

Dusek, Tamas

Conference Paper

Travel time and travel cost in European air travel

52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Dusek, Tamas (2012) : Travel time and travel cost in European air travel, 52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/120663>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Travel time and travel cost in European air travel

Paper presented to the 52th Congress of the European Regional Science Association
Bratislava, Slovakia, 21-25 August 2012

Tamás Dusek
Széchenyi István University
Győr
Hungary
9026, Egyetem tér 1.
dusekt@sze.hu

Acknowledgment

The research was supported by the TAMOP-4.1.1/A-10/1/KONV-2010-0005.

Abstract

The aim of the study is to examine two issues of consumer air travel accessibility in Europe, namely flight time and ticket costs. The first part of the paper discusses the various methodological problems of creating time matrix and cost matrix of air travel. Because of problems of conceptualizing of the air travel network and the modifiable areal unit problem the analysis is conducted on several spatial levels. The smallest network consists of 15 busiest airports and the largest network has 203 airports. Airports were selected based on the number of arriving and departing aircraft. The source of flight time data is the timetable for the non-stop flights. Flight time was calculated with a simple algorithm based on timetable flight time for one-stop and two-stop connections. The source of ticket cost data is an internet query of travel itineraries. Several distance matrices were created for different networks and date of flights.

The applied part of analysis uses simple methods also, such as average flight time, speed, cost and unit cost. The deformation of time and cost space from the Euclidean space is analyzed by multidimensional scaling. The comparison of geographical space on one side, and time space and cost space on the other side is made by the simple regression analysis and bidimensional regression. Results show significant local and regional biases in time and cost space, relative to the air distance.

Keywords: time space, cost space, air travel, multidimensional scaling, bidimensional regression

JEL code: R40

Introduction

Differences between various spaces can be measured with various global and local indices. Global indices show the size of differences between two spaces as a whole, whereas local indices describe the distortion of a point or a smaller area compared to a reference space. The reference space of comparison is often but not always the geographical space. Local indices are able to detect points and areas where some barrier of connection may exist and where improving the network may have the biggest effect on the change of accessibility. Graph theory also can be effectively used in measuring the properties of the networks.

In this paper an exploratory analysis will be conducted about the geometry and topology of the space of European air traffic by the help of some elementary indicators, multidimensional scaling, bidimensional regression and visual methods. Not only the whole network, but the parts of the network (airports and cities) can be analysed. The maps are important part of the analysis, the visual perception cannot be substituted with verbal or mathematical description.

The study area and sources of time space data

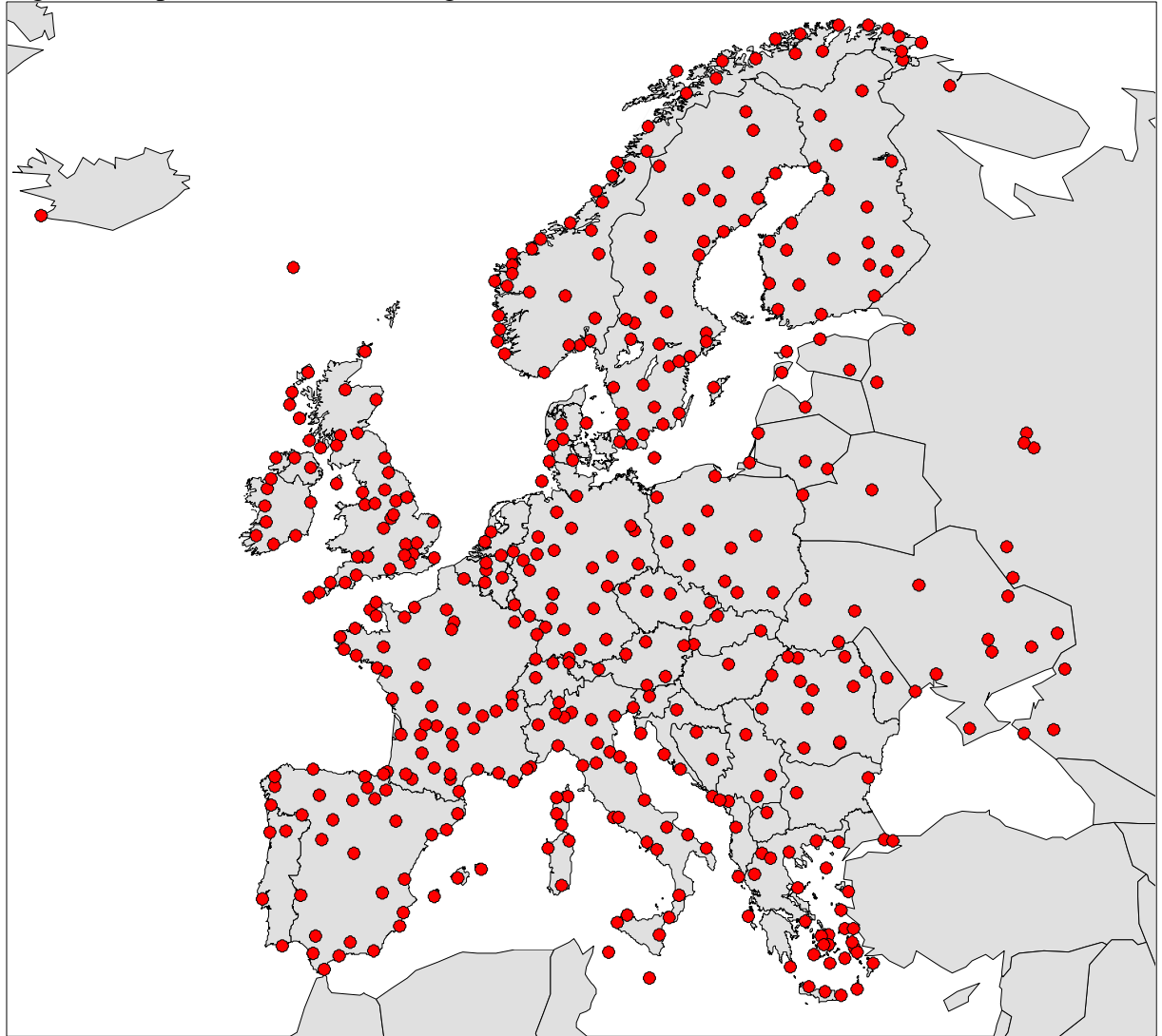
In the analysis the travel time and cost between the access points of air travel, namely the airports will be analysed. The supplementary time and cost of the travel between airports and the endpoints of the travels will not be taken into accounts.

For the determination of analysed network five decisions should be made: geographical coverage (delimitation of Europe), choosing the airports inside Europe, treatment of the airports which are close to each other, the temporal (daily, monthly and so on) variability of time schedule, and the differences of the number of flights between various airports.

Northern borders of Europe are clear, the other directions have border territories sometimes treated as part of Europe, sometimes treated as part of Asia or Africa. From the big islands Iceland was taken into account, but Canary, Azores, Madeira and Ciprus not. European part of Turkey, Istanbul is part of the analysis with his two airports. Russian territories behind Moskau and Caucasian countries are omitted. The delimitation of the study area has some impact on the results therefore the results can be applied only to the area under investigation. Investigations under the world level have to cope with the problems arising from the omission of external contacts.

In this area there were approximately 446 airports with scheduled flights in December, 2010. The exact number cannot be determined because of the treatment of very small airports. The source of time schedule is the database of OAG. The geographical distribution of airports can be seen on Figure 1. The distribution is uneven and not similar to the uneven distribution of population, because for example the sparsely populated Scandinavian countries has very dense airport network.

Figure 1 Airports with scheduled flights in December, 2010

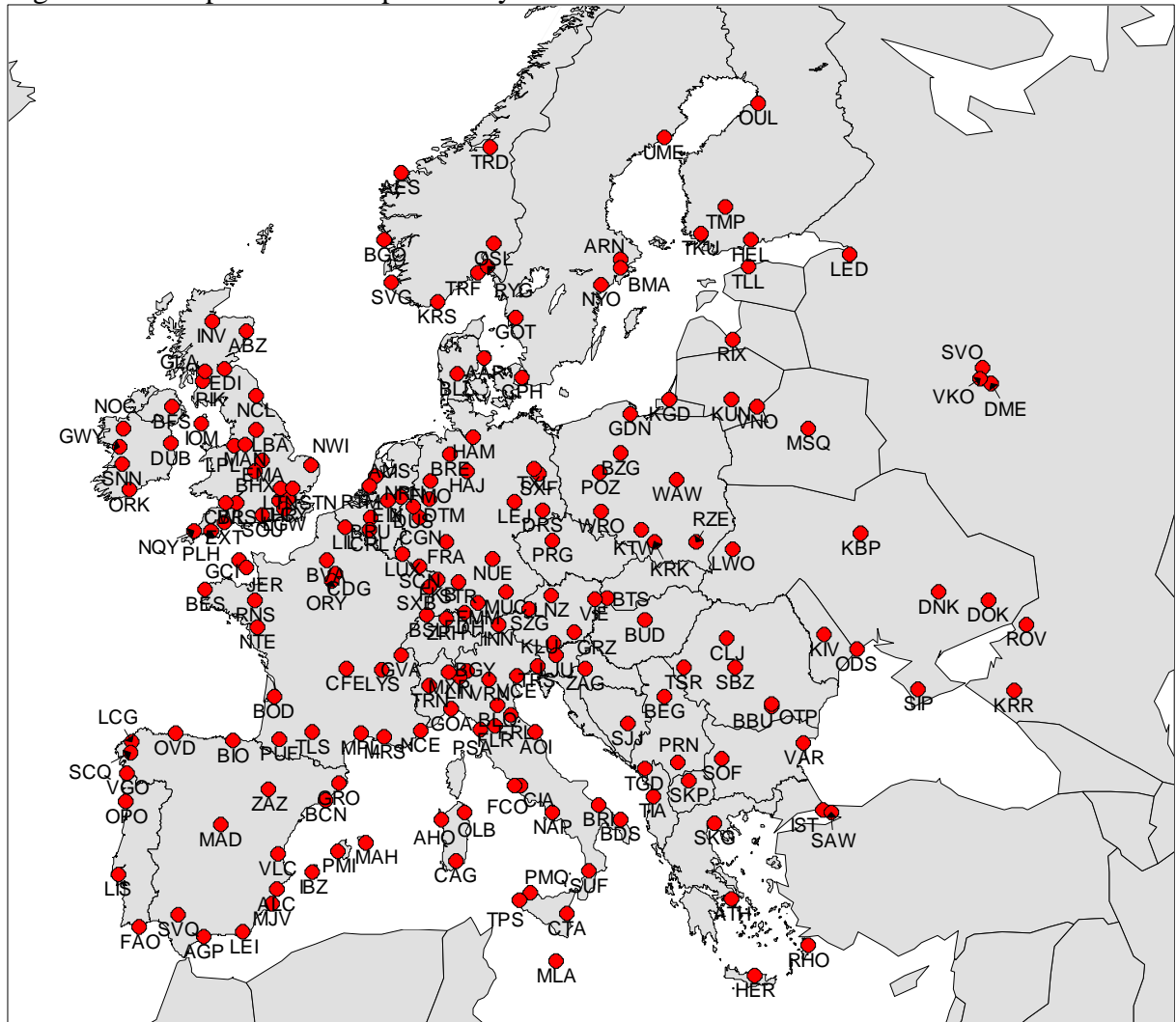


Source: OAG

The present analysis belongs to those interesting and uncommon cases, where instead of the analysis of the total and known population the analysis of a smaller subpopulation is more appropriate. The reason for this is that from some point of view the weight of the airports in the network is identical, in spite of the huge differences between the numbers of flights of different airports. Therefore the omission of very small airports is reasonable. The effect of small airports can be illustrated with an example. Tirgu Mures (in central part of Romania) has connection only with Budapest and Bucharest. If Tirgu Mures is an element of the network, it would be possible to travel from Budapest to Bucharest and from Bucharest to Budapest through Tirgu Mures also. However, these opportunity would not be a rational choice, the two big capitals is connected with many non-stop flights. Therefore omission of Tirgu Mures does not have any impact on the connections of the other airports which is accessible through Budapest or Bucharest. However, inclusion of Tirgu Mures would have a positive impact on the accessibility of Budapest and Bucharest and negative impact (in relative sense compared to Budapest and Bucharest) on the accessibility of every other airport. This is true to other small airports: Haguesund in Norway has connection with Oslo

and Bergen and so on. At the examination of time space there were two requirements for inclusion of an airport into the analysis: at least four flights on 9 December, 2010 and at least one international flight. These 203 airports can be seen on Figure 2. In Scandinavia and Greece the majority of airports have just inland flights therefore in these countries the reduction of the number of airports is higher than other parts of Europe.

Figure 2 203 airports in time space analysis



Basic characteristics of air traffic

The distance between close airports cannot be determined in a sensible way inside the network of air traffic. For example, London has five airports, without scheduled flights between these airports. Transfers between these airports are possible by train, coach or car in rational way and not with two flights. The case is similar not only in cities with more than one airport, but the airports which are very close to each other, for example Vienna and Bratislava, Liverpool and Manchester (closer to each other than airports in London). These airports cannot be treated in a unified way from the point of view of transfer flights, but the distances between these airports should be treated different from the distances between those

airports, where air traffic is a rational choice. We will go back to this question later during the analysis.

Temporal change of time schedule can be treated in two different ways: either by choosing one actual day or creating a typical, but not actual time schedule from different days. The second solution has many theoretical and practical drawbacks, therefore we chose one day for the investigation of time space, December 9, 2010 (Thursday). The results are valid only to this day without any limitations. We did not take into account the number of flights between the various airports, partly because of the lack of data, partly because of conceptual reasons.

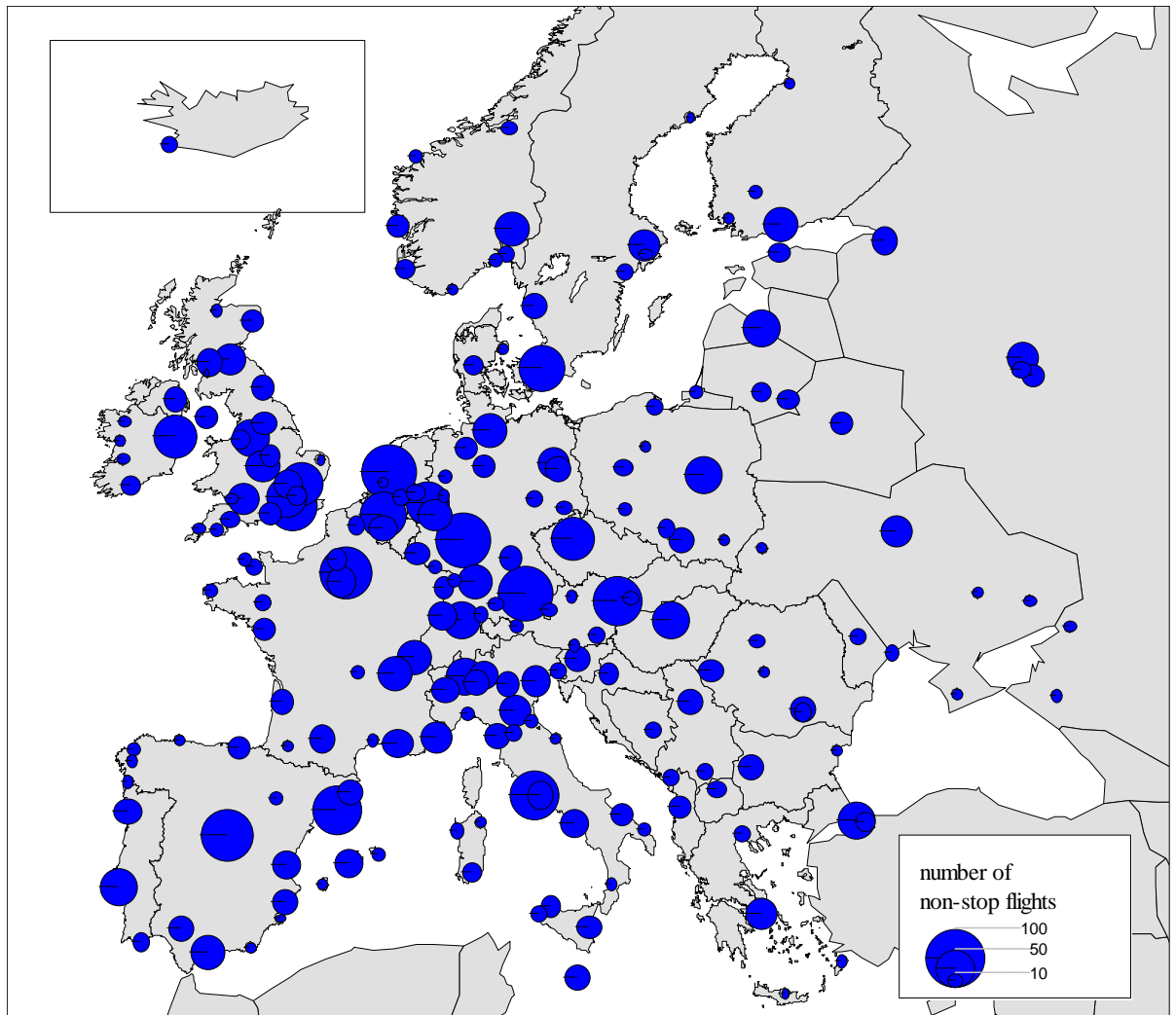
The time distance was calculated in the following way: We created first the direct flight matrix according to altogether 2219 flight pairs, 4438 connection between the 203 airports. The shortest duration of flight was chosen, without any waiting time. Between the indirect linked airports the time distance was calculated not according the time schedule, but we added two hours waiting/changing time to the shortest theoretically possible connection. In this case the constraint of time schedule was not taken into consideration. This may be a drawback, 0 can be seen on Figure 3 for every airport and on Table 1 for the biggest airports. The maximum number of the possible links is 202. According the internal links the picture would be different, for example London Heathrow has altogether 151 links (on 9 December), but many of them with non-European destinations.

Table 1 Number of non-stop flights (only in the network of 203 airports)

Code	Number	Code	Number	Code	Number
AMS	95	DUB	64	LIS	47
MUC	94	PRG	64	MXP	47
FRA	93	DUS	62	GVA	45
CDG	86	STN	60	HAM	44
MAD	84	LHR	53	OSL	44
VIE	81	BUD	52	LYS	42
FCO	80	IST	51	HEL	41
LGW	80	WAW	50	AGP	40
BCN	78	MAN	49	STR	40
CPH	73	ZRH	49	EDI	38
BRU	71	RIX	48	NCE	38

Source: OAG

Figure 3 Number of non-stop flights (only in the network of 203 airports)



Source: OAG

The second indicator is the percentage of non-stop, one-stop, two-stop and three-stop connections. The lack of connections between the very close airports does not mean a real lack in network. Of course, there is not a sharp distinction between “very close” and “not very close” airports. We used 300 kilometers for distinction of very close and not very close airports, because under this distance transport by car, coach and train is mainly faster than air traffic due to the much longer waiting time and transfer traffic of the latter one. We do not take into consideration the possible contacts between the airports closer than 300 kilometers to each other, thus the number of possible contacts ($203 \times 202 = 41006$) will be reduced by 1322 (3,2% of all possible contacts).

The distribution of non-stop, one-stop, two-stop and three-stop flights can be analysed with a classification method, namely cluster analysis. The results reflect the similarity and dissimilarity of various airports in a very plastic way. The numbers of various groups and the average values of the groups can be seen in Table 2. For example, in the first group 39,7 percent of the airports can be reach non-stop, 59,8 percent with one stop and just 0,46 percent with two stops. We categorized the 8 groups into 3 bigger groups and we depicted the

elements of the bigger groups in three figures (Figure 4-6). The first group has highly accessible European hubs, the last group has peripheral airports without non-stop connections to the main hubs. The non-stop connections have a great importance, for example, Lille has 11 connections, but 9 of them are with regional airport in France and two of them are with regional airports in Portugal and Spain. The second example is the third airport in Moskau, Vnukovo, which has altogether 76 connections, but each of them is in former Sowjetunion.

Table 2 Airport taxonomy

Main group	Group	Number of airports	Non-stop	Percentage of connections		
				One-stop	Two-stop	Three-stop
1	1	15	39,74	59,80	0,46	0
1	2	29	21,23	75,46	3,31	0
2	3	39	11,08	78,09	10,83	0
2	4	31	9,18	69,63	21,19	0
3	5	31	4,81	63,33	31,86	0
3	6	40	3,54	52,40	44,04	0,01
3	7	12	2,97	41,67	55,16	0,21
3	8	6	3,24	27,25	68,18	1,34

Figure 4 Airports in first main group

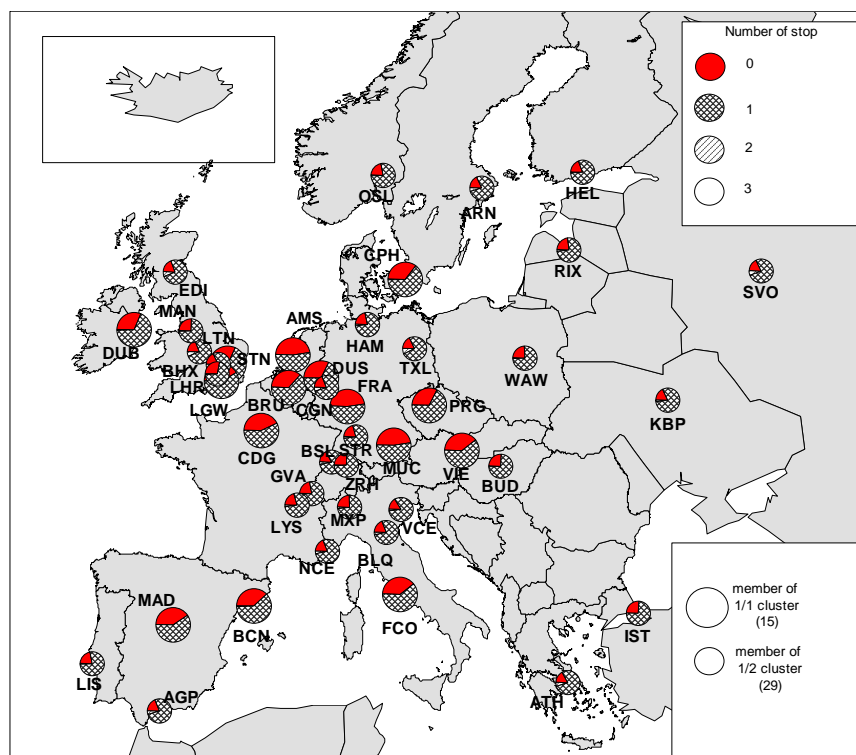


Figure 5 Airports in second main group

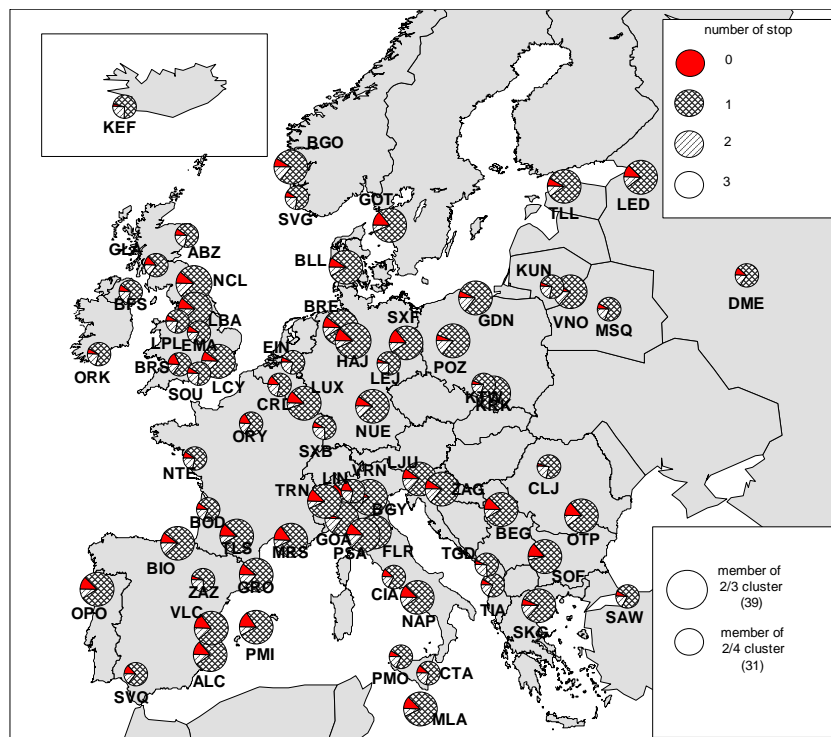
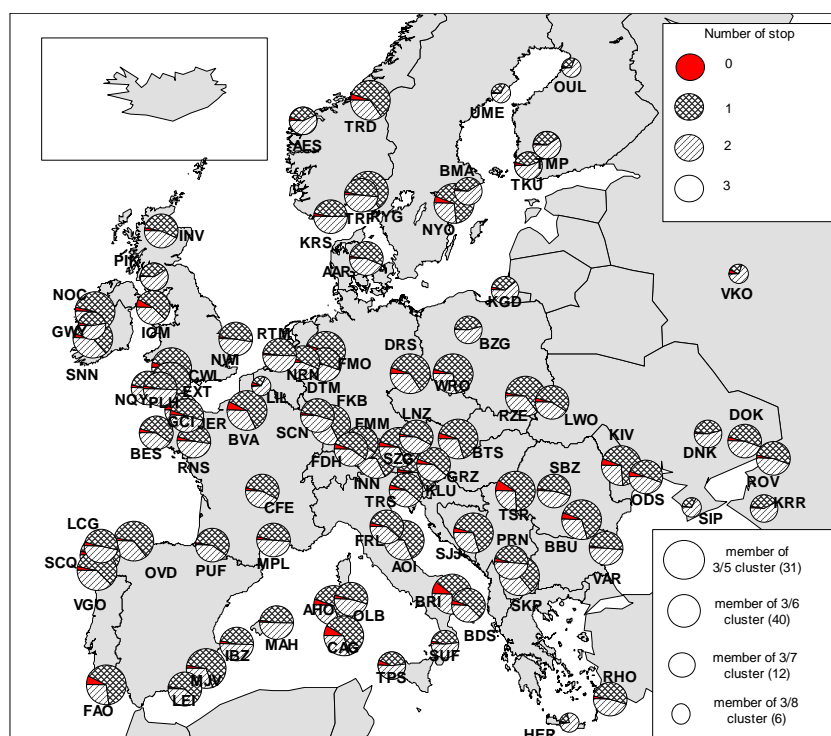


Figure 6 Airports in third main group



It is interesting to compare the difference between the percentage of sum of time distance in the whole network and the percentage of sum of geographical distance in the whole network in each airport. This indicator will be 1, if an airport has an average accessibility, less

than 1 if an airport has better accessibility than average, more than 1, if an airport has worse accessibility than average. For example, the sum of distance between Budapest and the other airports is 243737 kilometers, which is 0,424 percent of the sum of total network distance. The share of Budapest in sum of total time distance is 0,369 percent. Thus the indicator will be $0,369/0,424=0,869$. The problem of close airports was treated in following way: we compare the time distance in minute and geographical distance in kilometer and if the latter value is smaller then we used this value as time distance.

In the results two different effects are mixed: the connectivity and the location of airport. The location means that geographically peripheral airports have longer connections in average, and longer connections have higher speed. This is the explanation for the very good ratio of Lisbon, Madrid, Moskau, Istanbul and Reykjavik. (Figure 7 and Table 3)

Table 3 Airports with smallest and highest ratio of the percentage of sum of total time distance and the percentage of sum of total air distance

Percentage in total network				Percentage in total network			
Code	Air distance	Time distance	Time/air	Code	Air distance	Time distance	Time/air
LIS	0,725	0,472	0,65	SZG	0,362	0,480	1,32
MAD	0,584	0,382	0,65	INN	0,358	0,475	1,33
SVO	0,757	0,499	0,66	TRS	0,381	0,512	1,34
IST	0,677	0,453	0,67	BVA	0,385	0,520	1,35
KEF	0,940	0,643	0,68	LNZ	0,369	0,500	1,36
AGP	0,699	0,481	0,69	FRL	0,397	0,550	1,39
HEL	0,629	0,443	0,70	FDH	0,352	0,492	1,40
ATH	0,664	0,479	0,72	BZG	0,425	0,594	1,40
BCN	0,491	0,355	0,72	SCN	0,352	0,494	1,40
KBP	0,613	0,451	0,74	DTM	0,360	0,521	1,45
DUB	0,519	0,383	0,74	FKB	0,349	0,506	1,45
SVQ	0,700	0,519	0,74	LIL	0,377	0,586	1,55
DME	0,763	0,568	0,74	HHN	0,351	0,548	1,56
LED	0,687	0,514	0,75	NRN	0,365	0,582	1,59
OPO	0,660	0,500	0,76	FMM	0,352	0,564	1,60
OSL	0,537	0,409	0,76	RTM	0,377	0,637	1,69

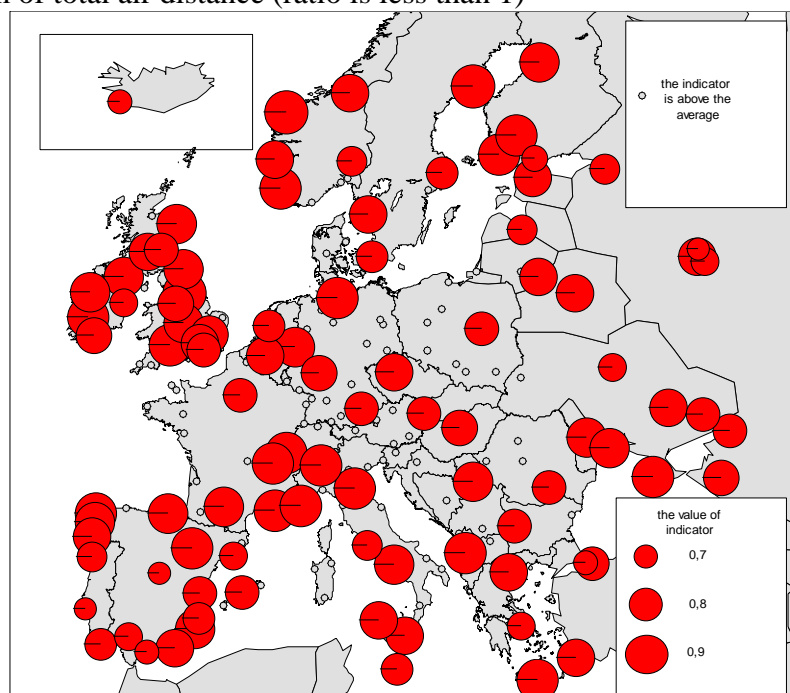
The nominator and denominator of the previous indicator can be interpreted in its own right as a centrality measure. (Table 4) The minimal values are smaller in time space than in geographical space, because there are centrally located main hubs in geographical space.

Table 4 The most central and most peripheral airports in geographical space and time
space

Code	City	Time, percentage	Code	City	kilometer, percentage
MUC	Munich	0,293	STR	Stuttgart	0,349
FRA	Frankfurt	0,296	FKB	Karlsruhe	0,349
AMS	Amsterdam	0,301	FRA	Frankfurt	0,350
CDG	Paris	0,316	SXB	Strasbourg	0,351
VIE	Vienna	0,321	HHN	Hahn	0,351
BRU	Brussel	0,323	SCN	Saarbrücken	0,352
DUS	Düsseldorf	0,331	FMM	Memmingen	0,352
PRG	Praha	0,332	NUE	Nuremberg	0,352
LGW	London	0,338	FDH	Friedrichshafen	0,352
CPH	Kopenhagen	0,339	ZRH	Zürich	0,354
DNK	Dnepropetrovsk	0,639	VKO	Moskva	0,752
KEF	Reykjavik	0,643	OUL	Oulu	0,755
UME	Umea	0,680	SVO	Moskau	0,757
VKO	Moskau	0,682	HER	Heraklion	0,758
RHO	Rhodos	0,686	DME	Moskau	0,763
ROV	Rostov	0,690	DOK	Donetszk	0,770
OUL	Oulu	0,693	RHO	Rhodos	0,776
SIP	Simferopol	0,709	ROV	Rostov	0,825
HER	Heraklion	0,722	KRR	Krasnodar	0,836
KRR	Krasnodar	0,727	KEF	Reykjavik	0,940

Source: own calculation

Figure 7 The ratio of the percentage of sum of total time distance and the percentage of sum of total air distance (ratio is less than 1)



Comparison of time space and geographical space

The comparison of time space and geographical space is a methodologically interesting issue, because both spaces are non-Euclidean. The methodological framework of analysis can be briefly summarized as follows. There are a set of distance relations between various locations, obtained from the transportation system of a geographic space. The data should be organized in a matrix with all sets of origins and destinations. Multidimensional scaling uses the distance matrix as input and then generates another matrix, containing the coordinates of points of the investigated space. Diagnostic tools of multidimensional scaling help to determine whether a meaningful spatial structure exists. (Ahmed – Miller, 2007) Bidimensional regression can compare the result of multidimensional scaling (MDS) with the geographical space. Bidimensional regression is a method to compare two or more two-dimensional surfaces. It is an extension of linear regression where each variable is a pair of values representing a location in a two-dimensional space. Bidimensional regression numerically compares the similarity between two-dimensional surfaces through an index called bidimensional correlation. The visual representation of various spatial relations and map transformations were carefully examined in the path-breaking works of Waldo Tobler (Tobler, 1961; Tobler, 1963). Multidimensional scaling is a well-known statistical tool used in many fields of research. Regarding the use of multidimensional scaling in spatial analysis, one has to mention among the first use of method Marchand (1973) paper, Gatrell's monograph (Gatrell, 1983), articles by Spiekermann and Wegener. Bidimensional regression was originally developed in 1977 by Waldo Tobler but was not widely known until the technique was published in 1994. (Tobler, 1994) Compared to the multidimensional scaling, bidimensional regression is not as well known method. It is applied to analyze and measure the relative distortion of historic maps (for example Lloyd and Lilley, 2009; Symington et al., 2001), to compare cognitive maps (Friedman–Kohler, 2003) and to compare spaces generated by multidimensional scaling (Ahmed–Miller, 2007). About the methodological framework of the analysis Ahmed–Miller, Axhausen–Hurni (2005) and Friedman–Kohler (2003) also give an excellent overview.

The modified time distance matrix (modification was the same for the close airports as in the case of the ratio of the percentage of sum of total time distance and the percentage of sum of total air distance) was analyzed by PROXSCAL technique of multidimensional scaling. The normalized raw stress is 7%. The geographical distance matrix was analyzed with the same method for solving the problem of sphericity and for the minimization of distance distortion. The two results can be compared with the bidimensional regression.

Visual representation of the results is not easy because of the high number of airports. The position of 17 biggest airports can be seen on Figure 8. The movement to the central location in time space shows the good accessibility of this airport. The direction of movement shows which direction has better connections as average. For example, Vienna displacement to the centre is much smaller than Budapest displacement, not because of less centrality or

less connection of Vienna compared to Budapest, but because of very good East European connections of Vienna.

Figure 8 Difference between geographical location and time space location

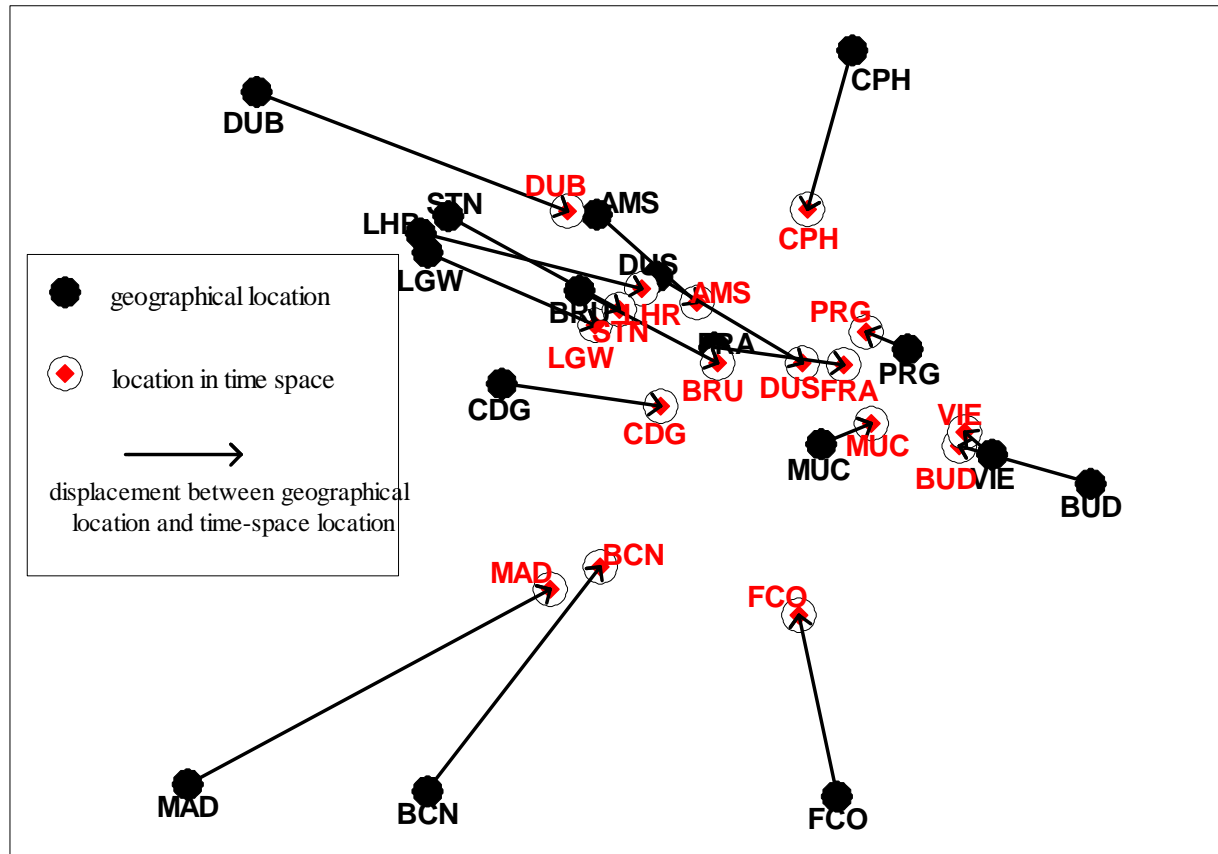


Figure 9 shows every airport. The size of circles is proportional to the displacement between the two spaces. For better visual perception only the 10 biggest displacements are indicated on the figure. For example, Kaunas (KUN) in Lithuania has very good North European and North-western European connections but bad connections to other directions and this leads to a displacement in western direction.

Figure 10 shows the displacement of airports in Central Europe. For example it can be seen very well, that Istanbul (IST) has a shift towards Central Europe because of the good connections, and in the time space its location is more central than for example Cluj (CLJ) in Central Romania. These displacements concentrate the information about the number and direction of connections.

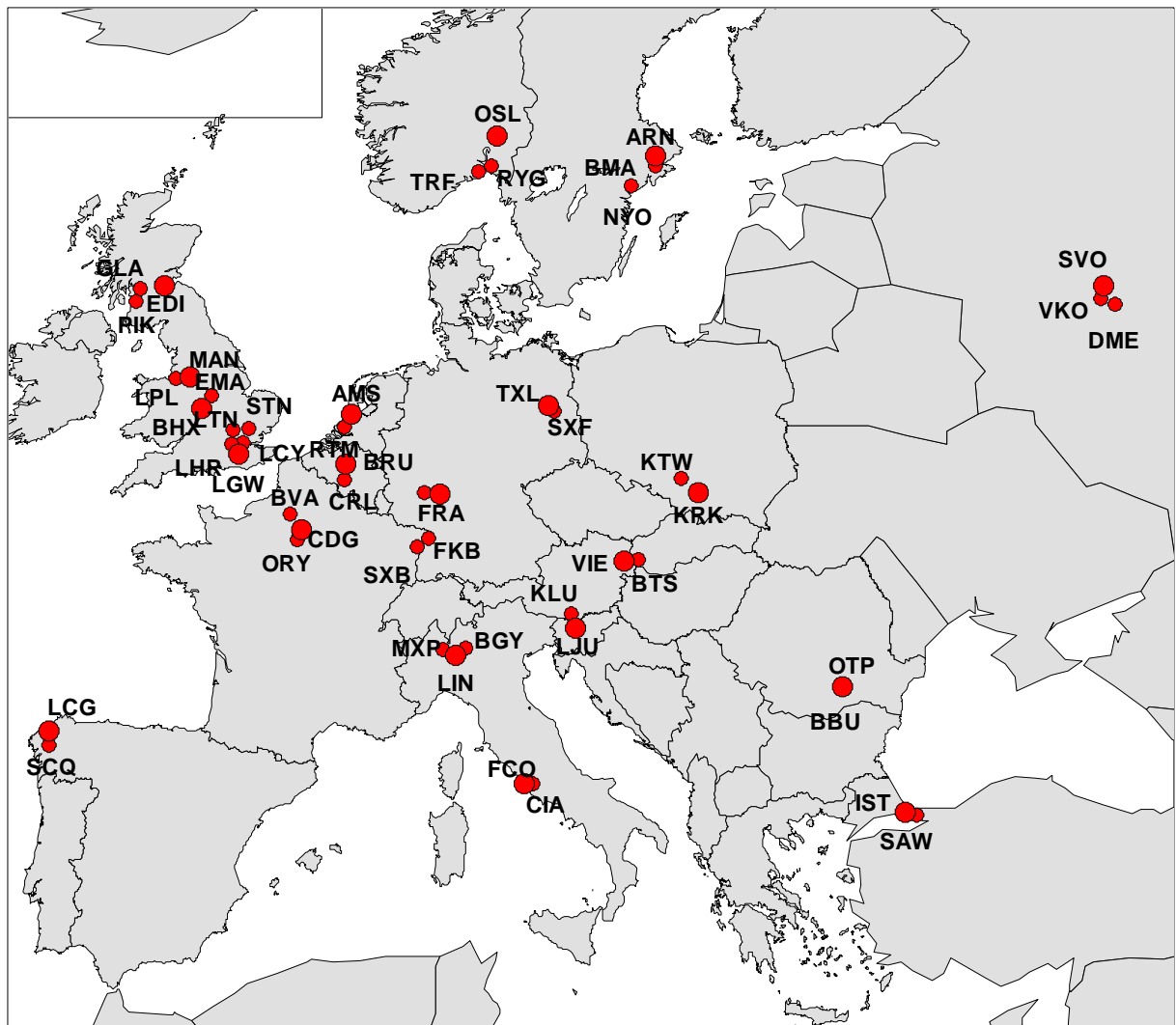
Figure 1 is a scatter plot illustrating the geographical location (black dots) and location in time space (red diamonds) of various airports. The plot includes labels for airports such as KEF, KUN, FMM, RTM, DTM, KUN, LIS, AGP, NRN, RTM, BBU, RHO, and BBU. The legend indicates that black dots represent geographical location and red diamonds represent location in time space.

[illegible]

Unified treatment of close airports

In the previous analysis the airports were treated separately, just there was some correction in the case of very close airports. In this part of analysis the close airports which serve the same city or agglomeration will be treated commonly. Altogether 51 airports were merged into 21 airport-group, from which one group consists of five airports (London), five groups have three airports and 15 groups has two airports. The location of these airports can be seen on Figure 11. In some cases there are huge differences between the sizes of two airports (for example Vienna-Bratislava, Manchester-Liverpool) in other cases the airports belong to the same size category.

Figure 11 Airports close to each other



The new network has 173 airports or airport-groups. The biggest 33 airports can be seen on Table 6. The most important change compared to the previous network is that London

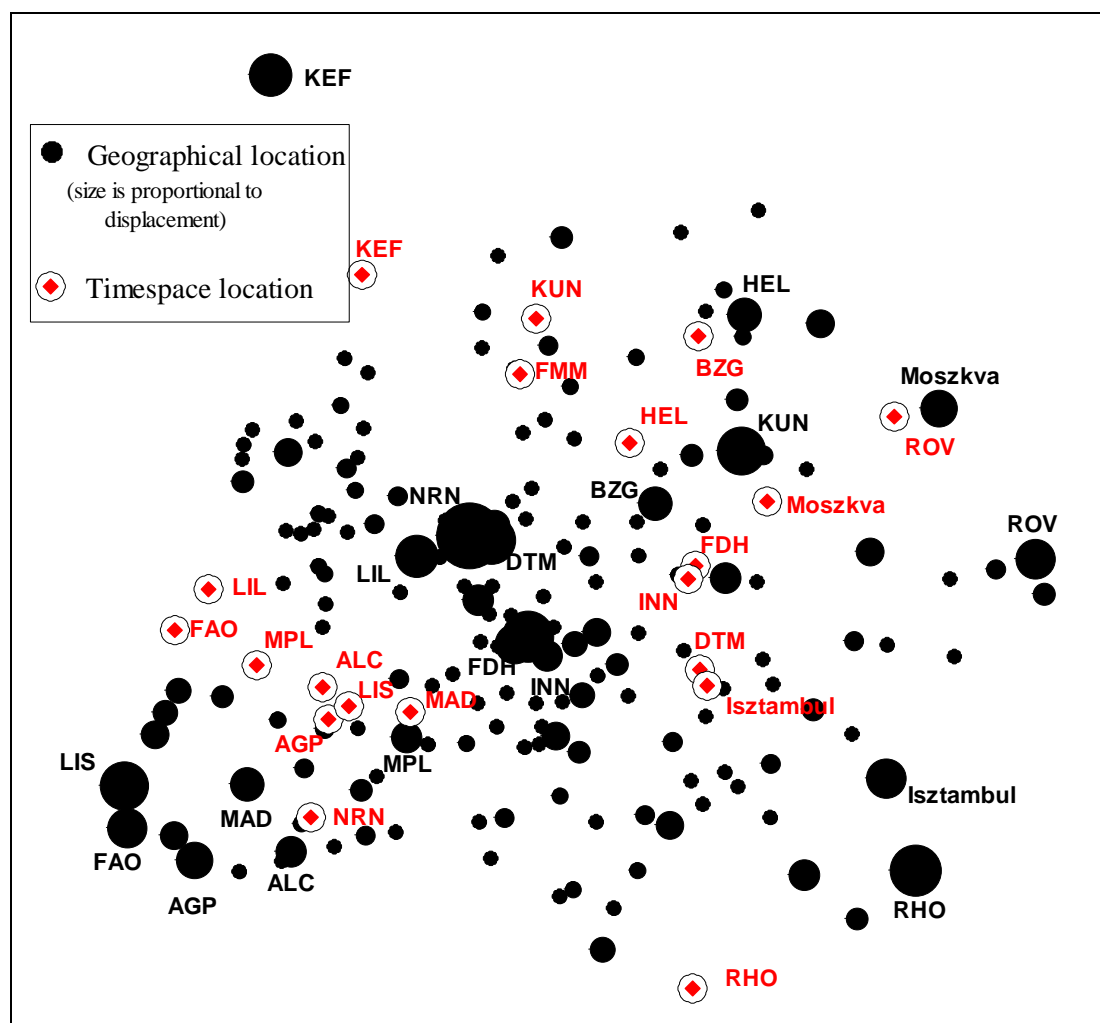
became the first. Otherwise there are not important differences. This is good, because it shows that the previous results are robust, different treatment of some airports is not very influential. (Figure 12)

Table 6 The number of non-stop connections on December 9, 2010

Kód/név	szám	Kód/név	szám	Kód/név	Szám
London	110	Milánó	60	LIS	43
Frankfurt	94	PRG	58	RIX	41
Párizs	93	DUS	57	Stockholm	41
MUC	86	Isztambul	53	Moszkva	41
Amszterdam	85	Manchester	53	GVA	40
Róma	80	Berlin	52	HAM	40
Bécs	78	DUB	50	HEL	39
Brüsszel	74	BUD	47	LYS	38
MAD	69	WAW	45	Birmingham	38
BCN	65	ZRH	45	STR	37
CPH	64	Oslo	44	Edinburgh	36

Forrás: OAG

Figure 12 The biggest differences between geographical location and time space location



Analysis of cost space

The conceptualization of time space of air traffic is not an easy task, but the conceptualization of cost space is much harder. We examined this problem in an other paper in a very detailed manner. Here we just show one examples for the different prices of perfectly same tickets on the same time in different travel agencies. (Table 7) About the problems of flight ticket prices see Bilotkach-Pejcinovska 2007; Bilotkach 2010; Bilotkach, V. – Rupp, N. (2011) GAO, 2003; empirical analysis can be found in Dudás – Pernyész (2011), Grubestic – Zook (2007).

Table 7 The price of London-Dublin flight tickets for May 5 2011. on 19 March 2011

Agency	Airlines	Price	Devisa	Price in euro
Bravofly	Ryanair	20,42	Euro	20,42
Pelikán	Ryanair	9175	HUF	33,56
Ryanair	Ryanair	19,69	GBP	22,53
Ryanair (20 March)	Ryanair	15,98	GBP	18,29
Statravel	BMI	25400	HUF	92,92
eDreams	BMI	61,55	Euró	61,55
Travelocity	BMI	77,4	USD	54,78
CheapOair	BMI	116,27	USD	82,29
AirTicketsDirect	BMI	119,96	USD	84,90
Bravofly	BMI	63,05	Euro	63,05
Pelikán	BMI	24257	Ft	88,74
BMI (with bankcard)	BMI	47,6	GBP	54,47
BMI (with creditcard)	BMI	52,1	GBP	59,62
Europebyair	BMI	150,47	USD	106,49
CheapFlights	BMI	84,4	USD	59,73
CheapFlights	BMI	52,1	GBP	59,62
CheapFlights	BMI	70,55	Euro	70,55
Aer Lingus	Aer Lingus	24,99	GBP	28,60
Bravofly	Aer Lingus	34,74	Euro	34,74

For the building of price database the offers of Bravofly travel agency was used because that seems the cheapest (in average) and from technical point of view also the most efficient agency. The investigated network was determined by four factors: technical constrain, the data collection cannot be made in automated way therefore the network cannot be too large; flight number; capital cities have priority; geographical coverage.

Due to the space limitation we can show only the most elementary results of the analysis. Figure 13-14 shows the average price of cheapest offers of a return flight for the respective networks. The collection was conducted in the beginning of March, 2011. The departure is on May 5, 2011 (Monday), return flight is on May 8, 2011 for the bigger network. In the case of smaller network altogether 17 different queries were conducted. Figure 15 shoes that distortion from geographical space is significant. London and Milan has the best position in cost space. Milan has central position in geographical space also, but the favorable position of London is attributable not to its geographical location but to its excellent air traffic availability.

Figure 13 Average distances in geographical space and cost space (ticket prices are averages of 17 prices at different point of time, altogether 238 tickets per city)

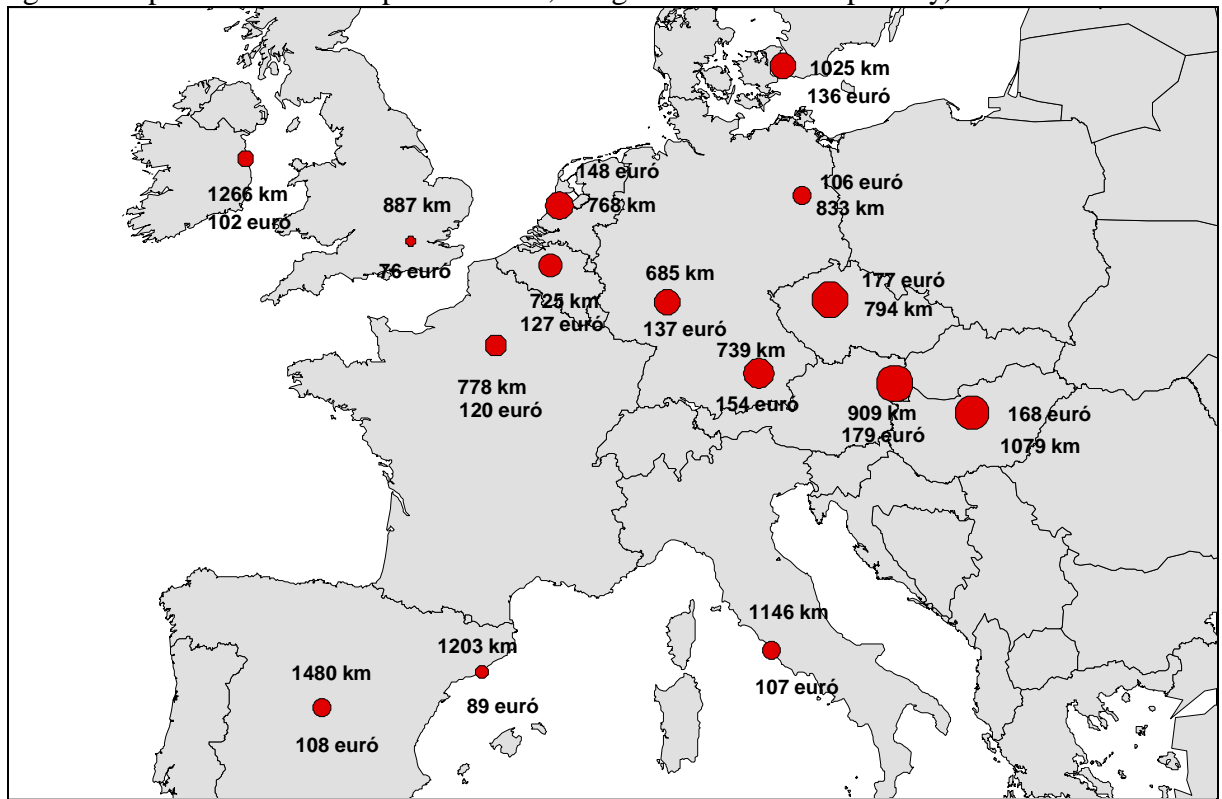


Figure 14 Average prices in euro (inside the network with 32 cities)

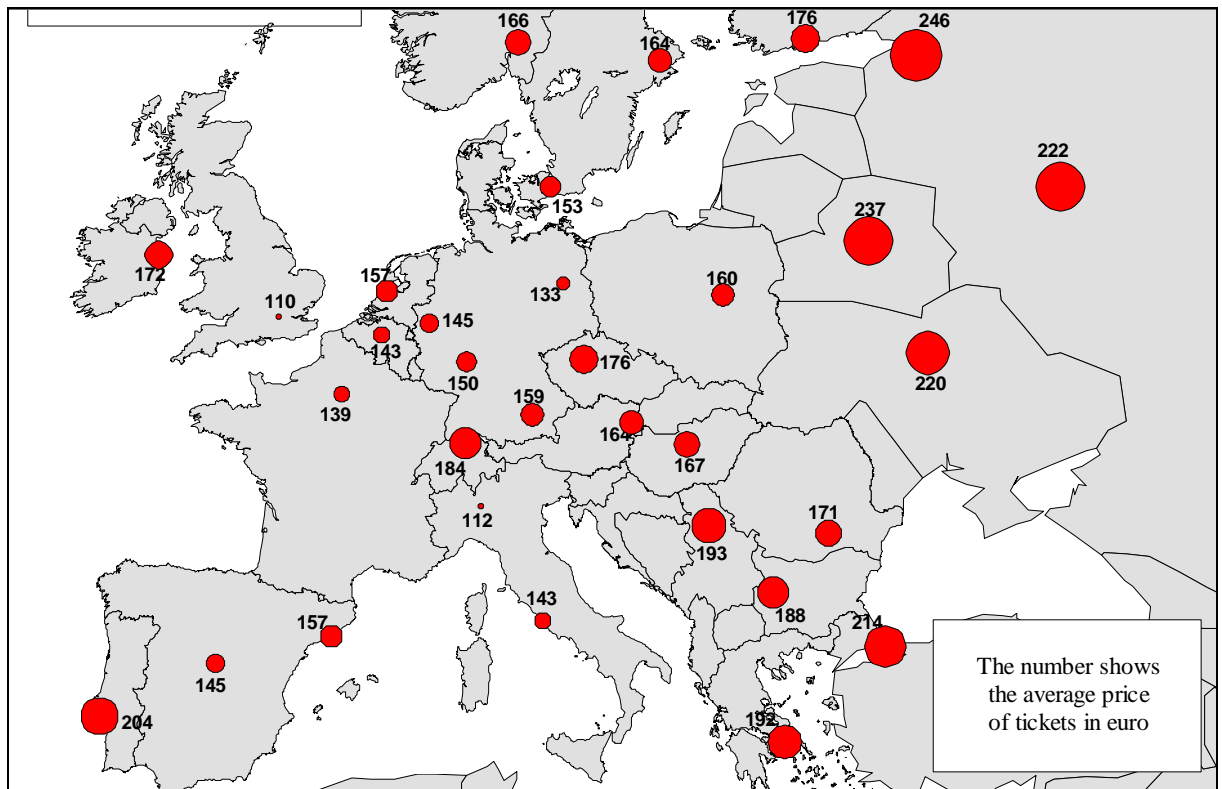
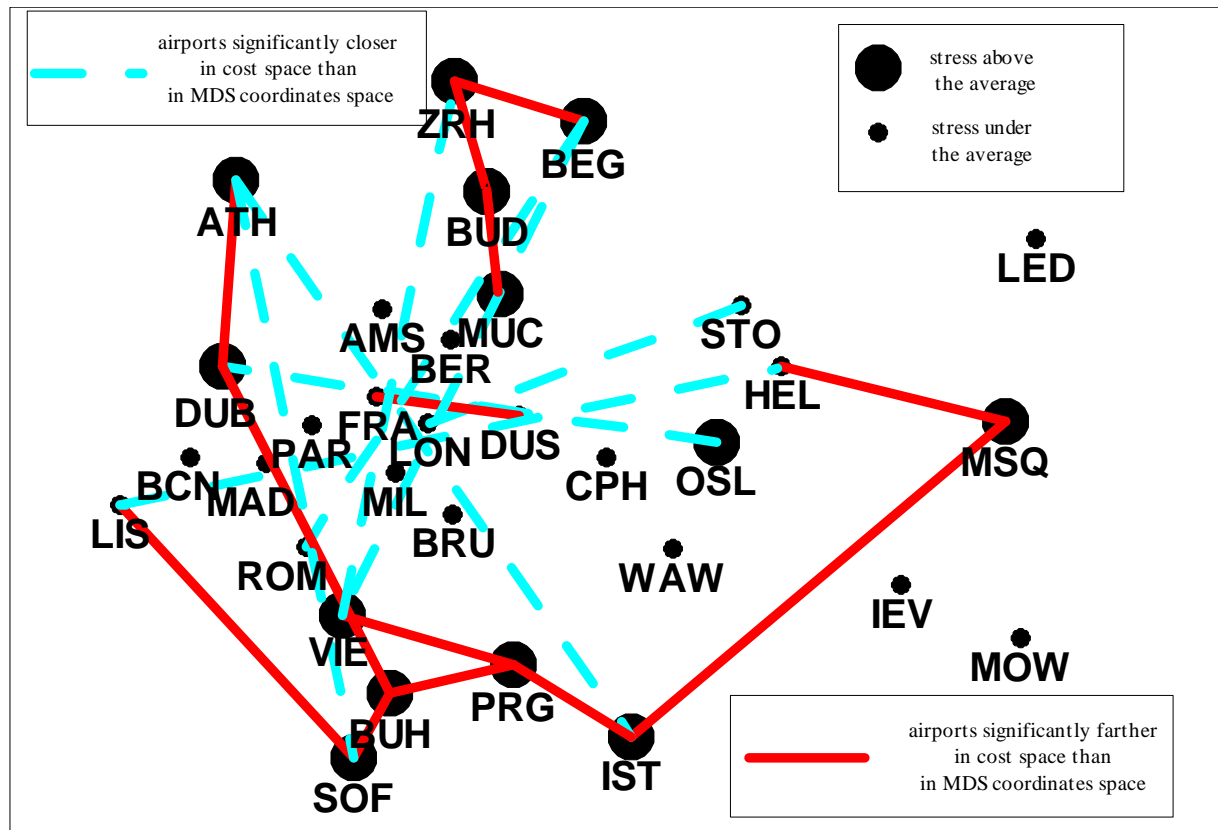


Figure 15 Cost space location of 32 airports (calculated with multidimensional scaling)



Literature

- Ahmed, N. – Miller, H. J. (2007) Time-space Transformations of Geographic Space for Exploring, Analyzing and Visualizing Transportation Systems. *Journal of Transportation Geography*, 15, 2-17. o.
- Airline Ticketing. Impact of Changes in the Airline Ticket Distribution Industry, United States General Accounting Office (GAO) 2003. July
- Axhausen, K. W. – Hurni, L. (2005) Zeitkarten der Schweiz 1950–2000. Institut für Verkehrsplanung (IVT), ETH Zürich Institut für Kartographie (IKA), ETH Zürich
- Bilotkach, V. (2010) Reputation, search cost, and airfares. *Journal of Air Transport Management*, 16, 251-257
- Bilotkach, V. – Rupp, N. (2011) A Guide to Booking Airline Tickets Online. Working Paper. http://www.ecu.edu/cs-educ/econ/upload/ecu1108-rupp_voldy_guide.pdf
- Bilotkach, V. – Pejcinovska, M. (2007) Distribution of Airline Tickets: A Tale of Two Market Structure. Working Paper
- Dudás Gábor – Pernyész Péter (2011) A globális városok térkapcsolatainak vizsgálata légiközlekedési adatok felhasználásával. *Tér és Társadalom*, 25, 81-105
- Ewing, G. (1974) Multidimensional Scaling and Time-space Maps, *Canadian Geographer*, 18, 161-167. o.
- Friedman, A. – Kohler, B. (2003) Bidimensional Regression: Assessing the Configural Similarity and Accuracy of Cognitive Maps and Other Two-Dimensional Data Sets. *Psychological Methods*, 8, 468-491. o.

- Gatrell, A. (1983) *Distance and Space. A Geographical Perspective* Clarendon Press, Oxford
- Grubisic, T. – Zook M. (2007) A ticket to ride: Evolving landscapes of air travel accessibility in the United States. *Journal of Transport Geography*, 417-430
- Lloyd, C. D. – Lilley, K. D. (2009) Cartographic Veracity in Medieval Mapping: Analyzing Geographical Variation in the Gough Map of Great Britain, *Annals of the Association of American Geographers*, 99, 27-48. o.
- Marchand, B. (1973) Deformation of a transportation space. *Annals of the Association of American Geographers*. 63, pp. 507-522.
- Spiekermann K. – Wegener M. (1994) The Shrinking Continent: New Time Space Maps of Europe. *Environment and Planning B: Planning and Design* 21, pp. 653-673.
- Symington, A. – Charlton, M. E. – Brunsdon, C. (2001) Using bidimensional regression to explore map lineage. *Computers, Environment and Urban Systems*, 26, pp. 201-218
- Tobler W. (1961) *Map Transformations of Geographic Space*, PhD dissertation, Seattle, University of Washington
- Tobler W. (1963) Geographic area and map projections. *The Geographical Review*, pp. 59-78.
- Tobler, W. (1994) Bidimensional Regression, *Geographical Analysis*, 26, 186-212. o.