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# Aviation duoport as a way of efficient development of aviation infrastructure – international and national experience

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**ABSTRACT**

The expansion of low-cost airlines over the last few decades has significantly influenced the requirements and directions of development of aviation infrastructure, opening up development opportunities for many regional and former military airports.
In the second phase of development, low-cost airlines increased their presence at major airports. The low-cost model is evolving, just like the models of traditional and charter airlines. These changes are followed by the development and changes in the airport infrastructure. The model infrastructure adapted to serve low-cost airlines is geared towards reducing the cost for the airlines and shortening the turnaround time of aircrafts – it is therefore smaller and simpler, devoid of certain elements, e.g., jet bridges. Similarly, the time and comfort of travel from the airport to the centre of the metropolitan area are not as important as in the case of airports serving traditional airlines.
Meeting the requirements of low-cost airlines is influencing changes in the design of airport systems serving metropolitan areas. Various models of aviation market development are implemented around the world – they depend on the size and specificity of the market and, above all, on the social and environmental conditions related to new infrastructure projects. In many areas of the world, in response to the low-cost market boom, duoport systems have been developed in which one of the airports is focused on servicing traditional traffic, and the other on servicing low-cost airlines. Several such projects are being implemented at the same time. Based on these experiences, it is possible to construct an optimal model of a duoport that would enable the development of the aviation market, including both the development of the hub of the local flag carrier and the development of the low-cost segment. This model assumes the specialisation of both airports, cooperation between them, an appropriately attractive location of the secondary airport (serving low-cost airlines) as well as the flexibility of the system (enabling the adaptation of its elements to changing market conditions).
The layout of the Warsaw duoport consisting of Warsaw Chopin Airport and Warsaw Modlin Airport must be defined as far from optimal. This is mainly due to the lack of long-term support of the Polish state for this model and the resulting lack of cooperation between the two airports. However, there are objective reasons why the Warsaw duoport may become effective. Both airports have the ability to increase their capacity. Their location in relation to the serviced metropolitan area is optimal. Therefore, this model may be an attractive and worth detailed analysis alternative to the project of the construction of a new central airport within the framework of the CPK project (Centralny Port Komunikacyjny – Solidarity Transport Hub).

**Key words:** air transport, airport, low-cost airline, aviation infrastructure, regional airport, Warsaw Chopin Airport, Warsaw Modlin Airport

## Introduction

The expansion of low-cost carriers (also known in abbreviated form as LCC) has drastically transformed the landscape of civil aviation worldwide, consequently altering the requirements and directions of aviation infrastructure development. LCCs began operating from underutilised regional airports and former military airfields, particularly in Europe and the United States. In recent years, with further growth, low-cost carriers have also started utilising major airports. Deregulation and increased competition have also accelerated the transformation of airport management organisations into commercial enterprises. Privatisation of these entities has occurred in many parts of the world, sparking competition among airports.

In Europe, LCCs started to flourish in the 1990s due to aviation market liberalisation and the Internet, which facilitated efficient ticket sales. Their market share in Europe, measured by the number of available seats, increased from 5.3% to 37.3% between 2001 and 2019. Considering that the overall market doubled in size during the same period, this growth is phenomenal [Jimenez, Suau-Sanchez 2019]. The share of low-cost carriers in the European market continued to rise during the pandemic, and indications suggest that this trend will persist during the market's recovery.

The American airline Southwest, often regarded as a pioneer of the LCC model, began its operations in Texas in 1971. The original Southwest business model included features such as low prices, direct flights without layovers, a single-class dense cabin configuration, unassigned seating, and meals, excellent punctuality, utilisation of a single aircraft type for extended periods (over 11 hours daily), relatively short routes (under 800 km), utilisation of secondary or less crowded airports, and a 15–20 minute turnaround time, controlled growth (target of 10%), competitive wages, and a motivating compensation/incentive system [Dudás 2010]. Presently, the classic LCC model also incorporates utilisation of the Internet as a primary sales channel and a flexible network of connections, enabling them to seize market opportunities and enhance negotiation positions with airports. To maintain this flexibility, low-cost carriers now employ nearly all types of airports, including the world's largest terminals.

Both LCC and traditional airline business models have been evolving for several years. On one hand, low-cost carriers are becoming increasingly interested in serving business travellers and offering connecting flights through their hubs. On the other hand, traditional airlines, in an effort to compete with LCCs, are reducing costs and streamlining their core offerings, particularly on short distances (known as the "last mile" segment), including eliminating meals and introducing baggage fees. This leads to a convergence between these models. In the United States, carriers like JetBlue and Virgin America represent a model similar to traditional airlines, while in Europe, there's EasyJet. However, there's the category of ultra-LCCs, like Sprint and Frontier, representing a pure original low-cost model. Concurrently, traditional airlines are striving to develop their hub and spoke model, which allows them to capitalise on economies of scale and develop entry barriers in their key markets. To directly compete with low-cost

carriers on multiple routes, traditional airlines are establishing their own low-cost subsidiaries (e.g., Transavia, Eurowings, Vueling, Pobeda).

Charter airlines have been operating in the aviation market for decades, and for them, the expansion of low-cost carriers (LCCs) posed as significant a challenge as it did for traditional airlines. Traditional tourist charters, which involve arranging flights for one or several travel agencies, are becoming rarer due to competition and the demands of major customers. This has caused the model of these charter airlines to move closer to the LCC model. The largest airlines specialising in tourist charters, often referred to as leisure airlines, are evolving into hybrid airlines. Many of these airlines allow individual tourists to purchase tickets on their websites and, due to a similar business model (emphasis on low costs, *point-to-point operations*, etc.), they are often categorised as LCCs in statistical analyses. Examples of such airlines in Europe include carriers from the TUI Group, Jet2, Smartwings, Condor, and in Poland, Enter Air. Market divisions in the airline industry are becoming blurred, especially since traditional airlines have also offered charter flights for decades. In the case of LOT Polish Airlines, for example, charter activities have been ongoing since the 1960s and have intensified, especially since the outbreak of the COVID-19 pandemic.

In Europe, organised tourist traffic is the domain of charter and hybrid airlines (north-south routes). Low-cost airlines specialise in individual tourist travel, including city breaks, labour migration, and family trips. Traditional airlines focus on business travel (east-west routes). Despite a few low-cost players entering long-haul transportation, this market segment remains dominated by traditional carriers, with charter airlines playing a significant role when it comes to leisure routes. Tourist flights, which are the domain of charters and low-cost carriers, constitute the most seasonal part of the aviation market, impacting the operations of carriers and the utilisation of overall aviation infrastructure.

## The impact of low-cost airline development on aviation infrastructure

The rapid growth of low-cost carriers in recent decades was made possible by the existence of aviation infrastructure – both regional airports and smaller ones on the outskirts of large cities. These airlines particularly flourished in Europe and the United States due to the presence of suitable infrastructure, such as former military airports that could be easily adapted for LCC operations. As traditional airlines consolidated and expanded their major hub operations, the development of the low-cost segment prevented the concentration of air traffic in large hubs, resulting in traffic dispersion. The expansion of the customer base ("democratisation of flying") led to less affluent individuals choosing this form of transportation, as for them the distance from the airport or high onboard comfort were not major concerns.

In the past decade, there has been an increase in LCC presence at major airports. This was driven by the desire of low-cost airlines to tap into new passenger groups and the concern of large airports that they might miss out on the fastest-growing segment

of the aviation market. Notably, some low-cost carriers, like EasyJet, have always operated from major airports.

The development of low-cost airlines significantly influenced the development of aviation infrastructure across nearly all airports, both major ones seeking to attract LCCs and secondary and regional airports. Infrastructure designed to accommodate LCCs has a number of distinct features:

- Simple, non-monumental terminal architecture with smaller building volume and fewer windows, reducing construction and operational costs, allowing lower prices for airlines,
- Commercial areas within terminals are smaller, resulting in fewer shops and restaurants[1]. Due to passenger profile, there is often a lack of business lounges,
- Terminals lack jet bridges to expedite aircraft turnaround times, a crucial operational parameter. Most low-cost airlines use stairs attached to the aircraft and employ both front and rear doors for boarding and deboarding. In contrast, jet bridges usually allow only front-door use[2],
- The ideal configuration of an apron assumes that passengers transition directly from the terminal to the aircraft without the use of a bus, which also reduces costs and shortens turnaround time. The taxiway between the apron and the runway is kept as short as possible, allowing for maximum reduction in aircraft taxiing time. This is often a significant advantage for airports focusing on Low-Cost Carriers (LCCs) compared to major airports, where taxiing from the runway to the terminal can take even a dozen or more minutes[3]. For passenger convenience, the passage between the terminal and the aircraft stairs is often covered,
- When it comes to airport infrastructure, multi-level parking garages and hotels directly at the airport are rare. However, much more important are convenient and affordable single-level parking lots as in the case of charters,
- Providing fast and convenient access to the centre of the served urban area is not a priority. Therefore, airports serving Low-Cost Carriers (LCC) rarely have railway connections and are not always linked to the network of expressways. Instead, they always offer bus connections (often long-distance). An example of this is Beauvais Tille Airport (BVA), located 85 kilometres away from the centre of Paris, where public transportation to the city is only provided by buses, which a very large portion of passengers use[4],

[1] Despite this trend, many significant low-cost airports have been expanding their commercial areas in recent years in an effort to increase non-aeronautical revenues – for example, Stansted, Gatwick, Bergamo, and Charleroi.

[2] Most of the airplanes in Ryanair's fleet have built-in folding stairs at the front doors – this reduces operating costs and helps achieve a turnaround of the aircraft with nearly 200 passengers in under 30 minutes.

[3] At Amsterdam Schiphol Airport (AMS), one of the runways is located 5 kilometers away from the terminal.

[4] The bus line serving BVA is owned by the company managing the airport and operates as a monopoly, with its revenues constituting a significant portion of its total income.

– Often, low-cost airlines also expect infrastructure that enables the creation of a base, increasing the carrier's operational flexibility, reducing costs, especially for aircraft repairs and maintenance, and facilitating personnel management[5].

Practical solutions, which often involve adapting existing infrastructure to the needs of low-cost carriers or sharing infrastructure with traditional airlines, which almost always occur at regional airports, deviate from these theoretical assumptions. The terminal architecture for LCCs can also be very impressive and costly. Budget terminals at Singapore Changi SIN and Kuala Lumpur KUL, airports which became models for other low-cost terminals, have over time been replaced by more comfortable facilities. At Kuala Lumpur Airport, the new and probably the largest terminal of this kind in the world, KLIA2, was criticised by Tony Fernandes, the CEO of the low-cost airline Air Asia (the main client of the facility), as being overly extravagant in design.

Regarding the use of jet bridges, the policy of low-cost airlines is also diverse. Some, like EasyJet, use them very often, while others, like Ryanair, are very reluctant to use them[6].

With the entry of low-cost airlines into major airports, which often provide passengers with excellent access to city centres and connections to the expressway system, the issue of secondary airport availability has become much more significant. Many of them have invested in improving access in recent years – railway links and people mover systems (such as London's Luton) have been built. In the competitive airline market, a railway station connecting the airport to the centre of a large urban area can be a key element attracting customers – this was the case, for example, at the smallest airport serving the London market – London-Southend SEN. However, for the success of an airport focused on serving LCCs (Low-Cost Carriers), convenient road network connectivity, which most passengers use, remains crucial.

## Multi-Airport Systems in Europe

According to the definition proposed by de Neufville and Odoni [2013], a multi-airport system (MAS) is a set of significant airports serving air traffic in a metropolitan area, excluding military and general aviation airports, regardless of individual airport ownership. Four of the largest European metropolises, each with over 10 million inhabitants, are served by multi-airport systems. The world's largest system of this kind is London, which consists of 6 airports and handled 180 million passengers in 2019 (despite being the most congested even before the pandemic). In all of these systems, the largest airport also functions as the primary hub for the national flagship airline. Among the seven European metropolises with populations between 4 and 10 million, three are served

[5] However, this is not a rule; sometimes, large low-cost carriers have a significant presence at a particular airport without basing their aircraft there, for example, Beauvais Tille.

[6] In 2011, after the introduction of the requirement to use jet bridges in the new terminal at Alicante Airport, Ryanair demanded 2 million EUR in compensation from its owner in order to force the withdrawal of this requirement and temporarily reduce its operations at the airport. The legal case ended in the airline's loss, and after some time, Ryanair returned to Alicante with an extensive offer.

by a single airport – Madrid, Berlin, and St. Petersburg. The others have multi-airport systems comprising two or three airports. Berlin is an interesting case where a system of three airports, established for historical reasons, has recently been replaced by a single airport. Interestingly, among these "larger" metropolises, only three have airports that act as hubs. In several major cities, multi-airport systems were established even before the era of low-cost airlines – this was the case for London, Paris, Moscow, Milan, and Rome.

Among the 24 European "medium" metropolises with populations ranging from 2 to 4 million, 17 are served by one airport, 6 by two, and one – Stockholm – by as many as four[7]. Among those served by a single airport are important aviation markets such as Amsterdam, Munich, or Vienna. Half of the 24 medium-size metropolises in Europe have an airport that serves as a hub – of course, most of them are small hubs with local significance – for instance, Minsk, Dublin, or Brussels-Zaventem. In total, there are at least 15 multi-airport systems in Europe (see Table 1).

The largest airport in the London Multi-Airport System – Heathrow LHR – predominantly handles traditional airlines and serves as a hub for British Airways. The second-largest airport, Gatwick LGW, is gradually becoming more of a low-cost airport, as British Airways has gradually shifted its traditional operations to the main hub[8]. Two major airports, Stansted and Luton, almost exclusively handle low-cost traffic.

The grand Parisian airport system consists of three airports: Charles de Gaulle CDG, Orly ORY, and Beauvais-Tille BVA, but their significance for serving the metropolis varies greatly. In this system, CDG clearly dominates, functioning as both an Air France hub and handling low-cost carrier traffic simultaneously. The French flagship airline, which once maintained scheduled traffic to select African destinations at Orly, is gradually shifting its operations from that airport to CDG, with Orly increasingly becoming a low-cost traffic airport[9]. The smallest and furthest from the city, BVA, follows the model of an "old-style" low-cost airport and is heavily reliant on Ryanair. The proportion of low-cost traffic within the entire Paris Multi-Airport System is smaller compared to many other centres.

Milan has an interesting MAS layout. The system is comprised of three airports – Milan Malpensa MXP, Milan Linate LIN, and Milan Bergamo BGY. After Alitalia's withdrawal in 2008, it lacks a traditional carrier hub. Despite continuous changes, over the years, a relatively organised system has developed – Linate, located closest to the city and being the smallest, serves as a city airport, Malpensa functions as a versatile port with a significant focus on cargo, and the furthest Bergamo is a large low-cost airport. It seems that creating this transparent arrangement was possible because one owner controls the first two airports and has a significant stake in the third one.

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[7] The smallest and furthest airport from Stockholm, Vasteras, has marginal significance and is soon to be closed.

[8] Before the COVID-19 pandemic, British Airways operated at approximately ¼ of its capacity. Currently, this airline primarily serves holiday destinations at Gatwick, and direct competition with low-cost carriers has encouraged it to create a subsidiary company, EuroFlyer, with lower personnel costs.

[9] Orly is a base for the low-cost airline Transavia, which is part of Air France-KLM.

Table 1. Multi-Airport Systems in European Agglomerations

| Category | Metropolitan Area | Airports | Including Hub | No. of Passengers (million) 2019 | Comment |
|---|---|---|---|---|---|
| Over 10 million residents | Istanbul | Atatürk, Sabiha Gökçen | Yes | 103.7 | low-cost traffic focused on the smaller SAW airport |
| | Moscow | Sheremetyevo, Domodedovo, Vnukovo, Zhukovsky | Yes | 103.0 | low-cost traffic distributed to all airports |
| | Paris | CDG, Orly, Beauvais-Tillé | Yes | 112.0 | low-cost traffic divided into three airports |
| | London | Heathrow, Gatwick, Stansted, Luton, City, Southend | Yes | 181.0 | low-cost traffic outside the BA hub and London City Airport |
| 4 to 10 million residents | Madrid | Barajas | Yes | 61.7 | separate infrastructure for low-cost carriers |
| | St. Petersburg | Pulkovo | Yes | 19.6 | a significant share of low-cost traffic |
| | Berlin | Berlin Brandenburg | No | 35.6 | data for two airports – Tegel and Schoenefeld, which were replaced by BER |
| | Ruhr region | Düsseldorf, Dortmund, Weeze | No | 29.4 | low-cost DWeeze with marginal significance, others – mixed traffic |
| | Barcelona | Barcelona El Prat, Girona, Reus | No | 55.6 | the role of two smaller airports is marginal, with a very large share of LCC at the main airport |
| | Milan | Malpensa, Linate, Bergamo | No | 48.7 | Linate – city airport, Bergamo – large low-cost airport, Malpensa – mixed traffic |
| | Rome | Fiumicino, Ciampino | Yes | 49.4 | Fiumicino – mixed traffic, Ciampino – low-cost traffic |
| 2 to 4 million residents | Athens | Athens | Yes | 25.6 | a significant share of low-cost traffic |
| | Kyiv | Boryspil (trl.), Zhuliany | Yes | 17.9 | the smaller Zhuliany airport is evolving towards a city airport |
| | Manchester | Manchester, Liverpool | No | 33.4 | a large share of low-cost traffic at both airports |
| | Naples | Naples | No | 10.9 | a significant share of low-cost traffic |
| | Hamburg | Hamburg | No | 17.3 | Lubeka LBC low-cost airport went bankrupt |
| | Warsaw | Chopin Airport, Modlin Airport | Yes | 22.0 | Chopin Airport – mixed traffic, Modlin – low-cost |
| | Lisbon | Lisbon | Yes | 31.2 | planned construction of a low-cost airport |
| | Budapest | Ferenc List | No | 16.2 | a significant share of low-cost traffic |

| Category | Metropolitan Area | Airports | Including Hub | No. of Passengers (million) 2019 | Comment |
|---|---|---|---|---|---|
| 2 to 4 million residents | Vienna | Vienna International | Yes | 31.7 | growing share of low-cost traffic |
| | Munich | Munich International | Yes | 47.9 | a small share of low-cost traffic |
| | Amsterdam | Amsterdam Schiphol | Yes | 71.7 | the new low-cost airport Lelystad awaits its opening |
| | Stuttgart | Stuttgart | No | 12.7 | a very large share of low-cost traffic |
| | Frankfurt/ RenMen | Frankfurt, Hahn | Yes | 72.1 | low-cost airport Frankfurt Hahn has a marginal share |
| | West Yorkshire | Leeds Bradford, Doncaster Sheffield | No | 5.4 | a significant share of low-cost traffic, the smaller Doncaster airport closed in 2022 |
| | Birmingham | Birmingham International | No | 12.6 | a significant share of low-cost traffic |
| | Brussels | Zeventem, Charleroi | Yes | 34.6 | the smaller Charleroi airport is one of the largest LCC airports in Europe |
| | Upper Silesia | Katowice-Pyrzowice | No | 4.8 | dominance of the LCC and charter market |
| | Stockholm | Arlanda, Bromma, Skavsta, Vesteras | Yes | 30.4 | Bromma – city airport, Arlanda – mixed traffic, Skavsta – low-cost, Vesteras minimal LCC traffic |
| | Prague | Prague Vaclav Havel | No | 17.8 | large share of the low-cost market |
| | Bucharest | Henri Coanda | No | 14.7 | low-cost traffic transferred from the old airport, where only GA remains |
| | Lyon | Lyon Sain Exupery | No | 11.7 | large share of the low-cost market |
| | Cologne-Bonn | Cologne-Bonn | No | 12.4 | large share of the low-cost market |
| | Dublin | Dublin | Yes | 32.9 | mixed traffic, a significant base for Ryanair |
| | Minsk | Minsk | Yes | 5.1 | no low-cost airlines present on the market |

Note: In the table, the author has made certain assumptions (e.g., which airports serve which areas), and the division into metropolitan areas is partially arbitrary (e.g., Amsterdam is sometimes presented in geographical studies not as a separate agglomeration but as part of the Randstad conurbation – along with Rotterdam, The Hague, and Utrecht – with a total population of approximately 8.5 million).

Source: Own compilation based on OECD data (for Russia, Ukraine, and Belarus according to data from Citypopulation.de) and Wikipedia: https://en.wikipedia.org/wiki/List_of_metropolitan_areas_in_Europe

## Aviation duoport systems

The concept of a duoport is not strictly defined, and the broadest definition is that of two airports serving an agglomeration. Under this concept, one can point to at least 8 duoport systems functioning in Europe. However, such a broad definition seems pointless, because for example, Frankfurt and the surrounding Rhine-Main region are handled by two airports, but the smaller one, Frankfurt-Hahn HHN, plays a marginal role – in 2019, it handled only about 2% of the entire market. The concept of a duoport should thus imply a certain balance or comparability between its two elements. With this assumption, the Brussels market can be indicated – Zaventem and Charleroi airports, the Roman market – Fiumicino and Ciampino, Manchester (Manchester and Liverpool), and Warsaw – Chopin Airport and Modlin airport. Outside of Europe, it is worth noting the massive agglomerations handled by duoport systems in Asia – Tokyo, Osaka, Seoul, Beijing, and Shanghai.

The emergence of the first duoport systems was not related to the phenomenon of low-cost airlines. In some large agglomerations, due to market growth even in the last century, the decision was made to construct a second airport without closing the existing one, often located near the city centre. This was connected with ideas of relocating long-distance traffic – as was the case in Tokyo or internationally as a whole – as was the case in Seoul or Milan, to a new airport located farther from the centre. An important factor was the nuisance of noise for residents, especially from the largest airplanes. In the case of Rome, the construction of Fiumicino Airport involved transferring almost all of the traffic, but some charter traffic was left at Ciampino. Not all of these concepts proved successful – in Tokyo, the traffic division evolved with the expansion of the old, closer[10] Haneda airport, and in Milan, the non-functional layout was one of the reasons for transferring the hub to Rome's Fiumicino Airport. It's worth pointing out the example of Montreal in this context. After the construction of the new large Mirabel airport located far outside the city, contrary to the initial plans, the decision was made to keep domestic traffic at the old Dorval airport. This duoport system had a detrimental impact on Montreal's development as a hub, which ultimately led to the failure of the Mirabel project. The original market division system in the duopoly still functions and proves itself in Seoul – the old Gimpo airport, located close to the city, handles domestic traffic, while the new Incheon is focused on international traffic. The success of this duopoly was determined by the massive serviced market thanks to one of the world's largest agglomerations, Seoul. A similar arrangement functions in another enormous agglomeration, Shanghai, where the more distant Pudong PVG handles international flights, and the closer Hongqiao SHA handles domestic flights.

The same factor – a large serviced market – played a key role in the creation of a similar type of duoport without traffic segregation in two other metropolises – Tokyo and Beijing. The two massive Tokyo airports, serving almost 100% of the metropolitan traffic,

[10] ...and as a result, more attractive, especially for business passengers.

are hubs for the two major airlines, ANA and Japan Airlines. An interesting market division evolved at these airports. The second airport for the metropolis – Narita NRT – was built in the 1970s far from the city as a reliever airport designed to alleviate congestion from the main airport, with a focus on handling international scheduled flights. Haneda HND, located much closer to the city centre, became more attractive for business passengers after gradual expansion over the past decades. Therefore, the Japanese government currently promotes a new traffic division, under which Narita would primarily handle holiday and low-cost traffic[11]. After the opening of the new Daxing Airport, Beijing also has two large airports and has become one of the largest airport systems in the world. Both modern airports, well-connected to the centre of the Chinese capital, serve similar traffic – international and domestic. Similar to Tokyo, at this stage, no decision has been made to segregate the traffic.

It's worth pointing out another concept of a duoport – two closely integrated airports serving traditional traffic and acting as hubs for a local airline. Such concepts were attempted to be developed in Paris (CDG and Orly) and London (Heathrow and Gatwick). Integration and convenient transfers for local airline passengers were to be ensured by a convenient transportation infrastructure; for example, in the case of Heathrow and Gatwick, the construction of a fast train connecting these airports was considered. In both metropolises, this model was abandoned due to its impracticality (despite transfer facilities, transfers would be cumbersome for passengers) and the enormous costs of such a solution. In both metropolises, the hub function of smaller airports gradually diminishes in favour of expanding the main airport hub, while in its place, the flagship airline and competitors develop the low-cost and charter segments.

The expansion of low-cost airlines has opened up opportunities for development in the duoport aviation systems. On one hand, these airlines aimed to expand their operations in secondary airports serving metropolitan areas, which previously often handled charter traffic and for which previous decades were sometimes a period of stagnation. On the other hand, authorities responsible for the development of air traffic supported the growth of such secondary airports or the construction of new ones to provide development opportunities for the national airline hub in major ports. An example of such a setup is the Brussels market with the old main airport Zaventem BRU and the smaller Charleroi CRL, whose significance was minimal until Ryanair, in the 1990s, built its first base on the continent there. Since then, Charleroi has developed into one of the largest low-cost airports in Europe. Another example is Rome, where after the emergence of budget airlines, the old Ciampino airport focused on serving this market segment. In Brussels and Rome, airlines of this type currently operate at both airports – in the case of Rome, the limited capacity of Ciampino is the main factor.

[11] That is one of the reasons why Terminal 3 was put into use at this airport in 2015.

In Istanbul, which, after decades of dynamic growth, has joined the elite group of aviation markets serving over 100 million passengers, there is also a duoport in operation. Despite the recent construction of one of the world's largest airports there, Istanbul Airport IST, the second airport – Sabiha Gokcen SAW, located in the Asian part of the agglomeration, continues to operate and focuses on low-cost traffic, serving, among others, the local powerhouse Pegasus. The new airport has taken over the role of the flagship hub for Turkish Airlines from the old Ataturk Airport. A similar duoport arrangement is being implemented in Sydney, where the only Mascot SYD airport, surrounded by residential areas, gradually exhausted its capacity, lacked development opportunities, and was simultaneously one of the most expensive in the world. A new airport – Western Sydney Airport – is being built 44 km from the city centre. The plan envisions several stages of development, with the first phase, providing a capacity of 10 million passengers, to be completed by 2025. Initially, the airport will focus on LCC traffic, and in the long-term plan – possibly by 2060 – it might take on the role of the main metropolitan airport. It's worth adding that Western Sydney Airport has a large catchment area – 3 million residents live in the western part of the Sydney agglomeration[12].

A good example of a city with a functioning duoport is Mexico – one of the largest metropolises in the world, until recently served by a single, additionally very crowded Benito Juarez MEX airport. After the surprising decision to halt the investment in the new large Texcoco airport, to which all the traffic from the old airport was supposed to be transferred, a decision was quickly made in 2018 to build a second airport for the city at the site of a military facility, which was intended to serve LCCs and cargo. In March 2022, after two years, the new Felipe Angeles NLU airport was opened. It is located almost 50 km from the centre of the metropolis and is gradually gaining a share in the low-cost market for Mexico City. Currently, the main drawback is poor access to the city, but there are plans to connect it to the suburban railway network. Therefore, a nearly model duoport arrangement has been created, but in the case of this investment, considering the controversies related to the discontinuation of the Texcoco airport project, it is difficult to determine whether only substantive reasons were behind this decision.

The arrangement of the Warsaw airport market with the dominant Chopin Airport (WAW), and the low-cost Warsaw Modlin Airport (WMI), can be considered a typical duoport. Modlin Airport was opened in 2012 on the grounds of a former military airport, aiming to relieve the main airport of the agglomeration and simultaneously create opportunities for the development of low-cost traffic. The functioning of this arrangement was unfortunately disrupted, first by the temporary closure of Modlin due to the need for runway renovation, and then by the long-standing hindrance of the airport's development, which continues to this day and is linked to the plan of replacing

[12] Western Sydney Airport is being developed in an urbanised region, in part because the Australian government began acquiring land in this area as far back as the 1980s – this fact highlights the advantages of long-term planning.

the duoport with a new major airport as part of the CPK (Centralny Port Komunikacyjny – Solidarity Transport Hub) project.

At this point it is also worth mentioning two examples of douport projects being carried out in Europe – Amsterdam and Lisbon. The large Schiphol AMS airport, which serves as a hub for KLM airlines, has been grappling with congestion issues for many decades. At the end of the last century, Dutch authorities even considered relocating it to an artificial island in the North Sea. However, that idea was abandoned, and since then, the airport has been slowly but almost continuously expanding[13]. This gradual expansion has its limitations primarily due to the proximity of residential buildings. As a result, a few years ago, the owner of Schiphol decided on a different solution – the construction of a second airport for Amsterdam in the town of Lelystad, 55 km east of the city, where a small General Aviation facility operates. The Lelystad Airport (LEY) was supposed to be operational as early as 2018, but the investment process was slow due to resistance from the local community. Despite the pandemic, the investment with a cost of around 200 million Euros was finalised (runway, small terminal, four stands for the most popular Code C aircraft, and parking are already completed), but the opening has been postponed to 2024[14]. The Dutch authorities are currently not rushing with decisions, relying on the fact that the congestion problem at Schiphol has become less troublesome during the pandemic. Ultimately, after expansion, the new airport is intended to handle up to 45,000 flight operations (7–8 million passengers) annually and will take over a significant portion of the holiday traffic from Schiphol.

Another example is Lisbon, where the only Portela LIS airport is one of the most crowded in Europe. Additionally, it is located very close to the city centre and surrounded by intense residential development. For many years, the authorities of Portugal have been planning to build a new airport outside the capital. The closest variant to realisation is the construction of the low-cost Montijo airport on the grounds of a former military airport. The pandemic and resistance from the local community (including protests from two neighbouring municipalities) have caused the project to remain in the planning phase for now. Due to its location within the estuary of the Tagus River, the project also faces opposition from environmental activists (bird migratory routes). Currently, the government has used the pandemic crisis as an opportunity to reanalyse other possibilities, including the construction of a new major airport, which would be located far beyond the city[15]. Considering the crucial role of tourism in Portugal's economy,

[13] Recently, the plan to build a new terminal that was halted during the pandemic has been resumed., https://nltimes.nl/2022/09/05/schiphol-planning-new-terminal-expand-airports-capacity

[14] This happened, among other reasons, due to the need to meet additional environmental requirements., https://taketonews.com/lelystad-airport-wants-to-open-with-nitrogen-rights-from-livestock-farmerson-veluwe-lelystad-airport/

[15] In one of the locations, even approximately 70 km from Lisbon, https://www.euractiv.com/section/politics/short_news/experts-to-look-at-solutions-for-new-lisbon-airport/

the project will certainly be undertaken, although it is currently unknown whether it will take the form of a duoport.

The above examples of Sydney, Mexico City, Istanbul, and Amsterdam show that the currently implemented duoport projects are a response to the capacity exhaustion issues of large airports due to the growth of air traffic, especially in the low-cost segment. As a result of implementing such projects at the main airport, capacity is freed up for the development needs of the flagship carrier's hub, while simultaneously ensuring the growth of the low-cost segment at the new airport.

## Alternatives to aviation duoport systems

Duoport is, of course, not the only way to address the issue of airport capacity depletion in servicing a metropolis. There are also projects that maintain a single-airport service model – the construction of new major airports and the transfer of traffic there or the expansion of existing airports. Projects involving the relocation of an airport to a new location are relatively rare, considering the costs of such a solution and the fundamental challenges in finding a suitable and acceptable location. Properly designed old airports have the potential for expansion and absorbing the rapidly growing low-cost traffic. Madrid is the largest European city served by a single airport, in part due to the fact that the well-designed Barajas MAD, opened before World War II, has been expanding for decades. At the same time, the expansion of this airport has enabled the provision of adequate infrastructure for low-cost airlines by building a new terminal for traditional airlines and adapting old buildings for the needs of low-cost carriers.

A unique transformation of the aviation market occurred in Berlin – the system of three airports was turned into a single-airport system through the construction of the new Berlin Brandenburg BER Airport. The airport system, a legacy of the Cold War division of Berlin, was highly inefficient – two out of the three airports were located close to the city centre and surrounded by residential buildings, with no room for expansion. Transforming this system after the reunification of Germany took advantage of a unique situation, where the third airport – Schonefeld – was attractively located and had the potential for significant expansion. Implementing this concept provided the city with additional benefits, such as utilising the potential of the land and the old airport facilities. The historic Tempelhof airport is being transformed into a centre for culture and the arts, while Tegel is becoming a centre for science and modern technology. However, the resulting large airport is underutilised considering that it is not a hub for any airline, and low-cost carriers dominate, using the cheap infrastructure adapted to their needs[16]. If the operational area – airside of the main airport has not reached its capacity or there

[16] Ryanair has also decided to move to the low-cost Terminal 2, as until recently the airline utilised the old terminal of the former Schoenfeld airport.

is an economic possibility for its expansion (e.g., building an additional runway), a popular way to facilitate the development of low-cost traffic is to construct a low-cost terminal or adapt one of the existing facilities, typically an old terminal, to handle such traffic. Around the world, a whole series of such objects of varying scale and degrees of consideration for low-cost airlines' preferences have been created[17]. For example, as part of the construction of a new terminal at Frankfurt Airport, part of it – Pier G – is adapted to serve low-cost airlines[18]. It is worth noting the drawbacks of such a "two-in-one" solution – it leads to duplicating certain expensive elements of terminal infrastructure (security and baggage systems) and services. Nevertheless, many large airports opt for such investments because ultimately, economic considerations prevail. In the first decade of this century, Warsaw's Okęcie Airport operated in this way, adapting the former makeshift arrivals terminal to serve low-cost airlines (Etiuda terminal) (Table 2).

Table 2. The biggest European airports handling low-cost traffic in 2018

| No. | Airport | LCC share | Separate LCC infrastructure |
|---|---|---|---|
| 1 | Barcelona El Prat | 70% | yes, LCC primarily served in the old Terminal 2 |
| 2 | London Gatwick | 60% | to some extent, LCC operations take place in both terminals |
| 3 | London Stansted | 95% | yes, the old terminal is adapted to handle LCC |
| 4 | Istanbul SAW | 65% | to some extent |
| 5 | Palma di Mallorca | 60% | in limited capacity |
| 6 | London Luton | 98% | yes, low-cost airport |
| 7 | Oslo Gardermoen | 45% | yes, a separate pier is dedicated to LCC operations |
| 8 | Amsterdam Schiphol | 22% | partially, one of the piers is adapted for LCC service |
| 9 | Dublin | 43% | yes, one of the two terminals is tailored for LCC service |
| 10 | Paris Orly | 35% | no |
| 11 | Düsseldorf | 50% | no |
| 12 | Malaga | 68% | in limited capacity |
| 13 | Madrid | 21% | yes, the older terminal is adapted for LCC service |
| 14 | Rome Fiumicino | 25% | no |
| 15 | Copenhagen | 33% | yes, a separate CPH Go terminal is built for LCC service |
| 16 | Manchester | 42% | yes, LCC is handled in two out of three terminals |

[17] The prestigious industry award Skytrax even includes the category of "best low-cost terminal". In 2022, the award went to the Osaka Kansai Airport (KIX) and its Kansai T2 terminal, with two other Japanese low-cost terminals and Terminal T4 in Melbourne also in the top four. Kansai T2 serves as a model example of an LCC terminal – single-story, simple architecture, no elevators, escalators, or jet bridges.

[18] The investment is already completed, but the opening is awaiting the recovery of traffic after the pandemic – according to current plans, the entire Terminal 3 will be opened in 2026.

| No. | Airport | LCC share | Separate LCC infrastructure |
|---|---|---|---|
| 17 | Milan Malpensa | 44% | yes, the older terminal is adapted for LCC service |
| 18 | Berlin Tegel | 46% | the airport is closed, and traffic is transferred to Berlin Brandenburg BER |
| 19 | Cologne Bonn | 85% | no, LCC is served in both terminals |
| 20 | Milan Bergamo | 95% | low-cost airport |
| 21 | Berlin Schonefeld | 88% | the airport is closed, and traffic is transferred to Berlin Brandenburg BER |
| 22 | Alicante | 82% | no |
| 23 | Antalya | 46% | no |
| 24 | Stockholm Arlanda | 29% | no, LCC is handled in three terminals |
| 25 | Paris CDG | 12% | partially, LCC is handled in the former GA terminal and other terminals |
| 26 | Hamburg | 48% | no |
| 27 | Budapest | 62% | yes, separate infrastructure is built for Schengen and non-Schengen sides |
| 28 | Geneva | 44% | no |
| 29 | Lisbon | 26% | yes, a separate terminal for LCC service is adapted in the old building |
| 30 | Edinburgh | 57% | partially, one of the piers is adapted for LCC service |

Airports ranked by the volume of traffic of LCC (Low-Cost Carrier) flights (number of offered seats)
The share of LCC in overall traffic based on offered seats

Source: Author's estimates according to E.R.J. Perez, P. Suau-Sanchez 2019

Low-cost terminals are rarely created at newly built major airports because a separate terminal designed for handling LCC (Low-Cost Carrier) flights conflicts with the currently widely accepted convenient concept of "one terminal". An exception is Berlin Brandenburg, where airport authorities decided to construct an additional low-cost terminal, T2, after building the main terminal, in order to encourage budget airlines to develop the Berlin market.

There are numerous examples of aviation markets where the main airport has been expanded or adapted to accommodate LCC operations while simultaneously constructing new smaller airports as typical low-cost airports. For example, Barcelona, Paris, Stockholm, and Oslo.

## Optimal duoport model

The examples discussed earlier demonstrate the diversity of airport systems and the numerous factors influencing their development directions. Even among the provided duoport examples, significant differences exist. It is worthwhile to consider what the desired duoport model would be, one that would be best suited to the current aviation

market situation. This model should encompass two main objectives – ensuring the long-term development of the flagship carrier and its hub while simultaneously facilitating the economic growth of low-cost traffic. This means that the owner or owners of aviation infrastructure should generate returns on their airport investment over the long term. One could argue that an optimal duoport model should exhibit the following characteristics:

**Specialisation**. The study describes a series of duoport examples that turned out to be ineffective, including the division of traffic into domestic and international. An optimal duoport model would involve adapting the infrastructure of the main (dominant) airport to the needs of traditional airlines, including the needs of the flagship carrier's hub and the development of this infrastructure in that direction. At the same time, the secondary airport's infrastructure should be adapted to serve low-cost carriers and charters. This does not mean that the main airport would have to serve only traditional airlines and the secondary airport only LCC (Low-Cost Carriers), but these two categories of carriers should have a clear advantage in both airports. On the one hand, this would result in the desired natural market segregation, and on the other hand, airport assets would be used efficiently.

**Cooperation, not competition**. In literature pertaining to the subject matter discussed herein, the issue of the benefits of competition between airports often arises, primarily for the benefit of passengers. On the one hand, this is true, but on the other hand, one should remember that major low-cost airlines exploit such competition between closely located airports without hesitation. Hard price negotiations, opening and closing routes, or sudden withdrawals from airports are part of the DNA of low-cost carriers. Among numerous examples of such situations, one can point to the Frankfurt market[19], or the fate of Düsseldorf Weeze NRN airport. Considering the growing dominance of major players in the LCC segment and their traditionally aggressive policy towards airports, the demand for coordination of policies between airports on a regional scale is entirely justified, as it allows for the necessary balance between the parties. To illustrate the issue of the powerful position of major low-cost airlines, it is worth mentioning the following data: in June 2017, Ryanair flew to 199 airports, handled 1492 pairs of flights between these airports, and was a monopoly on 69% of these routes[20]. To make the duoport system effective, it is necessary to find a balance between a major low-cost airline and a secondary airport. The model of an effective duoport does not have to assume a single owner but undoubtedly requires a joint strategy, coordination of actions, and a coherent state policy.

**Attractive location of the low-cost airport**. Several low-cost airport projects have ended in failure. Examples of such projects in Europe include Ciudad Real in Spain, which was supposed to be the second airport for Madrid, Paris Vatry XCR in France, Forli Airport in Italy, Glasgow Prestwick in the United Kingdom, German Lubeka LBC, Portuguese Beja port, and Vesteras in Sweden. Other similar projects, despite years

[19] The competition between the main airport FRA and the secondary airport Hahn HHN is being ruthlessly exploited by Ryanair and WizzAir.

[20] The numbers for EasyJet were as follows: 132, 809, and 43%.

of effort, are still struggling, such as Frankfurt Hahn and Düsseldorf Weeze. In Poland, several airports geared towards serving LCCs also struggle despite significant investments, and the prospect of achieving financial stability for them is distant – examples include Lublin LUZ and Olsztyn-Mazury SZY. All these airports share one characteristic – a significant distance from the serviced centre and too few residents in the catchment area. Some of these airports are located well over 100 km from the centre of the serviced metropolitan area, with Ciudad Real being an extreme example at a distance of up to 220 km. As the distance increases, there is a greater risk that customers of budget airlines will not accept such a location not only due to the time but also the cost of getting to the airport. It seems that a reasonable maximum distance for a medium-sized European metropolitan area is 50 km. At the same time, the location of a low-cost airport should not be more attractive than the location of the main airport. A number of instances, such as Milan, show that if a smaller airport is better located, traditional airlines that are competitors to the flagship carrier are willing to move to it. This weakens the position of the flagship carrier and its hub. A sufficiently large distance from the city centre also typically increases the ability to operate at night, which is not significant for LCCs (Low-Cost Carriers) but is important for charters.

**Flexibility**. The brief description of the evolution of the aviation market in recent decades contained in this study shows that the aviation market is evolving, with changes in business models and market participants. It is evident that the evolution of this market will continue. The pace of market consolidation, convergence between existing models, the growth rate of individual segments, and the development of low-cost, long-distance travel are just examples of unknowns and variables. Therefore, regardless of the need for long-term planning and the necessity of ensuring capacity, it is essential to choose solutions and projects that are safe and guarantee adaptation to different conditions at minimal costs. Flexibility is therefore needed – the ability to adapt more easily to changes in the aviation market.

## Conclusion

Various development models for the aviation market have been and continue to be implemented worldwide. Some of these development concepts have proven to be unsuccessful, while others have become outdated due to market changes. In practice, especially in Europe, the direction has been determined not only by the ideal model for managing the aviation market but also by social and environmental constraints associated with airport investments. For decades, these constraints have hindered or significantly complicated the expansion of existing airports and the construction of new ones[21]. The choice of implementation variant was therefore influenced by the actual availability

[21] These limitations can be seen in the project to build a third runway at London's Heathrow Airport, the expansion of the airport in Vienna, as well as the construction of new airports in Lisbon and Amsterdam.

of different options and their analysis, including the possibility of aligning infrastructure with market prospects – for example, the attractiveness of the potential location of a second airport, environmental, and social aspects (support or resistance from local communities). In some projects, there is also a noticeable politicisation (Mexico, Lisbon). Many projects were unsuccessful, and some had to be modified and adapted to new conditions[22]. Certain factors that once played a crucial role in moving air traffic far from cities, such as noise[23], no longer play such a significant role.

In Japan and South Korea, several airport investments were carried out at sea, despite the enormous costs. This approach allowed the aforementioned countries to avoid the expenses of purchasing land and dealing with social resistance (casus Narita). In Europe, such projects (London, Amsterdam) did not succeed. A unique situation occurred in the last two decades in China, where the lack of existing attractive infrastructure, rapid market development, minimal environmental restrictions, and the absence of social protests resulted in the creation of massive new airport systems.

Duoport, as a variant of a multi-airport system, has been implemented in many places around the world. Its current version, adapted for the significant presence of low-cost airlines, operates in several locations worldwide, and several such projects are currently in progress. It should be noted that despite the attractiveness of the current Duoport model, some trends in aviation, such as the convergence of traditional and low-cost airlines, the gradual increase in cooperation between them, the development of transfer options in some low-cost airlines, and the phenomenon of "self-connecting"[24], may reduce its attractiveness in the future.

The Warsaw duoport – WAW and WMI – is currently far from an optimal arrangement. On one hand, before the pandemic, the development potential of the hub of the LOT Polish Airlines at the Chopin Airport was running out, and on the other hand, limited infrastructure hindered the growth of low-cost traffic in the Modlin airport (after the pandemic, the rebuilding of this traffic was so rapid that its capacity was once again exhausted). The problems of the Warsaw duoport were caused by the lack of support from the Polish state for such an arrangement and the lack of cooperation between the airports. The reason for this is the competitiveness of the duoport in relation to the flagship CPK project. However, two characteristics of this system – the possibility of further economic expansion of both airports to ensure the development of both market segments and the excellent location of these airports in relation to the served metropolis – indicate that with the right conditions, the Warsaw duoport could become an optimal system in the foreseeable future. For this to happen, political support for the development of this system and long-term cooperation between the two airports are necessary.

[22] For example, London Stansted – from an intercontinental airport to a low-cost one, Berlin BER – at the new airport, a terminal had to be added for low-cost airlines.

[23] Prime examples here are Stockholm and Oslo.

[24] Self-connecting – the phenomenon of arranging a connecting journey by a passenger based on two separate tickets.

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## Duoport lotniczy jako sposób efektywnego rozwoju infrastruktury lotniczej – doświadczenia międzynarodowe i krajowe

**STRESZCZENIE**

Ekspansja linii niskokosztowych w ostatnich kilku dekadach znacząco wpłynęła na wymogi i kierunki rozwoju infrastruktury lotniczej, otwierając szanse rozwoju dla wielu lotnisk regionalnych i byłych lotnisk wojskowych. W drugiej fazie rozwoju linie niskokosztowe zwiększyły swoją obecność w głównych lotniskach. Model działania tanich linii ewoluuje, podobnie jak modele linii tradycyjnych i czarterowych. Za tymi zmianami podąża rozwój i zmiany w infrastrukturze lotniskowej. Modelowa infrastruktura przystosowana do obsługi linii niskokosztowych jest nakierowana na zmniejszenie kosztu i obsługi linii lotniczych oraz przyspieszenie czasu obsługi samolotów – jest zatem mniejsza i prostsza, pozbawiona niektórych elementów, np. rękawów w terminalach. Podobnie czas i komfort dojazdu do centrum aglomeracji nie jest tak istotny, jak w przypadku lotnisk obsługujących tradycyjne linie.
Spełnienie wymogów tanich linii wpływa na zmiany w kształtowaniu systemów lotniskowych obsługujących metropolie. Na świecie realizowane są różne modele rozwoju rynku lotniczego – zależy to od wielkości i specyfiki rynku, a przede wszystkim od uwarunkowań społecznych i środowiskowych związanych z nowymi inwestycjami lotniczymi. W kilku miejscach na świecie, w odpowiedzi na rozwój segmentu *low cost,* ukształtowały się systemy typu duoport, w których jedno z lotnisk skoncentrowane jest na obsłudze ruchu tradycyjnego, a drugie na obsłudze linii niskokosztowych. Jednocześnie kilka takich projektów jest realizowanych. Na podstawie tych doświadczeń można skonstruować optymalny model duoportu, który umożliwiałby rozwój rynku lotniczego, w tym zarówno rozwój hubu miejscowego przewoźnika flagowego, jak i rozwój segmentu niskokosztowego. Model ten zakłada specjalizację obu lotnisk, współpracę między nimi, odpowiednio atrakcyjne położenie lotniska drugorzędnego (obsługującego linie niskokosztowe), a także elastyczność systemu umożliwiającą adaptację poszczególnych jego elementów do zmieniających się warunków rynkowych.
Układ warszawskiego duoportu składającego się z Lotniska Chopina i Lotniska Modlin trzeba określić jako daleki od optymalnego. Zdecydował o tym przede wszystkim brak długofalowego wsparcia polskiego państwa dla tego modelu i będący tego rezultatem brak współpracy między dwoma lotniskami. Jednak istnieją obiektywne przesłanki, dzięki którym warszawski duoport może stać się efektywny – oba lotniska mają możliwość zwiększenia przepustowości i ich położenie wobec obsługiwanej aglomeracji jest optymalne. Model ten może być więc atrakcyjną i wartą szczegółowych analiz alternatywą wobec projektu budowy nowego centralnego lotniska w ramach realizowanego obecnie projektu CPK.

**Słowa kluczowe:** transport lotniczy, lotnisko, tania linia lotnicza, linia niskokosztowa, infrastruktura lotnicza, lotnisko regionalne, Lotnisko Chopina, Lotnisko Modlin

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