City and Southend), the system evolves into different stages as the mechanisms trigger different traffic patterns. The stages are defined by the airports included in the system and the level of low-cost traffic in each airport.

Once the airport system transitions to a new stage, market dynamics are the main mechanism through which the system can reach a different stage. Alternatively, any new state can be considered as an initial state for the future evolution of the system according to the development of the market conditions and the regulatory environment that is uncertain. Perhaps the most likely transition from any state with more than one airport is related to closing airports to concentrate all traffic segments in a single airport (as in Berlin, whenever the new airport opens). Likewise, the most likely transition from a state involving one airport is the expansion of the airport system by developing emergent airports possibly focused on a given type of traffic (not necessarily low-cost, as airline business models may evolve in different directions in the long-term).

6 Conclusions and policy implications

LCCs in Europe have significantly impacted both major and secondary airports. By analysing historical traffic and the key recent events that affected the evolution of 42 European airports, 38 of them part of Multi-Airport Systems, this paper proposed a conceptual model to explain the dynamic evolution of airport systems in relation to low-cost traffic. Four mechanisms normally trigger different stages of low-cost traffic development: i) Capacity expansion at primary airports; ii) New/emerged primary airports; iii) New/emerged secondary airports; and iv) Market dynamics.

The first three mechanisms are related to the development of physical infrastructure that encouraged the growth of LCCs, even when not aimed directly at them. The fourth mechanism involves the occurrence of events that affect either the airlines that use the airports or the airports themselves (e.g. bankruptcies, mergers and acquisitions, change of strategy focus, emergence of start-up or spin-off airlines, creation or abandonment of bases or hubs, etc.).

More research is needed to conclude on the causality of the interactions between the mechanisms. Some cases suggest that infrastructure-related dynamics trigger market dynamics. In Barcelona or Alicante, for instance, the new passenger buildings provided sufficient capacity for LCCs to move and grow strongly in the primary airports. However, these two openings, particularly in Barcelona El Prat, occurred amid harsh economic times. Under such conditions, traditional carriers were already struggling to provide service, let alone to expand, and airports were eager to start repaying their investments. Common ownership of most Spanish commercial airports hinders this analysis in the sense that market dynamics could have been different should the management of every airport in the MAS be able to respond independently.

This paper contributes a dynamic perspective that is usually missing in existing analysis on the impact LCCs have had at European airports. Understanding the dynamics that impact the evolution of airport systems is paramount in forecasting uncertain future traffic levels in an industry with strong variability due to LCC entrance and withdrawal. Our findings highlight the need for a new paradigm in airport strategic development that incorporates the planning and design of infrastructure, along with the definition of a corresponding business strategy. Encompassing infrastructure and business plans, airport planners and managers can aim at ensuring long-term sustainability.

Moreover, understanding the dynamics that we identified and the interaction between them may prove valuable for policy making. As some European regions keep promoting the development of air transportation as a means to foster local economies, it is crucial to understand that infrastructure provision alone cannot guarantee a desired outcome. Moreover, infrastructure developments in one airport may greatly influence the evolution of traffic (and jobs, tourism and commercial opportunities) in other airports, even when airport competition is not explicitly considered. This points out to the importance of considering uncertainty in airport strategic planning, as infrastructure may become available under conditions that are radically different than those initially foreseen.

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References

- Abda, M. B., Belobaba, P. P., & Swelbar, W. S. (2012). Impacts of LCC growth on domestic traffic and fares at largest US airports. *Journal of Air Transport Management*, 18(1), 21–25.
<https://doi.org/10.1016/j.jairtraman.2011.07.001>
- AENA. (2014). Estadísticas - Aeropuertos Españoles y Navegación Aérea. Retrieved 1 August 2014, from <http://www.aena-aeropuertos.es/csee/Satellite?pagename=Estadisticas/Home>
- Barbot, C. (2006). Low-cost airlines, secondary airports, and state aid: An economic assessment of the Ryanair–Charleroi Airport agreement. *Journal of Air Transport Management*, 12(4), 197–203. <https://doi.org/10.1016/j.jairtraman.2006.04.001>
- Barret, S. D. (2004). How do the demands for airport services differ between full-service carriers and low-cost carriers? *Journal of Air Transport Management*, 10(1), 33–39.
<https://doi.org/10.1016/j.jairtraman.2003.10.006>
- Bonnefoy, P. (2008). *Scalability of the air transportation system and development of multi-airport systems: A worldwide perspective* (Doctor Of Philosophy in Engineering Systems). Massachusetts Institute of Technology, Cambridge. Retrieved from <http://hdl.handle.net/1721.1/46800>
- CAA. (2014). UK Airport Statistics | Aviation Intelligence | About the CAA. Retrieved 29 August 2014, from <http://www.caa.co.uk/default.aspx?catid=80&pagetype=88&pageid=3&sglid=3>
- Copenhagen Economics. (2012). Airport competition in Europe. ACI Europe.
- de Neufville, R. (1995a). Management of multi-airport systems: A development strategy. *Journal of Air Transport Management*, 2(2), 99–110. [https://doi.org/10.1016/0969-6997\(95\)00035-6](https://doi.org/10.1016/0969-6997(95)00035-6)
- de Neufville, R. (1995b). Policy Guidelines for the Option of a Development of a Multi-Airport System, the basis of a Dynamic Strategic Plan to provide the capability for flexible response to future challenges. Report Prepared for Amsterdam Airport Schiphol, Netherlands. Retrieved from http://ardent.mit.edu/airports/ASP_papers/multi-

airport%20systems%20policy%20guidelines.PDF

de Neufville, R. (2008). Low-Cost Airports for Low-Cost Airlines: Flexible Design to Manage the Risks. *Transportation Planning and Technology*, 31(1), 35–68.

<https://doi.org/10.1080/03081060701835688>

de Neufville, R., & Odoni, A. R. (2003). *Airport systems: planning, design, and management*. New York: McGraw-Hill.

Dobruszkes, F. (2006). An analysis of European low-cost airlines and their networks. *Journal of Transport Geography*, 14(4), 249–264.

<https://doi.org/10.1016/j.jtrangeo.2005.08.005>

Dobruszkes, F. (2009). New Europe, new low-cost air services. *Journal of Transport Geography*, 17(6), 423–432. <https://doi.org/10.1016/j.jtrangeo.2009.05.005>

Dobruszkes, F. (2013). The geography of European low-cost airline networks: a contemporary analysis. *Journal of Transport Geography*, 28(0), 75–88.

<https://doi.org/10.1016/j.jtrangeo.2012.10.012>

Dobruszkes, F., Givoni, M., & Vowles, T. (2017). Hello major airports, goodbye regional airports? Recent changes in European and US low-cost airline airport choice. *Journal of Air Transport Management*, 59, 50–62.

<https://doi.org/10.1016/j.jairtraman.2016.11.005>

Dunn, J. C. (1974). Well-separated clusters and optimal fuzzy partitions. *Journal of Cybernetics*, 4(1), 95–104.

European Parliament. (2007). The consequences of the growing European low-cost airline sector. Directorate-General for Internal Policies of the Union. Retrieved from <http://www.europarl.europa.eu/activities/expert/eStudies.do?language=EN>

Forgy, E. (1965). Cluster analysis of multivariate data: efficiency versus interpretability of classifications. *Biometrics*, 21, 768–769.

Francis, G., Fidato, A., & Humphreys, I. (2003). Airport–airline interaction: the impact of low-cost carriers on two European airports. *Journal of Air Transport Management*, 9(4), 267–273. [https://doi.org/10.1016/S0969-6997\(03\)00004-8](https://doi.org/10.1016/S0969-6997(03)00004-8)

Francis, G., Humphreys, I., & Ison, S. (2004). Airports' perspectives on the growth of low-cost airlines and the remodeling of the airport–airline relationship. *Tourism Management*,

25(4), 507–514. [https://doi.org/10.1016/S0261-5177\(03\)00121-3](https://doi.org/10.1016/S0261-5177(03)00121-3)

Franke, M. (2004). Competition between network carriers and low-cost carriers—retreat battle or breakthrough to a new level of efficiency? *Journal of Air Transport Management*, 10(1), 15–21. <https://doi.org/10.1016/j.jairtraman.2003.10.008>

Gillen, D., & Lall, A. (2004). Competitive advantage of low-cost carriers: some implications for airports. *Journal of Air Transport Management*, 10(1), 41–50. <https://doi.org/10.1016/j.jairtraman.2003.10.009>

Graham, A. (2013). Understanding the low cost carrier and airport relationship: A critical analysis of the salient issues. *Tourism Management*, 36, 66–76. <https://doi.org/10.1016/j.tourman.2012.11.011>

Graham, B., & Shaw, J. (2008). Low-cost airlines in Europe: Reconciling liberalization and sustainability. *Geoforum*, 39(3), 1439–1451. <https://doi.org/10.1016/j.geoforum.2007.12.006>

IATA. (n.d.). Innovata the SRS Provider. Retrieved 31 July 2014, from <http://www.iata.org/publications/srs/Pages/innovata.aspx>

Jimenez, E. (2015). *Airport strategic planning in the context of low-cost carriers ascendancy: insights from the European experience* (PhD Thesis). Universidade do Porto, Porto, Portugal. Retrieved from <http://repositorio-aberto.up.pt/handle/10216/78345>

Jimenez, E., Claro, J., & Pinho de Sousa, J. (2013). The airport business in a competitive environment. *European Journal of Transport and Infrastructure Research*, 13(4), 315–335.

Lloyd, S. (1982). Least squares quantization in PCM. *IEEE Transactions on Information Theory*, 28(2), 129–137. <https://doi.org/10.1109/TIT.1982.1056489>

Malighetti, P., Paleari, S., & Redondi, R. (2008). Connectivity of the European airport network: ‘Self-help hubbing’ and business implications. *Journal of Air Transport Management*, 14(2), 53–65. <https://doi.org/10.1016/j.jairtraman.2007.10.003>

Malighetti, P., Paleari, S., & Redondi, R. (2009). Pricing strategies of low-cost airlines: The Ryanair case study. *Journal of Air Transport Management*, 15(4), 195–203. <https://doi.org/10.1016/j.jairtraman.2008.09.017>

Malighetti, P., Redondi, R., Martini, G., & Paleari, S. (2007). An empirical investigation on the

efficiency, capacity and ownership of Italian airports. *Rivista Di Politica Economica*.

Retrieved from

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.586.1925&rep=rep1&type=pdf>

Martini, G., Manello, A., & Scotti, D. (2013). The influence of fleet mix, ownership and LCCs on airports' technical/environmental efficiency. *Transportation Research Part E: Logistics and Transportation Review*, 50, 37–52. <https://doi.org/10.1016/j.tre.2012.10.005>

Pels, E., Njegovan, N., & Behrens, C. (2009). Low-cost airlines and airport competition. *Transportation Research Part E: Logistics and Transportation Review*, 45(2), 335–344. <https://doi.org/10.1016/j.tre.2008.09.005>

Rousseeuw, P. J. (1987). Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, 20, 53–65.

Zhang, A., Hanaoka, S., Inamura, H., & Ishikura, T. (2008). Low-cost carriers in Asia: Deregulation, regional liberalization and secondary airports. *Research in Transportation Economics*, 24(1), 36–50. <https://doi.org/10.1016/j.retrec.2009.01.001>

Annex A – Summary of the multiple-case study: Major events at sampled airports over the period of study (2004 - 2013)

MAS	Airport	Infrastructure dynamics	Market dynamics
Alicante	ALC	2007 – New passenger building T2 opened 2011 – New passenger building TN opened (declared capacity 20 million annual passengers)	2002 – easyJet acquired Go (British Airways LCC spin-off) and became major airline at ALC 2007 – Ryanair started operations and opened a base 2009 – Decline in total passengers due to economic downturn 2011 – 2012 – Legal dispute between Ryanair and AENA over the use of jet bridges (-1 million passengers for Ryanair in 2012 vs. 2011) 2012 – 2013 – Dispute settled (+0,3 million passengers for Ryanair in 2013 vs. 2012) 2013 – Iberia abandons ALC. Replaces services with Iberia Express then with Air Nostrum
	MJV	2004 – Passenger building expansion 2006 – Passenger building expansion 2011 – New runway opened exclusively for military operations	2007 – Ryanair concentrated growth at ALC 2011 – Jet2.com concentrated growth at ALC
Amsterdam	AMS	2003 – New runway 18R/36L (Polderbaan) opened (mostly for noise control considerations) 2005 – “Low-cost pier” (H/M) opened (Transavia does not use it)	2005 – Transavia (Holland) converts from charter airline to LCC
	RTM	Expansions opportunities are limited due to lack of space available in airport location	2005 – Transavia (Holland) converts from charter airline to LCC 2004 – 2013 Business service to LHR and LCY changed operator: from KLM to Air France to British Airways and City jet
	EIN	2003 – New passenger building opened (declared capacity: 1,5 million annual passengers) 2013 – Passenger building expansion opened (declared capacity: 5 million annual passengers)	2002 – Ryanair started operations 2005 – Transavia (Holland) converts from charter airline to LCC 2013 – Ryanair opens base
Barcelona	BCN	2003 – Expansion of passenger buildings TA and TB 2004 – New runway opened 2007 – New building to connect terminals TA and TB opened 2008 – Expansion of passenger building TC opened 2009 – New passenger building T1 opened (declared capacity: 55 million annual passengers). Buildings TA, TB and TC rebranded T2. T2A closed. Vueling moved operations to T1, all other LCCs use T2.	2004 – Vueling starts as independent LCC 2006 – Iberia transfer all flights but “airbridge” MAD – BCN to LCC spin-off Clickair 2007 – BCN – MAD was the busiest route in the world (971 flights per week in both directions according to OAG) 2007 – Air Europa reduced services to focus on hub development at MAD 2008 – AVE High-Speed Rail line Barcelona – Madrid opened in February 2008 – Economic recession affected passenger numbers 2009 – Merger between Vueling and Clickair (Iberia acquires stake at Vueling) 2010 – Ryanair opens base 2012 – Spanair (Catalonia’s FSC) goes bankrupt 2013 – IAG (British Airways + Iberia) takes over Vueling entirely
	GRO	(No major expansions during the analysis period)	2002 – Ryanair enters the Spanish market with services at GRO 2004 – Ryanair opens base 2011 – Ryanair downsizes base
	REU	2005 – New arrivals building 2008 – New “check-in building” connecting arrivals and departures buildings 2009 – Apron expansion for new aircraft stands 2010 – New boarding area	2008 – Ryanair opens base 2011 – Ryanair closes base
	BRU	2007 – Plan to develop “low-cost pier” announced 2011 – Plan to develop “low-cost pier” abandoned	2001 – Sabena went bankrupt ((became SN Brussels) 2006 – SN Brussels and LCC Virgin Express merge to form Brussels Airlines
	CRL	2008 – New passenger building and apron extension opened (declared capacity: 5 million annual passengers)	1997 – Charleroi becomes one of the first four Ryanair destinations in continental Europe 2001 – Ryanair opens its first base in continental Europe following an agreement with the Walloon government 2004 – WizzAir start services

MAS	Airport	Infrastructure dynamics	Market dynamics
Copenhagen	CPH	2010 - CPH Go “low-cost terminal” (a pier within a terminal actually) opened (Norwegian does not use it)	2008 – Sterling Airlines went bankrupt and Norwegian established a major base
	MMX	(No major developments)	2012 – Cimber (Air/Sterling) went bankrupt 2007 – 2011 – Ryanair suspended all services
Glasgow	GLA	2004 – New passenger building “Terminal 2” opened (departures-only) 2008 – Major expansion of “Terminal 1” opened	(No major events)
	EDI	2006 – New “South East pier” opened (6 boarding gates) 2010 – New departure lounge in main passenger buildings 2013 – Terminal expansion and tram line to the airport started construction (opened in 2014)	2012 – BAA was forced to sell out EDI. Acquired by GIP, owners of London Gatwick and London City at the moment
	PIK	2005 – Passenger building refurbished	- Sold to private investors in the 1980’s 1994 – Airport railway station opened 1994 – Ryanair start services 2013 – Airport acquired by Scottish government from private owners that were considering closing it. Ryanair, the only passenger airline reduced services but uses the airport as a major maintenance base
	IST	2000 – New passenger building - International terminal (declared capacity: 20 million annual passengers) 2010 - “International terminal” expansion opened (new declared capacity: 45,5 million annual passengers)	2004 – 2013 – Turkish airlines tripled seats offer at IST 2005 – Airport concessioned to TAV
Istanbul	SAW	2001 – New (greenfield) airport opened (declared capacity: 3,5 million annual passengers) 2009 – New passenger building and apron (declared capacity: 25 million annual passengers)	2005 – Pegasus airlines converts to LCC and adopted SAW as its main base 2008 – 20-year airport concession to ISG started 2013 – Turkish Airlines opens a base for non-connecting traffic
	LHR	2005 – Eastern extension of Terminal 1 2006 – A380 pier at Terminal 3 2008 – New passenger building and air-side and land-side infrastructure (Terminal 5) 2014 – New Terminal 2	2012 – IAG (British Airways + Iberia) acquired bmi and integrated it into British Airways. Bmi regional was sold and bmi baby (the low-cost subsidiary was closed down)
London	LGW	2005 – New “Pier 6”	2002 – easyJet opens base 2008 – easyJet acquired GB Airways 2009 – BAA is forced to sell the airport, acquired by GIP 2010 – New “airport strategy” with stronger focus on LCC along with long-haul traffic 2013 – easyJet acquired all of Flybe slots at LGW
	STN	1991 – New passenger building and overall airport redevelopment with railway station and satellite terminals connected with an automated people mover (estimated capacity: 35 million annual passengers) 2008 – Expansion and renovation of the arrivals area in the main passenger building	1991 – Ryanair started services 1997 – Ryanair transfers its main London base from Luton to start expansion in continental Europe 2002 – easyJet acquired Go (British Airways LCC spin-off) and gained a base at the airport 2008 – Dispute between Ryanair and BAA over airport charges 2013 – BAA forced to sell STN, acquired by Manchester Airports Group 2013 – Manchester Airports Group signs individual agreements with Ryanair and easyJet
	LCY	(No major expansions)	2013 – easyJet acquired all of Flybe slots at LGW. Flybe moved to LCY from 2014. LCY is owned by GIP, same owner of LGW
	LTN	1992 – 1996 – Major renewal of airport infrastructure 1999 – New passenger building and railway station (1,8 km from the terminal) 2005 – Passenger building expanded and renovated	1986 – Ryanair started services 1995 – easyJet is created with headquarters in Luton 1998 – Luton Borough Council granted a 30-year concession the airport to a private consortium (WizzAir has made Luton one of its major airports without being a formal base)
	SEN	2011 – New control tower and railway station 2012 – New passenger building and runway extension 2014 – Passenger building expansion	2008 – Sobart Group acquired the airport 2012 – easyJet opens base 2012 – Stobart Air (partly owned by airport owner) starts services (first on behalf of Aer Lingus then of Flybe)
	MAN	2001 – New runway opened 2004 – New railway station opened 2009 – Improvements across the three terminals	2012 – bmi acquired by IAG and integrated it into British Airways 2008 – easyJet acquired GB Airways 2011 – Ryanair opens base

MAS	Airport	Infrastructure dynamics	Market dynamics
Milan	LPL	2002 – New passenger building opened	1997 – easyJet opens its second base after Luton 2004 – Ryanair opens base
		(No major developments)	2003 – Jet2.com is created as a spin-off from freight and charter carrier Channel Express
	LBA		2007 – Airport privatised 2010 – Ryanair opens base
	MXP	1998 – New passenger building “Terminal 1” opened, part of “Malpensa 2000” plan for a hub in the region	1998 – Alitalia established main hub at MXP 2005 – easyJet starts services
		2013 – New satellite terminal for Terminal 1	2006 – “Terminal 2” dedicated as “low-cost terminal” and easyJet opens base. The airline is the sole user of “Terminal 2” and the largest airline at MXP since Alitalia’s dehubbing 2008 – Alitalia moved its main hub back to Rome Fiumicino 2009 – 2011 Lufthansa created “Lufthansa Italy” with a hub at MXP. The subsidiary transferred back operations to the parent airline in October 2011
		(No major expansions)	The airport was due to reduce its services (all but a shuttle service to Rome) after MXP renovation in 1998. This downscaling was never realised.
	LIN		
	BGY	2005 – Parking lot expansion and aviation equipment improved	2002 – Ryanair started services
		2007 – Refurbishment of check-in area and baggage handling system	2003 – Ryanair opens base (by 2013 it was the largest base in continental Europe)
		2009 – Extension and renewal of departures area 2010 – Passenger building expansion increasing boarding gates and commercial space air-side	The airport holds a long-term agreement with Ryanair (until 2022)
Oslo	OSL	1998 – New (greenfield) airport opened (old Oslo Airport Fornebu closed and was dismantled) 2012 – “Pier South” opened (intended as a temporary extension whilst work progress on a major expansion)	Largest base for Norwegian
	RYG	2007 – Airport redevelopment (from former exclusive military use) opened (declared capacity: 2 million annual passengers)	2008 – Norwegian opens base, closed in 2012. Services moved to TRF 2010 – Ryanair opens base 2016 – Airport closed to civilian use after Ryanair closed the based and moved back to TRF
	TRF	2003 – New international terminal opened	1997 – Ryanair started services. Moved partly to RYG in 2010
	CDG	2003 – Passenger building Terminal 2E opened (part of its boarding dock collapsed and reopened in 2008) 2007 – Automated People Mover (CDGVAL) opened (connects main passenger buildings except 2G) 2007 – Satellite 3 of Terminal 2E (Hall L) opened 2008 – Terminal 2G dedicated to regional flights in small aircraft opened 2009 – Terminal 1 renovation 2012 – Connecting building between Terminal 2A and Terminal 2C opened 2012 – Satellite 4 of Terminal 2E (Hall M) opened	Terminal 3 is referred as “low-cost terminal”. It is used mainly by charters and small LCCs. easyJet, the largest LCC at CDG (sixth largest base for the carrier) uses other terminal.
Paris	ORY	2006 – Renovation of Hall 2 in Terminal Ouest (West) 2007 – 2008 – Renovation of Terminal Sud (South) 2013 – RATP tram line T7 opens connecting the airport to metro line 7 and suburbs in South Paris	2007 – Transavia France (Air France LCC spin-off and sister company of Transavia Holland) starts operations based at ORY
	BVA	2010 – Passenger building “Terminal 2” opened	1997 – Ryanair start services to continental Europe after market liberalisation, BVA was one of the initial four destinations (The airport is not a base for any airline)
	XCR	2000 – Airport redeveloped to focus on cargo traffic 2004 – New passenger building intended for LCCs opened	(No major events)
	FCO	(FCO opened in the 1960’s to replace CIA, which lacked expansion opportunities. CIA remained open for charters and general aviation, and later LCCs) 2008 – “Terminal 5” opened (only departures to US and Israel in some airlines)	2008 – easyJet moved all its flights from CIA to FCO 2008 – Vueling starts services 2008 – Air One and Alitalia merge 2012 – Vueling opens base 2013 – Ryanair opens base
Rome	CIA	2007 – ENAC (Italian civil aviation authority) capped the number of flights per day allowed at CIA to control noise (100 movements/day)	2008 – easyJet moved all its flights from CIA to FCO Ryanair is the largest user at CIA and WizzAir is the only other airline with scheduled services

MAS	Airport	Infrastructure dynamics	Market dynamics
Malaga	AGP	<p>2010 – New passenger building “Terminal 3”. “Terminal 2” was merged with the new building and “Terminal 1” closed</p> <p>2010 – New railway station opened</p> <p>2012 – New runway opened, along with apron and taxiways</p>	<p>2007 – Clickair (Iberia’s LCC spin-off) opens base</p> <p>2009 – Merger between Vueling and Clickair (Iberia acquires stake at Vueling), Vueling inherits base</p> <p>2010 – Ryanair opens base</p> <p>2012 – Spanair (Catalonia’s FSC) goes bankrupt</p> <p>2012 – Iberia ceased services at AGP</p>
Dublin	DUB	<p>2007 – New “Pier D” (no jet bridges) for Terminal 1 (used for all Ryanair flights)</p> <p>2010 – New passenger building (Terminal 2). Ryanair, main user at DUB, opposed this development</p>	<p>2009 – 2010 – Irish financial recession (Ryanair headquarters are located in DUB, which is a destination for the airline since its inception in 1986, before turning LCC in 1990. Between 2004 and 2008 Ryanair became the largest carrier. By 2012 AerLingus was again the largest carrier after Ryanair reduced service in opposition to the new Terminal 2)</p>
Madrid	MAD	<p>1998 – 2006 “Plan Barajas deployment”</p> <p>2006 – New passenger buildings Terminal 4 and satellite Terminal 4S, and associated aprons, taxiways and traffic control (declared capacity of the expansion: 35 million annual passengers; of the airport: 70 million annual passengers). All LCCs (except Vueling and Iberia Express) operate in Terminal 1-2-3</p>	<p>2006 – Ryanair opens base</p> <p>2007 – easyJet opens base</p> <p>2007 – BCN – MAD was the busiest route in the world (971 flights per week in both directions according to OAG)</p> <p>2007 – Air Europa focuses on hub development at MAD</p> <p>2008 – AVE High-Speed Rail line Barcelona – Madrid opened in February</p> <p>2012 – Ryanair downsize operations following airport fees increase</p> <p>2012 – Iberia creates LCC spin-off Iberia Express</p> <p>2013 – easyJet closed base</p>
Palma	PMI	<p>2003 – New passenger building “Module B” for inter-island traffic only (Passenger building “Module A” is used only during summer season)</p> <p>2011 – Expansion and refurbishment of “Module C” concourse</p>	<p>(Air Europa headquarters are located in PMI, which is the second largest airport for the airline. It is also the third largest airport in Air Berlin’s network. Air Berlin changed business model from FSC to LCC in early 2000’s)</p> <p>2007 – Ryanair started services</p> <p>2012 – Ryanair opens base</p>



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