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TOWARDS A FUNCTIONAL GEOMETRY OF WESTERN EUROPE¹

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Abstract.

The European Commission's spatial planning discourse places strong emphasis on the development of a regionally balanced urban system, recognising the importance of towns, cities and metropolitan urban regions in achieving the objectives of the revitalised Lisbon Agenda. This paper draws upon network analysis to examine the functional relationships between a sample of 28 European metropolitan urban regions, through an evaluation of air passenger flows. The evaluation of these flows contributes to an enhanced understanding of the spatial dynamics of the European metropolitan hierarchy, extending well beyond that deriving from more standard analyses of the individual components of the urban system. The visualisation of the resulting spatial configuration and the positioning of the different metropolitan urban regions contrasts with the more traditional map-based geographical image of Europe, going some way towards meeting the challenge before spatial planners today of effectively communicating the ever changing spatial dynamics at the European scale.

1. Introduction

The spatial configuration of Europe has changed enormously over the last twenty years. On the one hand this is directly due to the geopolitical changes resulting from the re-union between the former Eastern European bloc of countries and that of the Western European countries following the lifting of the iron curtain at the end of the 1980s and ending more than 60 years of political isolation throughout the duration of the Cold War. What began as an agreement between the six founding member countries of the European Economic Community (Belgium, France, German Federal Republic, Italy, Luxembourg and the Netherlands, the EU6) through the signing of the Treaty of Rome in 1957³ has resulted today in a European Union (EU) of some 27 countries⁴, with other countries waiting at the door. Today's Europe, extends over an area of some 43 million km² and has a population of over 489,885,300 inhabitants, of which some 80% live in urban areas.

¹ This article draws upon the author's unpublished PhD Thesis [*The (re)positioning of the Spanish metropolitan system within the European urban system (1986-2006)*] defended within the UPC's Doctoral Programme in Gestión y Valoración Urbana (Urban Land Management and Valuation) in July 2008; and previously published work undertaken within the CPSV (Burns, Roca and Moix, 2007 and 2008).

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³ Treaty signed 25 March 1957, entering into force on 1 January 1958, not published in the Official Journal. (See <http://eur-lex.europa.eu/en/treaties/index.htm#founding>)

⁴ Belgium, France, Germany, Italy, Luxembourg, The Netherlands, the United Kingdom, Denmark, Ireland, Greece, Spain, Portugal, Austria, Finland, Sweden, the Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia, Slovakia, Bulgaria and Rumania.

However what have also had a crucial effect upon the spatial configuration of the European territory, its urban system and the relations between the largest cities of the urban system, have been the changes resulting from the restructuring of the international economic order from industrially based economies to advanced service economies, and the effects and implications produced through the increasing economic integration throughout Europe.

As a consequence all of these 27 countries are partisan to the EU's prime overall objective, announced in the *Lisbon Strategy* in 2000 (CEC, 2000), reiterated and expanded upon in the *Gothenburg Strategy* in 2001 (CEC, 2001), and more recently emphasised even further through the revitalisation of the Lisbon Agenda in 2005 (CEC, 2005) aimed at making the EU the most competitive economy in the world and achieving full employment by 2010.

The traditional spatial configuration of the European geography was based upon the core-periphery model. Until recently the 'pentagon', broadly comprising the area defined as lying between London, Paris, Milan, Munich and Hamburg, was seen as the area containing approximately one third of the European Union's entire population, some 164 million inhabitants. While this core area comprises just 14% of the EU territory it produces approximately 46.5% of the EU27 Gross Domestic Product. By contrast areas lying on the (far) periphery of this central area were deemed to be weaker in economic terms, deserving the injection of public resources afforded through the EU's Structural Funds in the case of the four cohesion countries of Greece, Spain, Portugal and Ireland. Such assistance was seen to be essential in order to close the spatial divide between the core and the periphery. The elaboration of the *European Spatial Development Perspective* (ESDP) (CEC, 1999) challenged this core-periphery model. European spatial planning policies, aimed at encouraging social and economic, and with ever increasing importance, territorial cohesion, seek amongst other aspects, to encourage the development of a balanced and polycentric urban system. The achievement of a polycentric urban system continues to be of prime importance in EU spatial policy terms, as expressed repeatedly through different policy documentations, such as the *Territorial Agenda of the European Union* (CEC, 2007a) and the Commission's *Green Paper on Territorial Cohesion* (CEC, 2008a and 2008b).

The EU's Communication on *Cohesion Policy and cities: the urban contribution to growth and jobs in the regions* (CEC, 2006) recognised that over the past two centuries, towns, cities and metropolitan urban regions have been the principal drivers of economic development in Europe, contributing to growth, innovation and employment. Today cities are essential to regions being able to achieve growth and employment, in line with the revitalised Lisbon Agenda. Furthermore cities "are the home of most jobs, businesses and higher education institutions and are key actors in achieving social cohesion" and "are the centres of change, based upon innovation, entrepreneurship and business growth" (CEC, 2006, p.5).

From a spatial planning perspective, one of the clear challenges facing planners lies in the ability to communicate contemporary European territorial dynamics effectively⁵. This paper seeks to make a small contribution to this challenge in the sense of proposing a methodological approach for helping to understand the spatial geometry of the European territory from a functional perspective. It draws upon research carried out in the context of examining the spatial positioning of Madrid and Barcelona within the European metropolitan hierarchy, through a quantitative analysis of air passenger flows between some 28 metropolitan urban regions. This approach has enabled the elaboration of a visual representation of the spatial positioning of each of the metropolitan urban regions to one another, which contrasts with more traditional map-based geographical representations, based upon Cartesian coordinates. However prior to

⁵ It is worth noting that ESPON has taken up the gauntlet in this respect seeking collaboration and participation on a wide scale to draw upon advances in ICT in order to promote cartographic language and the innovative visualisation of such territorial dynamics.

presenting an explanation of the methodological approach, some considerations are given to the graphical representation of spatial dynamics in a broad sense.

2. Cartesian conditioning and spatial positioning

Taylor and Hoyler (2000) refer to the different approaches to map the evolving economic space of Europe in terms of cities since the late 1980s, in the context of the development of the Single European Market (SEM) and the ostensibly increased competition between European cities deriving there from. They indicate on the one hand, the concern for the definition of new urban hierarchies, through the combination of different functional indicators (Brunet, 1989; and Rozenblat and Cicille, 2003) and on the other hand highlighting specific topical variables. As the authors point out “the geographical representation of new economic spaces in Europe has perhaps shaped the perception of policy-makers deeper than the various league-tables produced” (Taylor and Hoyler, 2000, p. 179).

These earlier studies sought to characterise Europe in terms of the ranking of important urban regions on the basis of their urban performance and developed the concept of ‘functional urban regions’ (FUR) (Cheshire et. al., 1986; Cheshire and Hay, 1989; and Cheshire, 1990). This line of research allowed for comparison with work previously undertaken by Hall and Hay (1980) seeking to apply the notion of Berry’s (1973) ‘daily urban systems’ (DUS) to the European urban system. In the main, the applicability of these studies and the reliability of the ensuing results of some of the countries studied, including Spain, were severely limited by the lack of comparable data. In this sense, the increasing incorporation of the European countries within the expanding European Union (EU) and the concomitant efforts of the part of EUROSTAT to establish ‘user friendly’ data bases have contributed enormously to the possibilities of transnational comparative urban and regional research, despite the inherent basic methodological problems relating to the ‘units’ of territorial analysis (Pumain, D. et. al., 1992). Although not related to the ‘structure’ of the European urban system, the on-going development of the Urban Audit initiative⁶, which started in 1997, is testimony to the sorts of projects which are now possible through the gradual harmonisation of data across Europe, allowing for comparisons between the 258 large and medium sized cities on the basis of demography, social and economic aspects, civic involvement, training and education, environment, travel and transport, information society, and culture and recreation.

Williams (1996) argues that the majority of planners working in the context of local planning, at a small scale, have an implicit understanding of the sense of place within which they are engaged within the wider national territory. However at a higher territorial scale, such as that at the supra-national and European level, the same ability to conceptualise and comprehend one’s location does not come so easily and indeed needs to be developed. The name he offers for this skill to think about one’s location within the wider European spatial structure is that of ‘spatial positioning’. Furthermore Williams (1996) suggests that spatial positioning ‘requires imagination and lateral thinking rather than any particular technical skill’ (p. 97) and that at the European scale spatial positioning may indeed ‘help to overcome the mental blocks of orthodoxy’ (p. 98).

As Dühr (2003) points out, the cartographic visualisation of the territory forms a fundamental aspect of spatial planning. According to Kunzmann (1996) ‘the visualisation of spatial problems in maps makes it much easier to communicate the problems to the public and the political arena. It facilitates the understanding of complex spatial systems’ (p. 144). Zonneveld and Waterhout (2005) cite De Vries (2002, 2004) in the distinction he makes between ‘planning as communication and planning as programming. If planning is regarded as communication, the

⁶ <http://www.urbanaudit.org/>

main function of spatial plans is to provide interpretive frameworks of spatial structure or spatial development, and the intended effect of plans is to change the actor's frame of mind' (p. 23).

Research carried out in the context of the ESPON Programme (ESPON, 2007) has produced a number of 'visions' of possible future territorial scenarios for Europe leading to some thought provoking 'images', as opposed to predictions, of what Europe could be like in 2030. These contrasting scenarios look at the possible territorial impacts on the territorial structure and balance of Europe and the regions, urban and rural areas. The territorial scenarios provide good examples of planning as communication, transmitting the complexity of spatial positioning. They illustrate the extent to which Europe might undergo changes in the until recently dominant spatial model of core and periphery. The simple comparison of the three scenarios indicates instantly how under the 'trend' and 'cohesion-oriented' scenarios, areas treated as peripheral and extending beyond the even more expansive 'pentagon' area lying between Manchester, Paris, Genoa, Venice and Berlin (ESPON, 2004), are projected to form areas of concentration of flows and activities.

In the same way it is suggested that the respective spatial images of Europe deriving from the different research studies relating to the respective ordering of the European metropolitan urban regions (Brunet, 1989; Beaverstock *et al.*, 1999; Rozenblat and Cicille, 2003; and ESPON, 2004), and in particular those Williams (1996) characterises as 'spatial metaphors', convey instantly the complexity of the issues at stake. The degree of 'lateral thinking' required to decipher the 'imagination' of the creators differs from case to case. This also depends upon one's capacity to step beyond what could be termed as Cartesian conditioning, and conceptualise the territorial impact and representation of issues at a more abstract level.

For example the concept of Brunet's (1989) Blue Banana, for all its abstraction, is nevertheless firmly anchored over the geographical base or map of Europe. By contrast the GaWC (Beaverstock *et al.*, 1999) inventory of world cities gives a notion of place and positioning, but requires a greater effort on part of the person trying to decipher the message. In both cases what is being conveyed is an ordering and some measure of relative positioning.

Figure 1 Transnational territorial divisions and the European dorsal; and (b) The European component of the GaWC Inventory of World Cities

Sources: (a) Brunet (1989) and (b) Beaverstock *et al.* (1999)

3. The Western European Metropolitan Hierarchy Based Upon Air Passenger Flows

The quantitative analysis adopted for the purpose of examining the dynamics between the metropolitan centres, rather than searching for the elaboration of some form of hierarchy of these centres based upon (a) single or multiple attribute(s) takes inspiration from the concept of 'space of flows' and 'network society', proposed by Manuel Castells, in the context of the changes resulting from the informational and technological revolution, and the new industrial space and the new service economy (Castells, 1989, 1996). According to Castells, contemporary society is 'constructed around flows: flows of capital, flows of information, flows of technology, flows of organisational interaction, flows of images, sounds and symbols.' Furthermore such flows are 'the expression of processes dominating our economic, political and symbolic life' (Castells, 1996, p.412).

If such an approach is to be adopted to ascertain the nature of the relations between the European metropolitan urban regions, the considerations that need to be addressed relate to a) the choice of the flows that can realistically be examined, and b) the selection of the said metropolitan urban regions, in order to proportion results capable of reflecting these relations.

In dealing with this first issue, there is an extensive literature relating to the use of air passenger flows in order to evaluate the concept of World (and European) City Networks (Cattan, 1995; Derudder and Witlox, 2005; Guimerà, et. al. 2005; Keeling, 1995; Smith and Timberlake, 1995a, 1995b, 2001 and 2002, and Timberlake and Ma, 2007). Other writers have used air passenger flows as a means of determining different aspects of urban economic development and labour markets (Alkaabi and Debbage, 2007; Breuckner, 2003, Debbage, 1999; Debbage and Dalk, 2001; and Liu *et al.*, 2007).

It is considered that the interpretation of the air passenger flows, between the different European metropolitan urban regions fits appropriately within the notion of a 'space of flows'. It is suggested that the evaluation of these flows to determine the degree of interaction between the metropolitan centres and the resulting relations can contribute to another understanding of the European spatial territory, which goes beyond that deriving from a straightforward analysis of the urban system in terms of the geographical position of the cities.

Turning attention to the selection of the metropolitan urban regions for the sample, the ESPON studies, carried out in the context of the INTERREG III Community Initiative have produced the most up to date results through taking a transnational comparative approach to determining the nature and characteristics of the contemporary European urban system. For this reason it is considered wholly appropriate that the selection should derive in the main from the classification of the upper echelons of the Metropolitan European Growth Areas (MEGA). Therefore the sample comprises some 28 cities, belonging principally to the global nodes and European engine classes of the MEGAs of the EU15+2⁷ urban system.⁸

A 'network analysis' methodology is adopted in order to come to a clear and succinct understanding of the nature of the air passenger flows. Several indicators are used, deriving from gravitational modelling techniques, to analyse the complexity of the flows between these cities within the European metropolitan system. Finally a mathematical technique of multidimensional scaling is drawn upon, in order to interpret and visualise the resulting spatial

⁷ EU15+2 = Belgium, France, Germany, Italy, Luxembourg, The Netherlands, United Kingdom, Denmark, Ireland, Greece, Spain, Portugal, Austria, Finland, Sweden; and Norway and Switzerland.

⁸ Paris, London, Munich, Frankfurt, Madrid, Brussels, Milan, Rome, Hamburg, Copenhagen, Zurich, Amsterdam, Berlin, Stockholm, Stuttgart, Barcelona, Düsseldorf, Vienna, and Cologne/Bonn, Helsinki, Oslo, Athens, Greater Manchester, Dublin, Gothenburg and Geneva, as well as Lisbon and Luxembourg, given their capital city status within the EU15 grouping.

configuration and the positioning of the different cities within the conceptual European 'space of air passenger flows'. Such a vision contrasts with the more traditional map-based geographical image of Europe, based upon Cartesian coordinates, permitting the comparison between the functional and physical proximity of the cities of the sample to the respective centres of gravity.

3.1 Network analysis

One of the limitations in carrying out a network analysis technique to understand an urban system rests in the complex data requirement. Since network analysis concerns relations, the data must itself be a measure of relations. The availability of appropriate data is therefore a crucial consideration. Another such limitation is that data must be available for every city or location in the system. Smith and Timberlake (2002) suggest that 'the data requirements can best be understood as an in-flow/out-flow matrix' with 'a measure of the relationship between each city pair in the network', and that 'formal network analysis on the international city system must be based on a thorough compilation of relational data among all possible pairs of cities to be included in the analysis' (p. 121).

3.2 Air passenger data sources

The first objective of the network analysis application comprised the construction of a (28×28) in-flow/out-flow or origin-destination matrix of passenger flows, providing data for the 784 city pairs of the European metropolitan urban region space.

These flows were taken from publicly available EUROSTAT transportation data⁹ for 2004, on the basis of being the most recent year for which such data was available for all of the 28 cities in the sample¹⁰. In the cases of Berlin, Paris, Milan, Rome and London, multiple airport combinations were used, given that these cities are served by more than one principal airport.

The EUROSTAT database contains data for *detailed* air passenger flows between airport pairs.¹¹ The exploitation of this data source proportioned detailed passenger flows for some 572 of the possible 756 combinations¹². The values of the flows were arrived at by taking the median value of a) the departure flow from one airport to another and b) the arrival flow at the destination airport from the airport of origin. In a number of cases only one such value - the departure flow from one airport to another or the arrival flow at the destination airport from the airport of origin - was available.

Having achieved values of the air passenger flows for the 756 cells of the (28×28) origin-destination matrix, the (vertical) totals for each of the airports were calculated as a means of examining the magnitude of the attraction (or weighting) of each of the 28 airports, with respect to the other airports of the European system i.e. in quantitative terms the number of passenger who depart from each of the airports of origin $X (1, \dots, 27)$ to travel to the destination airport Y .

⁹ <http://epp.eurostat.ec.europa.eu>

¹⁰ Other data sources such as the ICAO were considered but were rejected on the basis of not being complete for the sample of 28 cities and appearing to be restricted to returns from a limited number of airlines operating from the airports in question.

¹¹ <<Transport <<Air transport <<Air transport measurement <<Detailed air passenger transport by reporting country and routes <<Air passenger transport between the main airports of reporting country and their main partner airports

¹² While the matrix contains some $(n \times n)$ cells, the maximum number of possible combinations $[(n \times n) - n]$, on the basis of the values of the diagonal being zero. No passengers depart from and arrive at the same airport. Even in the case of London, with multiple airports, no data was found relating to passenger flows of this nature. Therefore after subtracting the 28 diagonal combinations registering zero, the 784 theoretical combinations was reduced in practical terms to 756 possible origin-destination combinations.

Figure 1 represents the clear visual complexity of the 756 air passenger flows between the 28 EU15+2 airports, with priority being given to the magnitude of the flows, in the sense of the greatest flows being apportioned greater visibility.

Figure 2 **Gross passenger flows between the 28 EU15+2 airports**

Source: EUROSTAT (2004) (own elaboration with aid of Flow Mapper)

3.3 Descriptive indicators deriving from the air passenger flows

Taking inspiration from work carried in the early 1970s in the United Kingdom by the Department of Labour to determine the spatial extent of employment areas or Travel to Work Areas (TTWA) (Smart, 1974; Coombes *et al.*, 1986; Sforzi, 1991 and EUROSTAT, 1992) several descriptive indicators were developed from the raw data of the air passenger flows, based upon gravity modelling.

According to Lee (1973) of all the different types of mathematical models used in planning and transportation studies, gravity models are probably the most popular. Gravity modelling simply adapts and applies to the social sciences relationships pertaining to the physical sciences. In the physical sciences context, these relationships are derived from the Newtonian concept of gravity, whereby the force of gravitational interaction between two bodies is directly proportional to the product of the masses of the bodies and inversely proportional to the square of the distance existing between these masses.

In the social sciences context in general, and more specifically in the context of urban systems, “the gravitational pull exerted by two bodies has been interpreted as the amount of interaction between two areas, and the mass of the bodies has been measured in terms of the size or attractiveness of the areas” (Lee, 1973, p. 58). Traditional applications of gravity modelling have included the determination of the location of retail centres of a certain magnitude, depending upon the pull or attraction generated by the potential spending power from two or more populations, as well as their use in residential location modelling (Wilson, 1971).

The TTWA methodology was based upon the concepts of self-sufficiency and self-containment¹³ of different labour markets; and the *interaction value* between the areas being studied. Roca and Moix (2005) recognise the benefits of the interaction value for representing the mutual interaction between two functional spaces. The interaction value considers the bi-directional nature of flows, as well as the weighting of the flows by the origin and destination masses, making it a quasi-gravitational measure. In the context of air passenger flows, it is possible to obtain the interaction value¹⁴ between two airports and in turn achieve the functional distance¹⁵ between the two same airports¹⁶.

The results of the application of the interaction value indicate that the strongest interaction was between Barcelona and Madrid (0.16750); followed by Milan and Rome (0.13942); London and Dublin (0.11933); Gothenburg and Stockholm (0.08515); Copenhagen and Oslo (0.06263); and Cologne/Bonn and Berlin (0.06014); and Amsterdam and London (0.04332).

The same order was repeated in the application of the functional distance, with the closest distance being that between Barcelona and Madrid (3.45); Milan and Rome (3.79); London and Dublin (4.09); Gothenburg and Stockholm (4.85); Copenhagen and Oslo (5.65); Cologne/Bonn and Berlin (5.77); and Amsterdam and London (6.80).

Figure 2 represents the magnitude of the relations between the 28 airports in terms of the interaction value and functional distance.

Figure 2 **Magnitude of the interaction value and functional distance between the 28 EU15+2 airports**

Source: EUROSTAT (2004) (own elaboration with aid of Flow Mapper)

¹³ Self-containment refers to the proportion of the workers who reside and work in the same municipality (RWL) with respect to the resident employed population who might work within or outside the municipality (REP). Self-sufficiency is seen as the proportion between the same RWL and total localised workplaces (DEP).

¹⁴ $IV = f_{ij}^2 / (DEP_i \times ARR_j) + f_{ji}^2 / (DEP_j \times ARR_i)$, where DEP represents air passenger departures from one location to another and ARR represents air passenger arrivals at that latter location from the former.

¹⁵ $FD = \sqrt{((DEP_i \times ARR_j) + (DEP_j \times ARR_i)) / (f_{ij}^2 + f_{ji}^2)}$

¹⁶ For a detailed explanation of the steps required to obtain these equations see Burns, Roca and Moix (2007) and (2008).

In the case of the interaction value, the higher the value then the more important is the relation. By contrast in the case of the functional distance, the more important relations are those with lower values. The ordering of the functional distances between the 28 airports is the complete inverse of that of the interaction value. While Figure 2 strictly illustrates the values of the interaction values, at the same time it serves to convey the strength of the functional distances. The broader the band of the 'flow' between two points is indicative of both the higher interaction value and the shorter functional separation distance.

3.4 Multidimensional scaling

While the results presented in the previous section enable an appreciation of the individual functional distance, as a measure of the individual relations, between each metropolitan urban region and the other 27 such urban regions, clear interest lay in exploring the nature of the functional distances or relations between all of the metropolitan urban regions. This meant treating the system of 28 metropolitan urban regions as a whole and examining the internal dynamics of that system. With this objective in mind, the mathematical technique of multidimensional scaling¹⁷ was drawn upon, enabling a clear and elegant insight into the spatial dynamics of this system.

The input data requirement for MDS is that it be in a square, symmetric 1-mode matrix indicating the relationships between a set of objects. Applied to the set of metropolitan urban regions, the set of objects was the metropolitan urban regions themselves, or at least the airports, and the relationships were the functional distances between the metropolitan airports. However owing to missing data for Luxembourg (with Gothenburg and Oslo), it was decided to exclude Luxembourg from the sample, with the resulting 27 x 27 sample matrix.

The PROXSCAL programme from SPSS was used, which automatically performs multidimensional scaling of proximity data in order to ascertain a least-squares representation of the objects on a low-dimensional space. The methodology reduced the 27 dimensions of functional distances (i.e. each *i* with every possible *j*) to just two dimensions ((*x*, *y*) or Dim_1 and Dim_2).

In the interpretation of an MDS map the axes themselves (Dim 1 and Dim 2) are meaningless and the orientation is completely arbitrary. The resulting graphical representation showed the German cities to be situated in the south-western quadrant of the space. However in order to reach a closer approximation or 'fit' of these results to the European spatial territory, the Dim_1 and Dim_2 coordinates were first inverted over the horizontal and vertical axes and then rotated around the central point (0, 0) leading to the graphical representation in Figure 3. This illustrates the broad geographical groupings of the metropolitan urban regions around the centre, for example indicating the location of Lisbon, Madrid, Barcelona, Rome, Milan and Athens in the southern quadrants, and the clustering of the Scandinavian, and German and Austrian metropolitan urban regions.

¹⁷ Multidimensional scaling (MDS) is an appropriate mathematical technique discovering the dimensional nature of the relationships among objects. MDS analysis leads to a rapid geometric representation, or spatial map, of the proximities between different objects. Such a map contributes to the quantification of the nature of the attributes of the said objects, thereby providing the researcher with a visual expression of relationships (O'Connell, 1999).

Figure 3 Graphical representation of the spatial positioning of the cities, with all the coordinate points rotated about the centre to obtain a best fit to the European territory.

Source: EUROSTAT (2004) (own elaboration)

While the orientation of the objects resulting from an MDS application is wholly arbitrary, what is of crucial interest is the proximity of the objects (in this case the metropolitan cities) within the two-dimensional plane. The Euclidean distance from each point to the central point (0, 0) was calculated. The results indicate that London (0.10) is the city lying closest to the centre of the European space of air passenger flows between these principal metropolitan urban regions, followed by Frankfurt (0.17), Paris (0.19), Amsterdam (0.28), Zurich and Munich (0.35), Brussels (0.47), Vienna (0.49), Barcelona (0.50), Copenhagen (0.53), Madrid (0.56), Düsseldorf (0.61), Rome (0.63), Milan (0.65), Manchester (0.72), Athens (0.76), Helsinki (0.78), Berlin (0.79), Hamburg (0.81), Geneva, Lisbon and Stockholm (0.82), Dublin (0.86), Stuttgart (0.87), Cologne/Bonn (0.95), Oslo (0.98) and Gothenburg (1.04).

Figure 4 illustrates the linear rank ordering of the cities from the centre of the 'space of air flows' deriving from the functional distance calculation. From a southern European perspective what is of critical interest is the closer proximity of Barcelona to the centre, than that of Madrid to the centre. On the basis of the functional distance calculation, Barcelona benefits from a higher degree of interaction with the other cities of the sample than Madrid. Moreover of the five countries with two airports in the sample (Great Britain: London and Manchester; Italy: Milan and Rome; Spain: Barcelona and Madrid; Sweden: Gothenburg and Stockholm; and Switzerland: Geneva and Zurich) Spain is the only one which indicates an ostensibly

'secondary' airport having a superior position over the primary one with respect to the functional proximity to the centre of the space of air passenger flows. It is considered that there is a strong message here needing to be acknowledged by governmental agencies in terms of the financing of airports and facilitating licensing for air operators.

Figure 4 Functional proximity of cities from the centre of the space of European air flows

Source: EUROSTAT (2004) (own elaboration)

In order to compare this functional proximity with physical proximity between the cities, the centre of gravity (COG) between the cities was calculated¹⁸. This resulting centre was found to lie to the west of Frankfurt¹⁹.

The physical distance between each of the cities and the centre of gravity was calculated²⁰. The maximum of all these distances, 1,821 Km. corresponding to the distance between Athens and the COG, was proportionally reduced to equate with the maximum value of the functional proximity. The remaining physical distances were all reduced by the same factor.

Figure 5 illustrates the corresponding functional and physical proximities of the cities to the centre of the space of European air passenger flows and to the centre of gravity between these cities. Only in seven cases is the functional proximity inferior to the physical proximity – namely Paris, London, Barcelona, Madrid, Helsinki, Lisbon and Athens. In all the other cases the functional proximity is more than the physical proximity. Paris and London – the two global nodes of the MEGA classification – are the only two cases lying within the so-called central pentagon area where the physical proximity to the centre of gravity exceeds that of the functional proximity.

¹⁸ $X_{cg} = (\sum M_i \times X_i) / (\sum M_i)$, for $i = 1$ to N ; and $Y_{cg} = (\sum M_i \times Y_i) / (\sum M_i)$, for $i = 1$ to N ; where X_{cg} and Y_{cg} are the x and y coordinates of the Centre of Gravity; X_i and Y_i are the x and y coordinates of the airports; M_i is the mass of the airport (in this case $M = 1$); and N is the number of airports.

¹⁹ Longitude 7.86725° East and Latitude 49.86725° North

²⁰ Great Circle Distance Formula (with radians) = $6,378.8 \times \arccos[\sin(\text{lat1}) \times \sin(\text{lat2}) + \cos(\text{lat1}) \times \cos(\text{lat2}) \times \cos(\text{lon2} - \text{lon1})]$

Figure 5 Functional and physical proximity of the cities from the centre of the space of European air passenger flows and from the centre of gravity

Source: EUROSTAT (2004) (own elaboration)

Focussing on the differences between the physical and functional proximities, these tend to be most pronounced in the case of the cities lying within the more central area, for example in the cases of Cologne/Bonn, Stuttgart, Geneva, Hamburg and Düsseldorf. At the opposite end of the scale, one can see that Paris, with a difference of +0.04, is almost as close to the centre of the space of air passenger flows, as it is to the centre of gravity between the airports. By contrast London, with a difference of +0.25, is located further away from the centre of gravity. There is negligible difference between the differences of Barcelona (+0.10) and Helsinki (+0.12), both located at ostensibly opposite extremes of the European territory.

4. Conclusions

Returning to the notions of spatial positioning and planning seen as communication discussed in Section 2, it is suggested that the spatial images deriving from the analysis of the flow of air passengers between the 28 metropolitan urban regions of the sample described in the previous section and reproduced in Figure 6, convey the complexity of the resulting 'space of flows' within the metropolitan urban region system.

Table 1 illustrates the ordering of the first twenty eight cities of the respective hierarchies deriving from previous studies examining the European urban system, (Brunet, 1989; Beaverstock *et al.*, 1999; Rozenblat and Cicille, 2003; and ESPON, 2004) together with the ordering of the cities, based upon the analysis of the air passenger flows carried out in Section 3. While clearly information can be extracted from this Table, the visual representations of the content are, it is suggested, considerably more communicative.

Figure 6 (a) Magnitude of the interaction value and functional distance between the 28 EU15+2 airports; and (b) Graphical representation of the spatial positioning of the cities

Source: EUROSTAT (2004) (own elaboration)

In each of the first four studies cited Madrid is positioned ahead of Barcelona, though as will be recalled these studies looked at a series of attributes and applied a score for the frequency of the attributes in each of the individual cases. Only in the final study, based on the interpretation of the European 'space of air passenger flows' i.e. the inter-city relations of a true network or system, do the results of the European ordering reflect the interrelationships between each and every one of the cities (airports).

However the key difference between the studies of the first four columns and that of the fifth column lies in the fact that only the last study determined a centre. The conceptual centre of the European space of air passenger flows enabled the Euclidean distances to be calculated from each airport to the said centre²¹. By contrast in each of the other studies there is no centre whatsoever and the ordering reflects a kind of nebulous positioning with no fixed frame of reference and certainly no notion of interrelations between the different cities. Only the last of the studies makes some headway in the direction indicated by the *Territorial state and perspectives* background document (CEC, 2007b), in the sense of proportioning an insight into the interrelationship between a fixed set of European metropolitan urban regions.

²¹ This gave the potential to calculate the distances between each of the airports. This was not carried out since it was considered the principal interest lay in determining the distance or proximity of each of the airports to the centre.

Table 1 Ordering of European metropolitan urban regions according to different studies

Ordering	Brunet (1989)	Beaverstock et. al. (1999)	Rozenblat and Cicille (2003)	ESPON (2004)	Space of air passenger flows
1	London	London	Paris	Paris	London
2	Paris	Paris	London	London	Frankfurt
3	Milan	Frankfurt	Madrid	Munich	Paris
4	Madrid	Milan	Amsterdam	Frankfurt	Amsterdam
5	Munich	Brussels	Milan	Madrid	Zurich
6	Frankfurt	Madrid	Barcelona	Brussels	Munich
7	Rome	Amsterdam	Berlin	Milan	Brussels
8	Brussels	Düsseldorf	Rome	Rome	Vienna
9	Barcelona	Geneva	Brussels	Hamburg	Barcelona
10	Amsterdam	Prague	Vienna	Copenhagen	Copenhagen
11	Manchester	Rome	Munich	Zurich	Madrid
12	Berlin	Stockholm	Stockholm	Amsterdam	Düsseldorf
13	Hamburg	Warsaw	Lisbon	Berlin	Rome
14	Stuttgart	Barcelona	Athens	Stockholm	Milan
15	Copenhagen	Berlin	Cologne	Stuttgart	Manchester
16	Athens	Budapest	Copenhagen	Barcelona	Athens
17	Rotterdam	Copenhagen	Dublin	Düsseldorf	Helsinki
18	Zurich	Hamburg	Lyon	Vienna	Berlin
19	Turin	Munich	Frankfurt	Cologne	Hamburg
20	Lyon	Dublin	Düsseldorf	Helsinki	Geneva
21	Geneva	Helsinki	Helsinki	Oslo	Lisbon
22	Birmingham	Luxembourg	Zurich	Athens	Stockholm
23	Cologne	Vienna	Florence	Manchester	Dublin
24	Lisbon	Athens	Hamburg	Dublin	Stuttgart
25	Glasgow	Birmingham	Marseille	Gothenburg	Cologne/Bonn
26	Vienna	Bratislava	Geneva	Turin	Oslo
27	Edinburgh	Bucharest	Oslo	Geneva	Gothenburg
28	Marseille	Cologne/Bonn	Toulouse	Lyon	

Furthermore, with regard to the notion of 'peripherality', the argument that the spatial or physical proximity of the more centrally located metropolitan urban regions of the sample to both the physical centre of gravity and the centre of the conceptual space of air passenger flows, with their concomitant dependence upon high speed rail travel doing away with their need for air connectivity certainly holds validity. Clearly here there is a question of choice. However in the case of the spatially separated metropolitan urban regions (in this case, Madrid, Barcelona, Lisbon, Helsinki and Athens) their functional proximity positions them more favourably in relative terms. Their spatial 'peripherality' is overturned by their functional proximity. So clearly connectability has more to do with the nature of the service or infrastructural connection, and the time required to connect, than the distance which has to be covered in order to be able to make the connection. Therefore these results add another dimension to the concept of spatial positioning and the comprehension of space, distance and interconnections. By stepping beyond the constraints of Cartesian conditioning, it is suggested that it is possible to arrive at a clearer understanding of the European metropolitan geography, or 'functional geometry', which reflects the 'spatial positioning' deriving from inter-city relations in the era of advanced producer services.

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