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CONNECTING AIRPORTS WITH CITIES. PERSPECTIVES OF AIR-RAIL LINKS DEVELOPMENT IN CENTRAL EUROPE

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Abstract: Air travel has increased rapidly in Central Europe in the first decade of the 21st century thanks to the admission of Czech Republic, Hungary, Poland and Slovakia to the European Union and the liberalization of their air travel market. Rapid increase in the number of air travelers in Central Europe created new challenges for Central European airports, which had to expand, modernize and better connect to urban cores. The best solution of the last problem is to organize rail transport, which can handle considerable high passenger volumes, avoids traffic jams, and exerts a relatively small impact on the natural environment. The creation of rail transportation systems increases the airports competitiveness of making cities and whole geographical regions more accessible in general. Another benefit of this transport is that the construction of airport-rail links includes metropolitan areas which had no efficient transport systems.

Keywords: airport access, air transport in Central Europe, rail transport, air-rail links

Introduction

The role of airports in Central Europe has changed substantially during the last decade in terms of their relationship with the areas they serve and general spatial order. Appold and Kasarda (2011) describe an evolution of airports from simple elements of air travel infrastructure to complex products or multidimensional enterprises. The airport-city-region relationship is now a key part of spatial management and transport strategy. This is equally true of new airports and that older ones surrounded by the urbanized areas (sometimes located close to the city centers), which need to optimize their transport solutions.

Airport functioning has become an important problem for Central Europe. Moreover, this problem began to be discussed much later than those of highway network construction and general quality of road transport infrastructure. The success of airports that followed the liberalization of air travel has created new challenges for airports in the region. Those airports served record numbers of passengers, thus are forced

to match their infrastructure with the needs of growing number of passengers in metropolitan areas and beyond. The lack of new infrastructure affected negatively functioning of those airport. A number of steps have been taken to make airports in the discussed region more accessible by car or public transport. For example, the European Union funds have been used to repair roads leading to airports and to build new ones.

The study area for this paper consists of Austria, the Czech Republic, Germany, Hungary, Poland and Slovakia. These are countries different considerably in terms of social and economic development, also in aeromobility. The creation of adequate transport infrastructure linking airports with cities and surrounding areas should increase airport passenger volumes. On the other hand, this is the efficient solution to transport problems. The common way for example in Germany is to link airports and cities via rail transport systems.

Discussion in the research literature and media inspired the authors to cover the issue of rail transport systems linking airports with cities and analyze types of solutions chosen for Central Europe airports. In the case of Polish airports, the success of such the rail link in Kraków made other airports in Poland to prepare plan of use the existing rail links (or building the new ones) to the urban cores. Since the opening of Krakow Airport rail link in 2006, support for these plans has been considerable.[1] In light of the ongoing discussion of airport rail links, this paper attempts to analyze the potential of existing rail links found close to existing airports in Central Europe. The paper also attempts to voice support for this type of transport solution.

Role of airports in the general transport system as a research problem

The airports are no longer perceived as simply facilities serving a transport function. In contrast, they are now understood as drivers of economic progress. The economic role of airports should not be limited to the creation of airport jobs or multiplier effects. The airports are also viewed as catalysts for economic progress that drive investment and increase GDP (Sellner, Nagl 2010).

The connection of airports with settlement units on a local and regional scale constitutes a research problem focused on basic access to air travel. This problem has been investigated since the 1970s when scholars began to analyze the travelers choice mode with respect to mean of transport to the airport (Gosling 2008). On the other hand, better access to airports and higher personal income are two factors driving air passenger market (Hsu, Wu 1997). Reasons for choosing one airport over another depend on many different factors including purpose of travel, which is determined largely by a passenger's social and economic profile. Ishii *et al.* (2009) found that business travelers and tourists consider airport accessibility a key consideration when choosing an airport.

[1] Second air-rail link in Poland (Warsaw Airport) was successfully established in May 2012, after paper's submission.

The issue of air transport in multiple airport cities (MAC) is considered to be separate from that of single airport ones (Derudder *et al.* 2010) or MAR – multiple airport regions (Başar, Bhat 2004; Fuellhart 2007; Harvey 1987; Loo 2008; Pels, Nijkamp, Rietveld 2003; Windle, Dresner 1995). In multiple airport cities, the challenge is not merely linking airports to city centers but linking multiple airports together. At the same time, rail links from city center to airports are not perceived as merely being convenient for air travelers but also as a profitable market niche that may be of interest to railway operators (Stubbs, Jegede 1998).

In addition to simply linking airports with city centers, railway operators are also perceived as feeding long-haul flights by linking domestic rail lines with airport rail links (Mandle *et al.* 2000). However, the construction of airport rail links entails high costs associated with new tunnels under built-up areas (de Neufville 2006).

An increasing congestion at airports seeking to maximize profits produced by growing passenger volumes leads to new airport investment designed to increase airport capacity. The reduction of congestion at terminals is time-consuming and often fits the business needs of airlines (Forsyth 2007). One gets the impression that airport expansion plans are not in any way linked to ground transport systems capacity. The construction of new ground transport infrastructure and improved schedules for ever larger streams of passengers produced by new flight connections are delayed significantly relative to the creation of new flight connections. In many cases, no ground transport upgrades are made when new flights are added. The absence of new public transport solutions leads to more personal transport (private cars) since there is no alternative (Humphreys, Ison 2005). Yet, air travel is supposed to be part of an intermodal transportation system, both with respect to passengers and cargo (Reynolds-Feighan, Button 1999).

The choice of means of transport from the city to the airport is related to costs to some extent. The meaning of airport accessibility is related to the rank and specific function of a given airport. Gosling (2008) notes that most of publications focus on airport accessibility from city centers. It suggests that passenger behavior is the same in the opposite direction. This is an erroneous generalization.

Regional airports attract passengers within a certain radius of the city they are located in. According to Barrett (2000), only 0.5% of air travelers rank the time needed to reach a regional airport as important. This is true of both driving time and access via public transport. Barrett views limitations of smaller airports and those serving low-cost carriers as competitive advantages. Fewer flights means less traffic on roads leading to the airport. Air travelers flying low-cost airlines are naturally more cost sensitive. Research in Spain by Castillo-Manzano (2010) has shown that the optimal distance between a city and an airport serving low-cost carriers is 10 km.

The airports serving low-cost carriers vary in a variety of ways in terms of airport transport options. In many cases, airlines only run shuttle buses to the airport (e.g. Paris Beauvais, Szczecin). This can be explained by the dominance of one carrier at a given airport. If the airline decides to move its flights to another airport, the original airport loses its entire business and any bus companies serving the airport lose a lot of their business.

On the other hand, there are examples of airports that run transport links to their parent cities, which leads to larger passenger volumes and perhaps more flights as well. Gillen and Lall (2004) discussed these issues on the examples of Rimini, which lost Ryanair to Ancona, and Frankfurt-Hahn, which is doing very well despite being far away from the city of Frankfurt. The ongoing success of Frankfurt-Hahn may be attributed, in part, to effective ground transport solutions from the city of Frankfurt to Frankfurt-Hahn Airport.

Research on new airport locations in Hong Kong (Tam *et al.* 2005), Athens (Psaraki, Abacoumkin 2002), and Kunming (Shi, Ying 2008) has shown that the relocation of an airport to a site far away from the city makes taxi transport much less practical and increases the importance of public transport. Larger distances appear to be better suited to railway-based solutions. A similar study was done for the TIA MRT system (Taoyouan International Airport Mass Rapid Transit), designed to link Taipei Airport with central Taipei and high-speed rail lines across Taiwan (You *et al.* 2011). Prior to the construction of the TIA MRT system, Taipei Airport was accessible only by road, which created substantial road congestion. In general, the construction of a large airport upgrades the status of a city in the world community (Goldman 2011). The establishment of flight connections to other major cities is a key step in the development of an airport as a relevant player in the city's overall transport network.

In Great Britain, limited opportunities to build new roads leading to airports along with large increases in airline passenger volume generate excess road congestion, which also threatens the natural environment (Budd *et al.* 2011). Ecological solutions to the problem of airport road congestion are currently a key problem to be solved: Hooper *et al.* (2003), Kaszewski and Sheate (2004), Trzepacz (2010) and Upham *et al.* (2003). The above papers focus on the need to adopt sustainable development solutions to airport-related problems such as airport-to-city transport. Such solutions need to effectively combat the problem of road congestion and limit toxic emissions at the same time.

An example of this type of solution was the construction of a rail link known as the Heathrow Express Link and the creation of a special bus line for Heathrow employees (Janić 2011). These two solutions were the first step towards the building of Terminal 5 at Heathrow Airport in London. Some research papers also note the lack of commuting options for airport employees (Humphreys, Ison 2003, 2005). The significance of this issue increases as the status of an airport increases and the number of airport and airport area business enterprises increases. The aforesaid solutions were designed to limit the use of personal transport to access Heathrow Airport.

Trends in air transport development in Central Europe

Central European countries differ substantially in terms of airport network functioning and air travel market characteristics. The largest passenger volumes are served in Germany (Fig. 1). Germany was the four greatest country in the world in terms of passenger volume until 1999. Better results were reported only for the United States (1.3 billion), Japan (202 million) and Great Britain (172 million). While Germany's

passenger volume has continued to increase, faster was the growth of air travel markets in Spain and China. Germany's high rank is largely due to its large population (82 mln) and the fact that it is the largest country in Central Europe. However German airports such as Frankfurt am Main, Munich and Düsseldorf often serve as transfer points for air travelers and not as travel destinations. Nevertheless, they still generate great passenger volume in Germany – 191,6 mln in 2010.

Austria is the second country in Central Europe in terms of passenger volume per year (24 mln). Although this country has a much smaller population than Poland, the global significance of the city of Vienna and the high global rank of Vienna Airport generate much more passenger volume here. Another factor for Austria's higher passenger volume is the high income level of its residents, which causes the higher aeromobility.

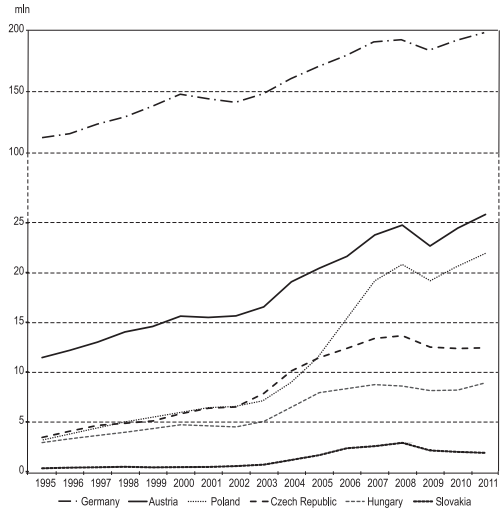

Fig. 1. Passenger volume at Central European airports in 1995–2011 by countries

Source: authors' own work based on flight schedules published by airports.

Poland started to approach Austria in terms of passenger volume in recent years and may outrank Austria in the near future. At the same time, passenger volumes increased at record rates at regional airports in Poland since 2004, which allowed Poland to substantially outpace the Czech Republic, Hungary and Slovakia due to slower passenger volume growth in those three countries.

In all six analyzed countries passenger volume decreased due to the global crisis in 2008. This was only a short-term loss for Germany, Austria and Poland. Airports in those countries regained passenger volume growth in 2009 and returned to a pre-crisis stage. Three remaining countries had troubles with regaining the previous volume after 2008.

Airports in Central Europe

The authors discuss statistics published by airports and online flight schedule data, too. Airports were classified based on destination data posted in 2011 as:

– global airports – offer flights to all continents (only Frankfurt am Main lists Sydney),
– long-haul intercontinental airports – offer flights to regions in other continents not adjacent to Europe (e.g. Hamburg to Shanghai and Kraków to Chicago);
– short-haul intercontinental airports – offer flights to regions in other continents adjacent to Europe (e.g. Nuremberg to airports in North Africa);

– inter-regional continental airports – offer flights to other regions in Europe (e.g. airports in Poland offering flights to airports in Great Britain);
– regional continental airports – offer flights to destinations in the same geographic region (e.g. Poprad Airport in Slovakia offers flights to Prague, Gdańsk, and Warszawa);
– domestic airports – do not offer scheduled international flights.

Domestic airport systems in Austria, Hungary, Slovakia and the Czech Republic are dominated by capital city airports. In recent months, regional airports in Poland have been downgraded due to the loss of transatlantic flights to the United States from Kraków and Rzeszów. While new flights to Frankfurt am Main and Munich have been added, it appears that LOT Polish Airlines is functioning as so-called feeder airline that delivers passengers to other carriers instead of operating its own transcontinental flights. The lack of transcontinental flights may impact on the range of airports catchment areas and consequently may affect the rationale behind city-to-airport transport options.

The small Slovak city of Poprad is an interesting case. Its airport is slated to become a key destination for tourist traffic headed for the Tatra Mountains, including their Polish side. Poprad already receives flights from Warszawa and Gdańsk. Travel agencies currently offer recreational packages that include airfare, lodging and ski passes. If Poprad becomes a popular destination for Polish tourists, then the Tatras may become best accessible by air. This is true primarily because the city of Kraków is linked to the Tatras via only one major road, which creates enormous congestion during the high season.

Germany possesses the best developed system of airports in Central Europe (Fig. 2). The most important airport is Frankfurt am Main, which is one of only three airports in Europe to offer direct flights to all inhabited continents including Australia. Other intercontinental airports are those of Munich, Düsseldorf, Berlin and Hamburg. The city of Berlin may expect to upgrade its airport standing when its brand new Berlin-Brandenburg Airport opens to the public in 2012. This new airport is designed to serve 50 million passenger per year and will replace Berlin's current largest airport – Berlin-Tegel – and Berlin's low-cost carrier airport – Berlin-Schönefeld. Despite the dynamic growth of Dresden Airport, Berlin-Brandenburg Airport will remain the only intercontinental airport in eastern Germany. This will maintain the existing airport disproportion between eastern and western Germany.

All airports in Poland, Slovakia, Hungary and the Czech Republic have at least doubled between 1995 and 2010 the number of air travelers served (Fig. 3). The surprisingly high rate of growth in air travel in Central Europe can be attributed to the following factors:
– the liberalization of the air travel market (a condition of entry into the European Union) has allowed low-cost carriers to enter the market in Central Europe;
– the opening of new job markets in Western Europe (especially UK and Ireland) to new EU member states;
– rising incomes in Central Europe, which makes air travel more affordable.

Most countries in Central Europe are dominated by a central airport – serving the capital city (Table 1). Notable exceptions are Germany and Poland. Poland's na-

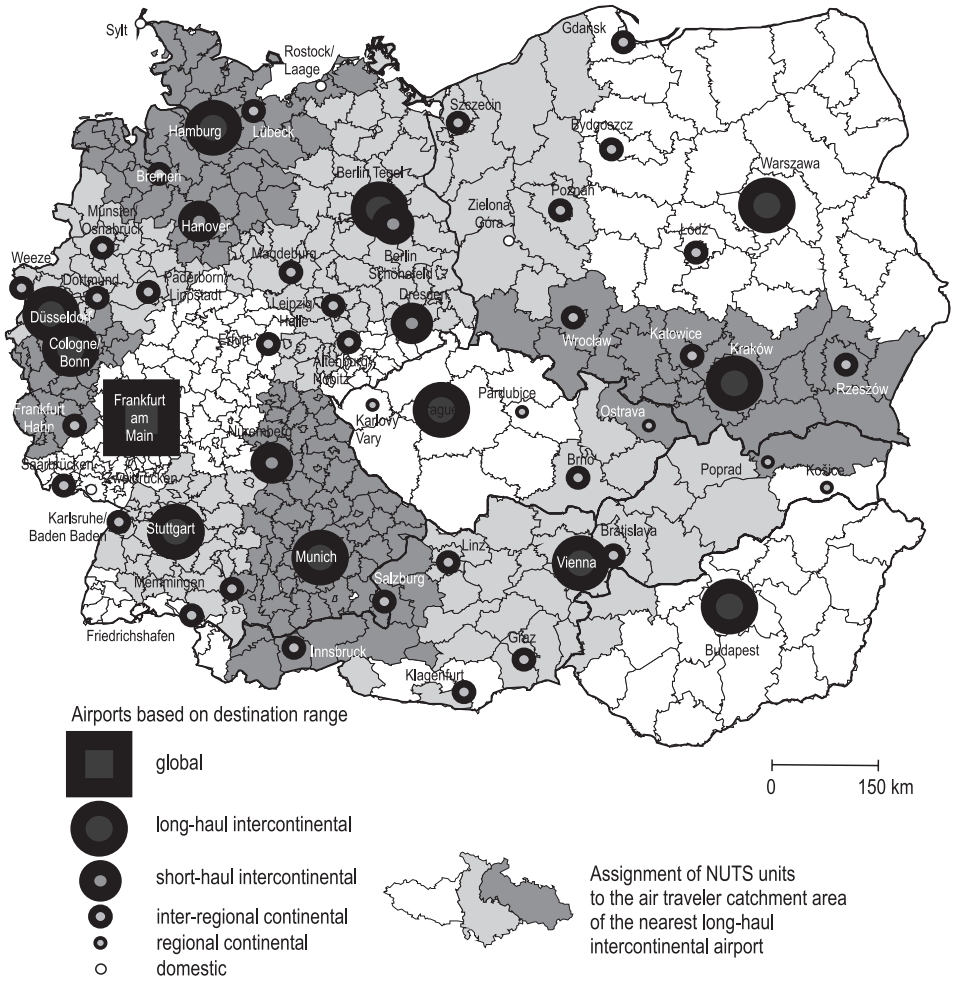

Fig. 2. Airports in Central Europe based on destination range in 2011

Source: authors' own work based on flight schedules published by airports; air traveler catchment areas of intercontinental airports are based on airport commutes calculated using the site: www.viamichelin.com.

tional airport in Warszawa began to lose passengers in favor to regional Polish airports in 2004, when Poland entered the European Union. Share of passenger volume in Warszawa airport (that of Okęcie) decreased from 80% to less than 50% actually.

The rising number of air travelers in Central Europe has also prompted a shift in the standing of airports in the region during the last ten years (Table 2). Polish airports have advanced the most in terms of rank. While initial increases in air traffic in Poland due to the opening of Poland's air travel market to low-cost carriers were rather small, this can be explained to some extent by the smaller size of Polish airports compared

Table 1. Air transport in six countries of the Central Europe

Specification		Germany	Poland	Austria	Czech Republic	Slovakia	Hungary
Airport types	global	1	–	–	–	–	–
	long-haul intercontinental	6	2	1	1	–	1
	short-haul intercontinental	5	–	–	–	–	–
	inter-regional continental	14	8	5	1	1	–
	regional continental	–	–	–	3	2	–
	domestic	3	1	–	–	–	–
	total	27	11	6	5	3	1
Share of capital city airport in total number of passengers served (%)	1995	9.9	84.5	74.6	93.8	68.5	100
	2010	11.7	42.1	80.5	93.4	84.9	100
Passenger air traffic (mln)	1995	112.5	3.2	11.4	3.4	0.3	2.9
	2010	191.6	20.7	24.4	12.4	2.0	8.2
	dynamics 1995–2010 (1995–100)	176	677	226	363	588	306
Aeromobility Index	1995	1.38	0.08	1.44	0.33	0.06	0.28
	2010	2.34	0.54	2.92	1.18	0.36	0.82
	dynamics 1995–2010 (1995–100)	170	646	202	355	610	290

Source: authors' own work based on data published by airports.

to Western European airports serving cities of similar size and rank. This helps explain why German airports serve more stabilized passenger volumes. In summary, airports in former communist nations in Central Europe are still trying to catch up to their Western European counterparts in terms of functionality and economics.

Given Central Europe's general shortage of infrastructure, it may be expected that the number of airports in the region will continue to grow. Behnen (2004) forecasts that the number of airports in Germany will double over the next 10–15 years. This growth will be limited to airports with runways longer than 1800 meters. The same is likely to be true in other parts of Central Europe where the number of airports is smaller. Two new airports will be put in operation in Poland in 2012. The first one will be that of Lublin Świdnik, which will serve eastern Poland, a region currently without an airport, populated by a large number of wage migrants, who travel to Western Europe for work. The second one will be that of Warszawa Modlin, the first true secondary airport in the formerly communist eastern part of Europe.

In the light of the regional airports success in Poland following the deregulation of the air travel market, many other cities in Poland have expressed their desire to build airports. However, European Union policy states that creating better access to existing airports is preferable to building the new ones. Yet, Humphreys and Francis

Table 2. Rank of Central Europe airports in 2000 and 2010

Central European rank	Airport	Country	Number of air travelers served by airport		European rank		Airport rank variance coefficient for: 2000-2010
			2000	2010	2000	2010	
1	Frankfurt am Main	Germany	49 360 630	52 710 228	2	3	–0.20
2	Munich	Germany	23 125 872	34 598 634	9	7	0.13
3	Vienna	Austria	11 939 571	19 691 206	22	17	0.13
4	Düsseldorf	Germany	16 030 646	18 943 720	18	21	–0.08
5	Berlin-Tegel	Germany	10 343 697	14 991 115	26	28	–0.04
6	Hamburg	Germany	9 949 269	12 918 279	28	30	–0.03
7	Prague	Czech R.	5 553 532	11 556 858	45	34	0.14
8	Cologne/Bonn	Germany	6 385 101	9 806 270	40	36	0.05
9	Stuttgart	Germany	8 132 677	9 162 175	34	41	–0.09
10	Warszawa	Poland	4 325 814	8 712 339	55	43	0.12
11	Budapest	Hungary	4 683 176	8 190 089	53	48	0.05
12	Berlin-Schönefeld	Germany	2 209 444	7 269 992	90	55	0.24
13	Hanover	Germany	5 515 265	5 016 888	47	70	–0.20
14	Nuremberg	Germany	3 149 881	4 034 071	72	89	–0.11
15	Frankfurt-Hahn	Germany	368 222	3 463 571	231	99	0.40
16	Weeze	Germany	–	2 889 651	–	108	–
17	Kraków	Poland	517 015	2 864 083	202	109	0.30
18	Bremen	Germany	1 918 064	2 663 929	100	117	–0.08
19	Katowice	Poland	168 126	2 403 253	319	121	0.45
20	Gdańsk	Poland	269 960	2 232 590	269	125	0.37
21	Leipzig/Halle	Germany	2 274 745	1 847 193	87	137	–0.22
22	Dresden	Germany	1 759 638	1 803 511	104	138	–0.14
23	Dortmund	Germany	719 365	1 740 642	175	142	0.10
24	Bratislava	Slovakia	292 515	1 665 688	254	146	0.27
25	Wrocław	Poland	210 873	1 651 057	303	150	0.34
26	Salzburg	Austria	1 261 516	1 625 842	125	154	–0.10
27	Poznań	Poland	227 874	1 419 121	294	168	0.27
28	Münster/Osnabrück	Germany	1 741 500	1 312 656	106	179	–0.26
29	Karlsruhe/Baden-Baden	Germany	185 604	1 168 399	312	189	0.25
30	Innsbruck	Austria	680 818	1 033 512	179	198	–0.05
31	Paderborn/Lippstadt	Germany	1 342 220	1 007 978	120	201	–0.25
32	Graz	Austria	752 507	990 118	163	205	–0.11
33	Memmingen	Germany	–	911 609	–	214	–
34	Linz	Austria	746 904	692 039	168	238	–0.17
35	Friedrichshafen	Germany	388 053	581 390	224	246	–0.05
36	Lübeck	Germany	130 900	537 633	337	254	0.14
37	Rzeszów	Poland	8 841	454 203	492	268	0.29
38	Klagenfurt	Austria	235 503	425 933	288	273	0.03
39	Saarbrücken	Germany	482 595	420 101	208	275	–0.14
40	Brno	Czech R.	112 797	396 589	357	280	0.12
41	Łódź	Poland	794	393 952	521	281	0.30
42	Zweibrücken	Germany	–	338 219	–	298	–
43	Erfurt	Germany	481 573	309 774	209	304	–0.19
44	Szczecin	Poland	56 605	282 472	410	316	0.13
45	Ostrava	Czech R.	114 904	279 973	353	317	0.05
46	Bydgoszcz	Poland	14 089	278 150	481	319	0.20
47	Košice	Slovakia	125 844	266 858	343	323	0.03
48	Rostock-Laage	Germany	99 841	161 812	364	361	0.00
49	Altenburg-Nobitz	Germany	27 208	143 155	453	367	0.10
50	Sylt	Germany	61 000	133 000	408	371	0.05
51	Karlovy Vary	Czech R.	19 919	70 903	469	427	0.05
52	Pardubice	Czech R.	6 087	62 302	505	435	0.07
53	Poprad	Slovakia	13 173	27 693	483	473	0.01
54	Zielona Góra	Poland	297	3 637	523	526	0.00

Source: authors' own work based on data published by airports.

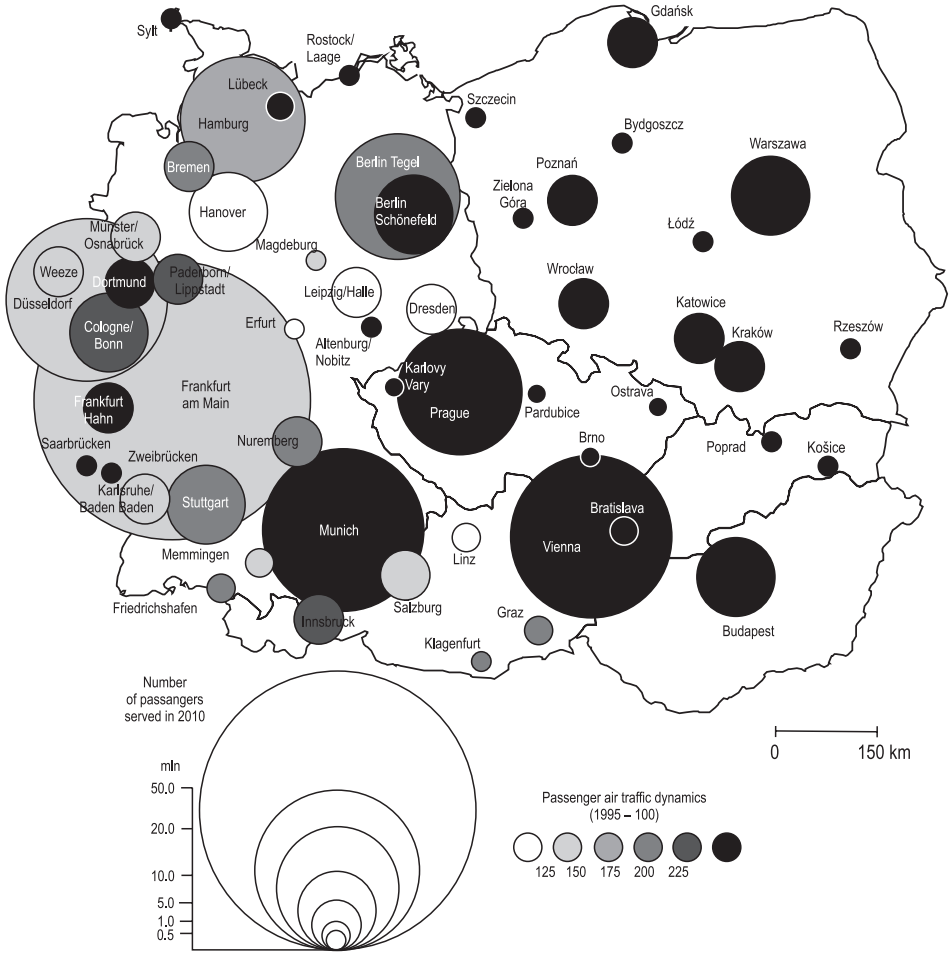

Fig. 3. Passenger air traffic at Central European airports in 1995–2010

Source: authors' own work based on data published by airports.

(2002) note that the distribution of existing airports presents a spatial problem. Even though the total national airport capacity may meet the needs of air travelers, its geographical distribution may not be adequate for the airlines. Graham (2003) notes that peripheral areas need to join the airport network in order to create greater social equality. If Graham's assertion is true, then Central Europe needs more airports.

Creating public transport for city-to-airport routes

The issue of airport access is currently a key issue in Central Europe. The authors explore the possibility that rail transport may be the right answer to this transport challenge. However, rail transport is generally characterized by relatively high fixed costs and high fees for access to rail infrastructure. This is also true in Poland. This prompts a reasonable question: Does every airport need to have a rail link, especially if this would call for the construction of a brand new rail line? In general, the answer is no. Airports with mostly seasonal traffic or generally low one do not need those links. A complete answer to this question would entail the analysis of many different factors, which is beyond the scope of this paper. However, an estimate of the air traveler volume needed to justify the construction of a new airport rail link is within the scope of this research.

The first step is to make certain assumptions regarding means of transport used by airport-to-city transport companies. Even at large airports, public transport does not serve more than 30% of passenger volume (Table 3).

Table 3. Airport access modal split

Airport	Means of transport (%)					Data obtained in	Source
	Car	Taxi	Bus	Rail	Other		
European average	66	–	–	–	34	·	Budd *et al.* 2011 after Reynolds–Feighan, Button, 1999
German average	70	12	1	15	1	·	Valentinelli et al. 2004
Regional average	99	–	–	–	1	·	Budd *et al.* 2011 after Reynolds–Feighan, Button, 1999
Amsterdam	45	18	4	33	–	2005	Kazda, Caves 2007
Berlin-Tegel	34	45	17	–	–	1995	Niblett 1996
Birmingham	65	15	7	11	1.9	2006	www.birminghamairport.co.uk
Bristol	92		5		·	2003	Humphreys *et al.* 2005
Brussels	54	20	10	16	–	1996	Fisher, Coogan 2000
Cologne/Bonn	64	22	11	–	–	1995	Niblett 1996
Copenhagen	26	33	4	37	–	2005	Kazda, Caves 2007
Cork	76	11	11	–	2	2008	www.corkcoco.ie
Dublin	40	22	32	–	5	2010	www.dublinairport.com
Düsseldorf	65	19	2	14	–	1995	Niblett 1996
Frankfurt am Main	56	12	3	29	–	1995	
Geneva	33	22	10	35	–	1996	Fisher, Coogan 2000
Hamburg	52	36	8	–	–	1995	Niblett 1996
Hong Kong	7	13	47	23	9	·	Tam et al. 2005
Kunming (new)	20	22	9	48	–	·	Shi, Ying 2008
Kunming (old)	25	47	27	–	–	·	
Leeds Bradford	98	–	2	–	–	2003	Humphreys *et al.* 2005
Liverpool	95	–	4	–	–	2003	

Table 3. Airport access modal split (continued)

Airport	Means of transport (%)					Data obtained in	Source
	Car	Taxi	Bus	Rail	Other		
London City Airport	79		2		·	2003	Humphreys *et al.* 2005
London Gatwick	53	17	9	21	–	2005	Kazda, Caves 2007
London Heathrow	61	26	12	23	–	2005	
London Luton	50	16	15	17	–	2010	http://www.london –lutoninthe-community.co.uk
London Stansted	66		34		·	2003	Humphreys et al. 2005
Madrid	61	40	7	14	–	2005	Kazda, Caves 2007
Manchester	55	28	11	6	–	2005	
Munich	44	11	13	32	–	2011	www.munich –airport.de
Newcastle	89		11		·	2003	Humphreys *et al.* 2005
Norwich	95		4		·	2003	
Nottingham East Midlands	98		2		·	2003	
Oslo	34	6	19	40	–	2005	Kouvenhoven 2008
Paris CDG	53	14	9	23	–	1995	Niblett 1996
Paris Orly	60	16	18	6	–	1995	
Rome	36	32	5	27	–	2005	Kazda, Caves 2007
Southampton	88		11		·	2003	Humphreys *et al.* 2005
Stockholm	52	16	17	15	–	2005	Kazda, Caves 2007
Zurich	43	10	5	42	–	2005	

Sources: listed in the table.

It may be assumed that the minimum frequency of trains to the airport must be every one hour. This gives 15 train pairs per day (Table 4). Every train should carry at least 50 passengers, which is how much an average tourist bus would carry at any one time. If it is then assumed that about 40% of airport users will use public transport, then this yields 1.35 million passengers served by an airport. This, of course, further assumes that rail transport will account for most trips taken via public means. The authors assumes that an airport needs to have an annual passenger volume of at least one million for a rail link to become profitable in any way.

It leads to collation of airport-city links in dependence from airport features and passenger volume (Table 5).

Table 4. Estimate of the minimum number of airport customers served

Number of connection pairs per day	Total number of connections per day	Minimum number of passengers	Daily total number of passengers	Annual total number of passengers	Minimum number of airport users
15	30	50	1 500	540 000	1 350 000

Source: authors' own work.

Table 5. Means of city-to-airport transport in Central Europe in 2010

Airports			Means of transport			
airport type	passenger volume in millions per year	number of airports	shuttle	public transport – bus	train (local*)	train (IC)
Global	>50	1	a	a	M	M
Long-haul intercontinental	>2.8	11	a	a	M	M
Short-haul intercontinental	>1.8	4	a	a	M	N
Inter-regional continental	>1	15	a	a	M	N
	<1	14	a	M	N	N
Regional continental	<0.3	5	a	M	N	N
Domestic	<0.2	4	M	N	N	N
	Total	54	x	x	x	x

Explanations: a – appropriate means, M – principal means, N – inappropriate means, * also tram or metro.

Source: authors' own work based on data published by airports.

Research has shown that twelve global and long-haul intercontinental airports in Central Europe should possess rail links to the cities they serve. Moreover, each of those great airports should have a train station designed to serve long-distance trains. The rationale for such the solution is the large size of the regions these twelve airports serve. Other airports serving more than one million passenger per year will only need such modes of transport as the metro (subway) or tram. For smaller airports scheduled bus service is sufficient. The small domestic airports will only need shuttle bus service. For example, Zielona Góra Airport serves only few planes a day, thus does not need even scheduled bus service. The shuttle buses from Gorzów and Zielona Góra serve this airport very well.

Airport access in Central Europe

Bus service remains the primary mode of public transport to and from airports in Central Europe. Special buses serve all airports in this region. Scheduled municipal buses link 42 (78%) airports with the local large cities they serve. Only three airports do not have any form of public transport (Table 6). Nine other airports possess rail links but no bus service, and nineteen (35%) possess rail links.

The rail transport, first and foremost, consists of urban rail lines found at 15 airports in Central Europe, 28% of all airports and 79% of those airports operating rail-based transport. While it is rather difficult to compare the S-Bahn found in Frankfurt and Berlin to Kraków airport rail line, all three rail lines may be called the local ones. One airport in Central Europe is served by subway and two by trams. Eight Central Europe airports have train stations serving also long-distance trains.

Table 6. Public city-to-airport transport by airport type in 2012

Airport type	Number of airports				Average number of		
	Type			Total	public transport connections	rail connections	connections per 1,000,000 passengers
	1	2	3				
Global	1	1	1	1	251.0	246.0	4.8
Long-haul intercontinental	11	8	3	11	132.9	74.9	11.7
Short-haul intercontinental	4	4	1	4	152.8	99.3	31.4
Inter-regional continental >1 mln	15	2	1	15	49.3	14.7	29.0
Inter-regional continental <1 mln	12	4	1	14	31.4	9.9	69.3
Regional continental	4	–	–	5	20.4	–	231.6
Domestic	4	–	–	4	6.5	–	98.8
Total	51	19	7	54	67.2	33.8	59.6

Explanations: airport types by transport means: 1 – airports with public transport, 2 – airports with rail-based transport, 3 – airports served by long-distance trains.

Source: authors' own work.

The number of public transport connections (Table 7) varies from several per day at small airports to 250 per day at Frankfurt am Main Airport, which equals to almost five connections per one million air travelers. According to Frankfurt Airport data, ⅓ of its air travelers use public transport to reach the airport. Hence, the average train carries about 50 passengers to and from the airport. It is important to note that Frankfurt's airport rail link is not a dedicated airport link but the line that serves other destinations in Germany.

Table 7. Public transport to Central-European airports in 2012 – recommended solutions

City	Number of connections	Number of rail–based connections	Number of connections per one million air travelers	Proposed solutions
Berlin-Tegel	395	–	26	–
Prague	28	–	2	rail line
Warszawa	120	–	14	rail line
Hamburg	106	106	8	long-distance rail line
Kraków	73	28	25	long-distance rail line
Munich	171	121	5	long-distance rail line
Stuttgart	100	100	11	long-distance rail line
Vienna	105	105	5	long-distance rail line
Bratislava	71	–	43	suburban light rail
Dortmund	13	–	7	suburban light rail
Hahn (Frankfurt)	12	–	3	suburban light rail
Gdańsk	35	–	16	suburban light rail

City	Number of connections	Number of rail–based connections	Number of connections per one million air travelers	Proposed solutions
Innsbruck	62	–	60	suburban light rail
Karlsruhe/Baden–Baden	15	–	13	suburban light rail
Katowice	17	–	7	suburban light rail
Münster/Osnabrück	36	–	27	suburban light rail
Paderborn/Lippstadt	33	–	33	suburban light rail
Poznań	35	–	25	suburban light rail
Salzburg	120	–	74	suburban light rail
Weeze	16	–	6	suburban light rail
Wrocław	54	–	33	suburban light rail
Berlin	308	208	42	–
Bremen	183	183	69	–
Brno	44	–	111	–
Budapest	110	110	13	–
Bydgoszcz	36	–	129	–
Dresden	39	39	22	–
Düsseldorf	169	169	9	–
Erfurt	52	52	168	–
Frankfurt am Main	251	246	5	–
Friedrichshafen	66	34	114	–
Graz	54	33	55	–
Lübeck	42	20	78	–
Hanover	77	40	15	–
Karlovy Vary	17	–	240	–
Klagenfurt	14	–	33	–
Cologne/Bonn	85	85	9	–
Košice	18	–	67	–
Leipzig/Halle	38	38	21	–
Linz	16	–	23	–
Łódź	71	–	180	–
Memmingen	19	–	21	–
Nuremberg	187	110	46	–
Ostrava	18	–	64	–
Pardubice	49	–	786	–
Rostock–Laage	3	–	19	–
Rzeszów	8	–	18	–
Saarbrücken	17	–	40	–
Sylt	8	–	60	–
Zielona Góra	1	–	275	–
Zweibrücken	14	–	41	–
Altenburg-Nobitz	–	–	–	bus service
Poprad	–	–	–	bus service
Szczecin	–	–	–	bus service

Source: authors' own work based on the web pages of airlines and airports.

Of the 54 airports in Central Europe, 31 feature passenger traffic large enough to warrant the consideration of a rail link creating. Each of those airports served at least one million air travelers in 2010. Nineteen of them are located in Germany, six in Poland, two in Austria, while Hungary, Slovakia and the Czech Republic possess only one airport of this volume.

Thirteen of the thirty one largest Central European airports possess a rail link. The suburban rail link currently exists between Central Warszawa and Warszawa Airport (Okęcie). The rail link is under construction from Central Gdańsk to Gdańsk Airport. Two other airports possess other types of rail links to city centers – the subway to Nurmberg and tram to Bremen. Ten out of the thirteen airports with rail links are found in Germany. Other airports served by rail are Vienna Airport, Krakow Airport, and Budapest. A new rail link is in the final stages of construction in Warszawa. Another new airport rail link is scheduled to open in Gdańsk. No airport in Slovakia or the Czech Republic has the airport rail link.

Fifteen airports in Central Europe, serving more than one million air travelers each do not have any type of rail link to the cities they serve: 7 in Germany, 4 in Poland, 2 in Austria, 1 in Slovakia, 1 in the Czech Republic. The largest of these 15 airports is Berlin-Tegel. However, Berlin-Tegel is being replaced by the new Berlin-Brandenburg Airport in 2012, which makes it irrelevant for further analysis.

Most airports serving 1.8 million air travelers or more per year have rail links to the cities they serve. However, there are some rather large airports without any rail service. An example of this is Prague with more than 10 million air travelers served per year. On the other hand, some smaller airports (e.g. Graz in Austria) have their own train stations serving long-distance trains.

Table 7 shows also the airports with insufficient city–airport links. Two intercontinental airports do not currently have any type of rail link – those of Prague and Berlin--Tegel. Both are located in formerly communist regions. It is likely that Berlin-Tegel Airport has suffered because of the lack of a rail link. Another five airports do not have direct long-distance links.

No rail links exist at 87% of inter-regional continental airports serving more than one million air travelers per year in Central Europe. Most of these airports are regional airports in Poland, Slovakia and Germany. Maybe those airports are growing so rapidly that public transport options are not being created fast enough to match potential demand. Finally, two small inter-regional continental airports and one regional continental airport do not have any type of public transport available: Leipzig, Poprad and Szczecin Airport.

Potential of rail links for airports in Central Europe

The linkage of airports with the cities they serve via rail-based infrastructure is still primarily a Western European solution (Fig. 4). All airports in London are linked to the city via rail. The same is true for Moscow. Except for Germany, Central Europe is behind in this respect. In light of this, the existence of a rail link between the city of Kraków and Krakow Airport seems like a major achievement, especially since Kra-

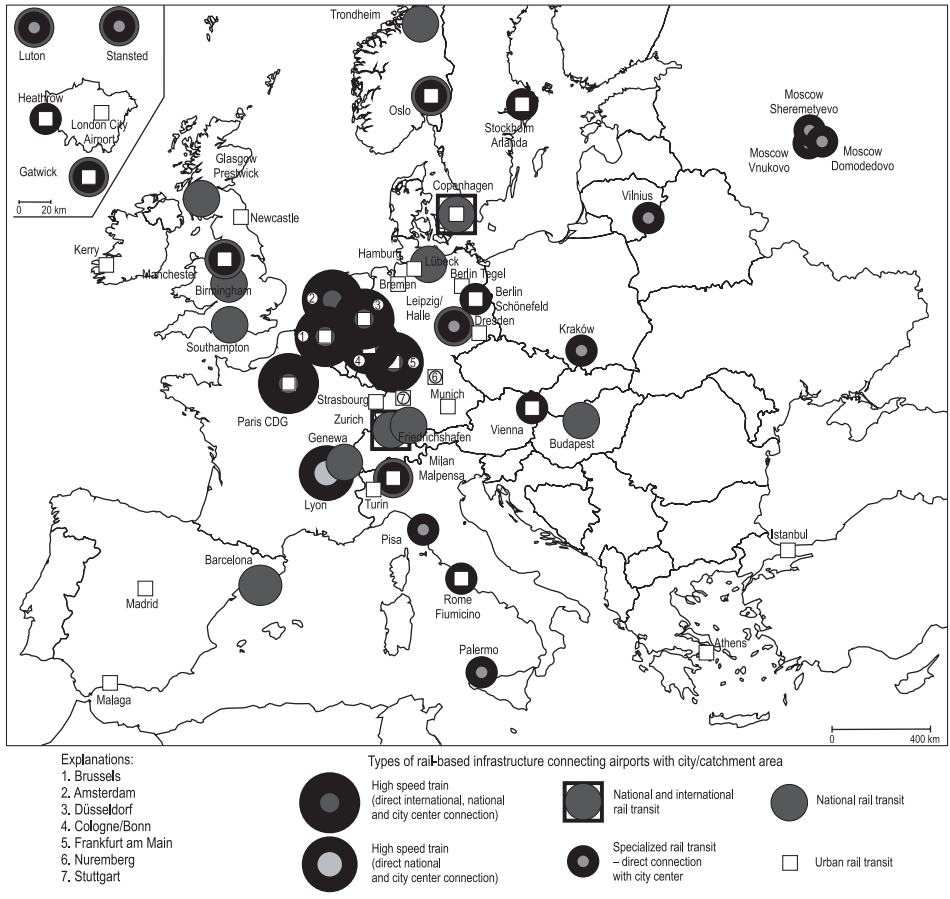

Fig. 4. Airports in Europe with an active direct rail link to the city center in 2012

Source: authors' own work based on data published by airports.

ków Airport is the second largest airport in Poland. Eastern Europe and Southeastern Europe are still farther behind in terms of rail-based city-to-airport transport.

In Central Europe, both market demand and a general trends towards transport upgrades have promoted a regional conversation on the issue of airport rail links. The potential of existing rail lines to link cities with airports varies substantially throughout the region.

Theoretically, the greatest potential can be observed in branch lines leading to airports. Those lines were often built to supply airports or adjacent military facilities, and can now be used to run passenger trains to and from the airport without building new tracks. However, many of them cannot served high-speed traffic and technical characteristics make them unsuitable for high-speed passenger trains. There are

sharp turns, large gradients, soft track ballast, and numerous intersections with roads. In addition, some branch lines are located too far away from terminals to serve air travelers conveniently.

A good example of this is the Krakow Airport rail link, which was launched in May of 2006 using a five-kilometer branch line built in the 1950s to connect Kraków Mydlniki train station with military facilities at Krakow Airport. Some repair work was done to prepare the tracks for service. Track entrance barriers were installed on Balicka Street. Light signals were installed at intersections with smaller roads. Finally, a train platform was built at the end of the line, about 300 meters from the airport terminal. However, no major construction work was done on this line. This may not seem like much but no new rail line has been opened for service in Poland in almost 30 years.

The Krakow Airport rail link does not fully meet the needs of air travelers seeking a fast connection with the city of Kraków mainly due to its overall technical state and large distance from the last stop to the terminal. Another problem is the frequent breakdowns of the diesel trains, which forces the train company to hire buses. In short, it appears to be an improvised solution. Modernization of this rail link in 2013 will contain constructing a second track and installing overhead wires as well as by extending the line just to the airport terminal. The planned airport train station is to be connected with the terminal by a footbridge. There are also plans to create more stops in order to make the airport rail link more useful and fully integrated with Krakow general plan for a Metropolitan Rapid Transit System (www.krakowairport.pl, 2012; www.plk-inwestycje.pl, 2012; www.rynek-kolejowy.pl, 2012).

The only other city that could utilize a branch line to reach its airport will be Wrocław (Table 8). Branch lines in Katowice, Gdańsk and Prague cannot be adapted to airport link use. Some of these lines are branches of rail lines, which in some cases, branch off rail lines that for the most part no longer exist (Katowice, Gdańsk). Other branch lines do not really go from city centers towards airports. In these cases, municipal authorities plan to build entirely new rail lines to the airports. A unique aspect of the new rail line in Gdańsk is the fact that it will largely follow a nonexistent since 1945 rail line from the Gdańsk district of Wrzeszcz to a small village called Kokoszki. This new airport rail link will be the part of the Pomeranian Metropolitan Railway system.

Industrial branch lines running near airports are also potentially useful. Both Salzburg and Karlsruhe possess such the lines that (more or less) run from the city center to the airport. However, new lines would be built off those old industrial branch lines. In Salzburg, this would be further complicated by the need to create a walkway under the runway. The new branch line would run along National Highway No 1 that is already being used by trolleybuses serving the airport. In Karlsruhe, a potential upside is the fact that the main rail line that connects with the industrial branch line is already used for tram traffic.

The most common scenario is where a local rail line is neither geographically nor functionally adequate for an airport rail link. Most of the branch lines studied are main lines with overhead wires. This includes Bratislava, Innsbruck and Dortmund. Some airports such as Frankfurt-Hahn and Paderborn/Lippstadt, are close to the unused or partially demolished branch lines. Regardless of their technical condition, those lines

Table 8. Existing potential of rail-based infrastructure for city-to-airport connections in Central Europe

Rank in Central Europe	Airport	Country	Number of passengers in 2010	Rail lines near airports					
				distance to active rail lines		distance to active branch wlines		distance to inactive rail lines and branch lines	
				≤2 km	≥2.1 km	at airport	≤2 km	at airport	≤2 km
7	Prague	Czech R.	11 556 858		+	(+)			
15	Frankfurt–Hahn	Germany	3 463 571						+
16	Weeze	Germany	2 889 651		+				
19	Katowice	Poland	2 403 253		+			(+)	
20	Gdańsk	Poland	2 232 590		+			(+)	
23	Dortmund	Germany	1 740 642	+, StB					
24	Bratislava	Slovakia	1 665 688	+, T					
25	Wrocław	Poland	1 651 057			+			
26	Salzburg	Austria	1 625 842				+		
27	Poznań	Poland	1 419 121		+, T				
28	Münster–Osnabrück	Germany	1 312 656		+				
29	Karlsruhe–Baden-Baden	Germany	1 168 399				+		
30	Innsbruck	Austria	1 033 512	+	T				
31	Paderborn Lippstadt	Germany	1 007 978						+

Explanations: + refers to a given category; (+) potential of branch line is negligible due to its location far away from the city center, a more distant rail line must be used. See +; T – tram; StB – Stadtbahn.

Caution: the tram and the Stadtbahn are considered only at distances of less than 5 km.

Source: authors' own work based on: Atlas drah České Republiky 2006–2007, 2006, Atlas of Polish railways 2010, 2010 and Eisenbahnatlas Österreich, 2005 and other maps.

may only serve as starting points for new airport rail links. In some cases, branch lines run close to terminals. This is the case in Innsbruck where the terminal is only 600 m away from such the line. Close proximity to unused branch lines does not always guarantee low costs. New airport rail links would often have to run across built-up areas and roads. Another issue is the effect of an airport rail link on the main rail line whose capacity may be reached when the new rail link opens.

Some airports are located close to existing tram lines, subway lines or fast tram lines known as Stadtbahn lines. These additional types of rail lines may be useful for building airport rail links, if they are less than 5 km away from the terminals. In practice, this applies mostly to tram lines. Traditional rail links become more practical when the distance exceeds 5 km mainly due to speed and capacity considerations.

Three of the studied cities have tram lines close to airports: Poznań, Bratislava, Innsbruck. The airports in the these cities are located close to the city center. In fact, the distance to built up areas is often negligible and this explains the close proximity to tram lines. In the city of Bratislava, the Ruzinov tram loop is located only 2 km away from the airport terminal, which makes linking the two much more practical. An extension of this tram line would be almost a natural step to take. The same is true of rail lines found at a similar distance to airport terminals, except that a new branch line would have to be built.

A tram line may also be a desirable solution in Poznań, where the nearest existing tram line is located farther away from the airport than the nearest existing rail line (4.3 km vs. 2.9 km), but the airport itself is located reasonably close to the city center and running a tram line from the airport to the city center would be more convenient for city residents. On the other hand, the situation in Innsbruck is difficult to manage from a variety of perspectives. While the distance from the airport to the nearest tram line is only 3.5 km, there are currently no tram lines on the left bank of the Inn River and the construction of an airport tram line would be costly. On the other hand, the extension of the tram system would be more beneficial for city residents than the construction of a new branch line off the main Innsbruck-Bregenz rail line, which would entail the construction of a new railway bridge over the Inn River and an overpass over the A12 motorway.

In Dortmund, the rail line nearest to the airport is the fast Stadtbahn line U43. However, the tram line runs on the surface and across the runway from the terminal, which would entail the construction of an underground branch line with a terminal station.

The potential of rail lines and tram lines running near airports varies from location to location due to the distance to airport terminals, existing rail traffic, and technical condition. Most rail lines running near airports are not in any way linked to them, being located more than 2 km away from terminals and serve long-distance passenger trains. Even when rail lines are found closer to an airport, they are often not useful for a variety of reasons. This is especially true of regular branch lines and industrial branch ones. In some cities, tram lines and Stadtbahn lines are best suited to be extended to airports.

Conclusions

The key conclusion in this paper is that airports need rail links to the cities they serve. However, the creation of such rail links must be done in an economically rational manner. Even when an airport is judged to be too small to justify a rail link, careful consideration must be given to the actual risks associated with the creation of a rail link. Good access to the local airport is a key element of a city's marketing strategy, which is easier to generate if a city is well connected. An effective connection to the local airport is a key element of proper overall connectivity. On the other hand, Button and Lall (1999) assert that economic growth at airline hubs is a reason for their existence and not a product of their existence. The airlines choose a given city in order to take advantage of growth that is already there.

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