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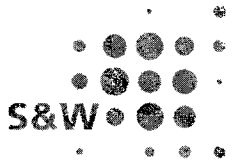


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**ESPON 1.1.1**

# How to Measure Polycentricity

## 1. Introduction

Polycentricity is one of the core concepts of ESPON. Following the European Spatial Development Perspective (ESDP), the promotion of a 'balanced polycentric urban system' is one of the most frequently cited policy objectives of the programme.

Two policy options are stated in support of polycentric development across the European territory:

- Strengthening of several larger *zones of global economic integration* in the EU, equipped with high-quality, global functions and services, including the peripheral areas, through transnational spatial development strategies.
- Strengthening a *polycentric and more balanced system of metropolitan regions, city clusters and city networks* through closer co-operation between structural policy and the policy on the Trans-European Networks (TEN) and improvement of the links between international/national and regional/local transport networks.

It is hoped that by encouraging polycentric urban regions, the competitive potential of these regions will improve and that 'dynamic global integration zones' can be formed beyond the 'pentagon' defined by the metropolitan areas of London, Paris, Milan, Munich and Hamburg.

The interest in polycentric development is fuelled by the hypothesis put forward in the ESDP that polycentric urban systems are more efficient, more sustainable and more equitable than both monocentric urban systems and dispersed small settlements.

The concept of polycentricity of settlement structures originated as an *empirical* concept in the 1930s. Central-place theory explained hierarchical decentralisation of cities by the fact that different goods and services command service areas (Christaller, 1933) and market areas (Lösch, 1940) of different size. A contrasting view was proposed by polarisation theory which

pointed out that increasing economies of scale lead to growing concentration in only few large cities (Perroux, 1955; Myrdal, 1957). Both perspectives are integrated in recent results of economic geography (Krugman, 1991; Fujita et al.,1999) which show that different constellations of economies of scale and spatial interaction costs lead to different spatial arrangements of production and consumption (see Figure 1). One important contribution of these approaches is that not only vertical linkages are important but also horizontal linkages between cities with complementary economic specialisation.

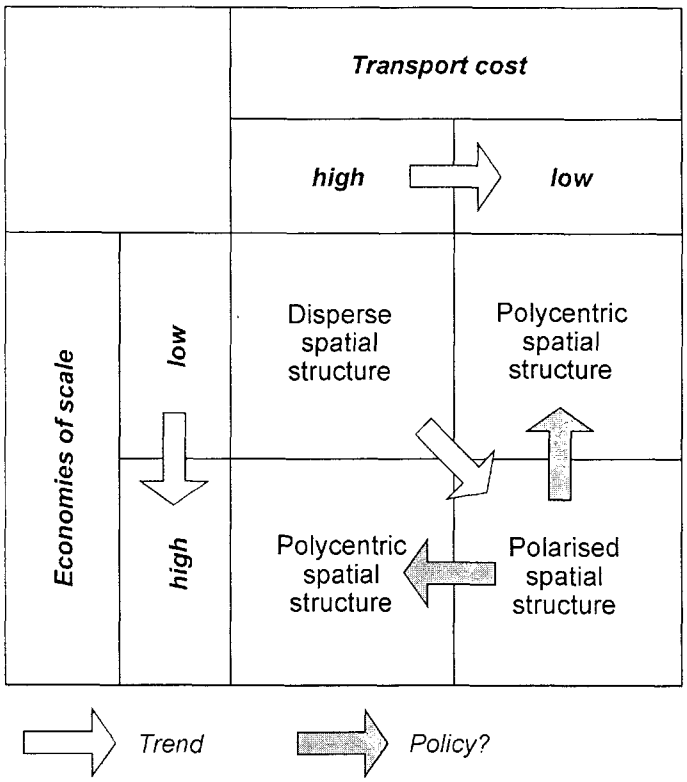


*Figure 1. Spatial structure as function of economies of scale and transport cost*

Polycentricity as a *normative* concept can be traced back to the concept of self-contained satellite towns connected to the central city by commuter railways promoted by the garden city movement (Howard, 1900). In the 1940s the Nazis applied Christaller's central-place theory to the occupied territories in Poland recognising that a hierarchical network of central places can also be used for military control:

> "The final domination of the Generalgouvernement will be based on the key positions of a regular network of central places. The central place in the Generalgouvernement, centre and leader of its region and focus of German culture, power and economy, will contain all elements required for the immediate expression of German dominance."
>
> (Schepers, 1942)

Despite this ambiguity of the concept, many countries adopted central-place concepts as principle for guiding their spatial development after World War II. The hypothesis was that central-place systems are both efficient (in terms of economies of scale) and equitable (in terms of equivalent living conditions).

It can in fact be argued that both extremes, *monocentricity* (all activities are concentrated in one centre) and *dispersion* (all activities are equally distributed over space) perform poorly with respect to the policy goals efficiency, equity and environmental sustainability:

- *Efficiency*. Large centres can exploit economies of scale and agglomeration effects but suffer from negative effects of over-agglomeration. Dispersed settlements enjoy nature but are too small to support efficient infrastructure facilities and units of production.

- *Equity*. Spatial polarisation is built on competition and so leads to spatial segregation between rich and poor, central and peripheral cities. Spatial dispersal is egalitarian in its distribution of poverty but denies its citizens opportunities for social mobility.

- *Environment*. Large settlements use less energy for transport but more for high-rise buildings, air-conditioning and waste management. Dispersed settlements can utilise local renewable resources but are wasteful in terms of transport energy and open space.

It is obvious that the optimum lies somewhere in between monocentricity and dispersal, i.e. in a balanced mixture of large, medium-sized and small cities arranged in a pattern favourable for exchange and co-operation.

This view was expressed by the 'bunch-of-grapes' metaphor proposed by Kunzmann (Kunzmann and Wegener, 1991) as a different and more 'co-operative' *Leitbild* for urban development in Europe" than the 'Blue Banana' proposed by French geographers (RECLUS, 1989), which was viewed as "the pure expression of the competition between the regions in Europe" (Kunzmann and Wegener, 1991). The authors claimed that the bunch of grapes was more suited to represent the polycentric structure of the urban system in Europe and the fundamental *similarity in diversity* of the interests and concerns of its member cities (see Figure 2):.

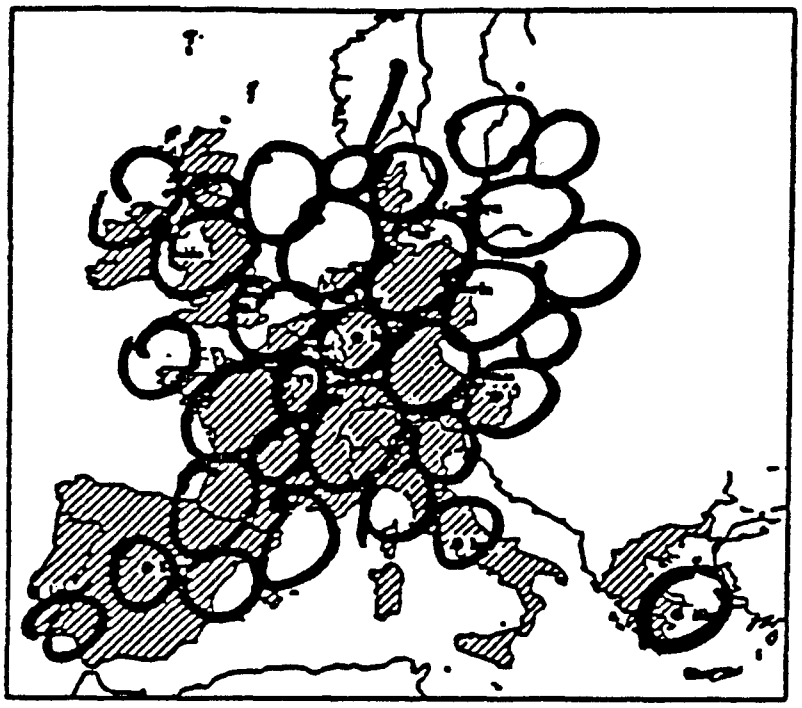

*Figure 2. The bunch of grapes (Kunzmann and Wegener, 1991)*

However, until today the concept of polycentricity has remained largely at the level of rhetoric without a precise operational definition (which puts it into a class with similarly vague concepts such as 'city networks' or 'industrial clusters'). There exists neither a method to *identify* or *measure* polycentricity at different spatial scales nor a method to *assess* the impacts of polycentricity (or the lack of it) with respect to policy goals such as efficiency (competitiveness), equity (cohesion) and sustainability. It is therefore not possible to determine an *optimal* degree of polycentricity between centralisation and decentralisation or, in other words, between the extremes of monocentricity and dispersal. This makes it difficult to formulate well-founded policy recommendations as to which cities should be developed with priority.

Such recommendations, however, are the ultimate task of ESPON 1.1.1. It is therefore essential that ESPON 1.1.1 develops a clear concept of polycentricity and operational methods for identifying and measuring the existing polycentricity of the European urban system, predicting their likely future development and assessing the positive and negative impacts of different degrees of polycentricity at the regional, national and European scale.
To be more specific, the following questions need to be answered for the territory of the European Union at large and for different countries or subregions:

- *Analysis.* How can polycentricity be defined in a way that makes it measurable? How polycentric is the European settlement structure? Are there countries that are more polycentric than others? Are there trends towards more polycentricity or towards more polarisation? Are these trends the same in all countries or subregions or are there significant differences?

- *Evaluation.* Is polycentricity desirable? Are polycentric systems more efficient and more competitive? Does polycentricity increase spatial cohesion? Is it good for the environment? Are there disadvantages, such as agglomeration diseconomies, marginalisation of peripheral areas or more traffic and congestion? Is there an optimum degree of polycentricity (a balance between efficiency, equity and sustainability?)

- *Policy analysis.* What should be done? Is it necessary to contain the growth of central regions? Should one strengthen medium centres or support peripheral areas? Which policies are available – taxation, regulation, subsidies, infrastructure?

- *Forecasting.* What would be the impacts of such policies? What would be their effects not only on polycentricity but also on regional competitiveness and economic performance, on spatial cohesion and on the environment?

- *Implementation.* How can the policies be implemented? Which policies need to be implemented at the European level, and which should be left to national and regions governments?

## 2. Concepts of Polycentricity

In ESPON 1.1.1 the current pattern of polycentricity and the potential of urban regions as nodes in a polycentric European urban system in the European Union, the twelve accession countries and Norway and Switzerland are being analysed at three spatial levels: at the regional and local level, at the national level and at the European level, including transnational urban systems (ESPON 1.1.1, 2003). As units of analysis, 'functional urban areas' were defined in each country. Of these, urban centres to be included in the analysis were selected us-

ing seven criteria: population, transport (airports, ports), tourism (hotels), industry (gross value added), knowledge (universities), corporate decision making (headquarters) and administrative function. The selected centres were classified using a typology of global, European, national, regional and local importance. In addition, accessibility and other indicators were collected and presented for the selected centres.

In a parallel approach of ESPON 1.1.1, CNRS-UMR analysed polycentricity based on the relational logic of territories ("the space of flows") proposed by Castells (1989) focussing on trans-border co-operations (Interreg IIa and IIIa), air traffic and co-operations between universities (ESPON 1.1.1, 2003).

The CPMR study (CPMR, 2002) proposed a typology of urban areas based on the indicators competitiveness (GDP per capita, labour productivity), economic decision-making (number of headquarters of the top 1500 European firms), human capital (share of R&D employment, share of population 25-59 years of age with higher education), connectivity (number of international flights and destinations) and 'drivers of change' (growth of GDP and productivity).

The Draft Guidance Paper prepared by ESPON 3.1 (2003) proposed a three-level hierarchy of urban areas: the *macro* level (European core, European periphery, accession countries and neighbouring countries), the *meso* level (metropolitan areas, urbanised areas and non-urban areas) and the micro level (metropolitan areas, cities, towns and villages). It proposed that each NUTS-5 region is classified by its membership in the macro, meso and micro categories and that each NUTS-3 regions is assigned to one meso level group based on the characterisation of its NUTS-5 members.

These approaches are useful analyses and classifications of urban areas but they fail to provide a measure of polycentrism or of its effects. The typologies proposed by the CPMR study and the ESPON 3.1 Draft Guidance Paper neglect the *spatial* dimension of polycentric urban systems, i.e. the distance between centres at the same level of the urban hierarchy and between centres at one level and those at lower and higher levels as well as the functional relations between centres of the same or different levels. The networking analysis concentrates on the interactions between the centres at one level and ignores the multilevel functional relationships between higher-level and lower-level centres, i.e. the linkages between the cities and their peri-urban and rural hinterlands.

What is needed is a methodology which allows (i) to *measure* the degree of polycentricity of a region, a national urban system or the European urban system at large, (ii) to *evaluate* it with respect to the policy objectives of European Spatial Development Perspective competitiveness, cohesion and environmental sustainability and (iii) to *forecast* the likely impacts of European, national or regional economic, transport and telecommunications policies on the degree of polycentricity and the three policy goals.

## 3. The Proposed Approach

In this section a method is presented to identify centres in the European urban system and to measure the degree of polycentricity of the urban systems of the member states of the European Union and of the accession countries and Norway and Switzerland as well as of the European urban system at large.

### 3.1 Three Dimensions of Polycentricity

The approach proposed here is to identify and measure polycentricity by three dimensions of polycentricity: *size*, *location* and *connectivity*.

These three dimensions are in line with the distinction made in ESPON 1.1.1 between *morphological* aspects of polycentricity (hierarchy, distribution, number of cities) and *relational* aspects (flows and co-operations bewteen urban areas at different scales): size and location describe morphological aspects, whereas connectivity describes relational aspects.

*Size*

The first and most straightforward prerequisite of polycentricity is that there is a distribution of large and small cities. It can be shown empirically and postulated normatively that the ideal rank-size distribution in a territory is loglinear. A population rank-size distribution of European cities over 50,000 population is presented in Figure 3.

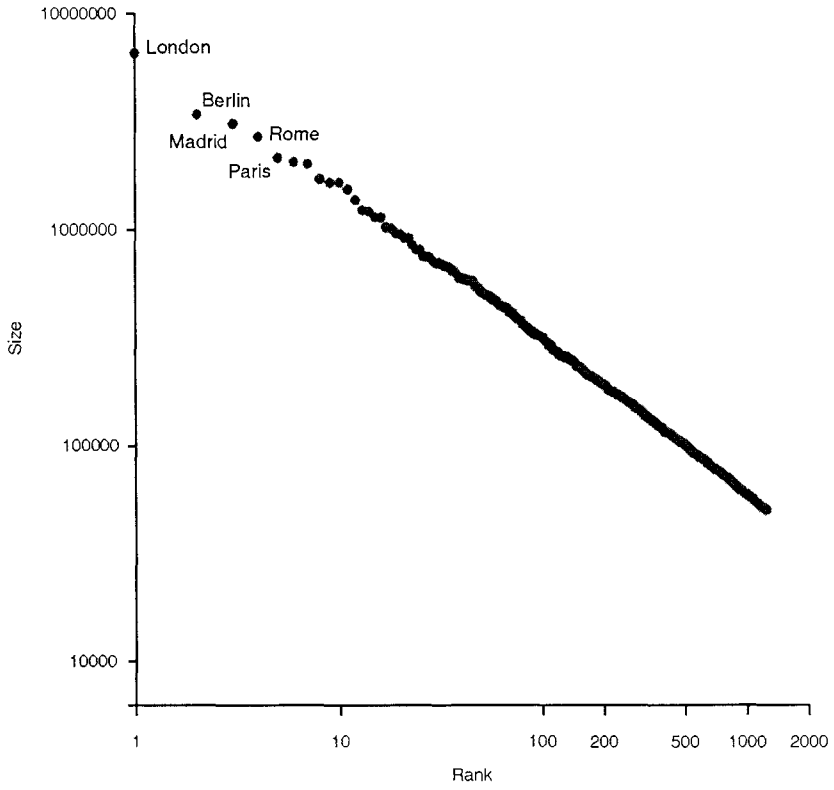


*Figure 3. Rank-size distribution of cities over 50,000 population in EU-27*

Rank-size distributions of cities in European countries differ significantly. Figure 4 shows the rank-size distribution of cities with a population of more than 50,000 in France, Germany, Italy and Spain. It can be seen that France has a predominantly monocentric city-size distribution, whereas Germany) has a historically grown polycentric urban system.

A first step in analysing polycentricity of an urban system would therefore be to derive its population rank-size distribution. A possible indicator of the size dimension of polycentricity would be the squared residuals of the rank-size distribution from the regression line of the logarithmic transformed population values: the smaller the residuals, the more polycentric is the urban system under investigation. Alternatively, a combined indicator of city size and importance may be used, such as economic activity, human capital, higher education, cultural importance, administrative status etc.

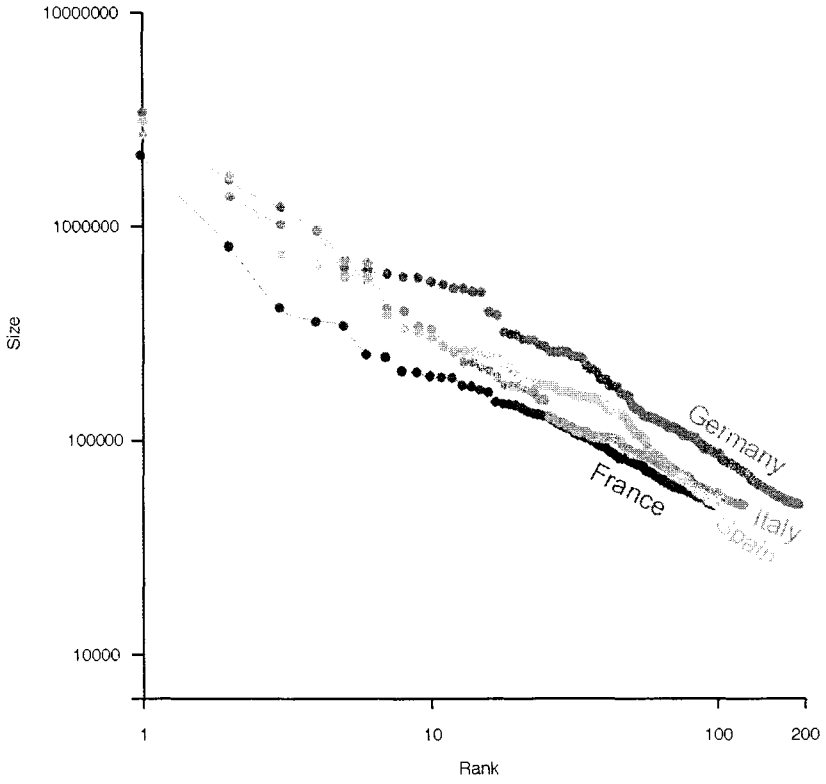


*Figure 4. Rank-size distribution of cities in France, Germany, Italy and Spain*

*Location*

The second prerequisite of a polycentric urban system is that its centres of equal size or rank are equally spaced from each other – this prerequisite is derived from the optimal size of the catchment area or market area of centrally provided goods and services. Therefore, a uniform distribution of cities across a territory is more appropriate for a polycentric urban system than a highly polarised one where all major cities are clustered in one part of the territory.

A second step in the analysis of polycentricity would therefore be to analyse the distribution of cities of equal size or rank over the territory.

One possible approach is to subdivide the territory of each country into catchment areas (Thiessen polygons) of each centre. This can be done by dividing the territory into raster cells of equal size and to associate each cell with the nearest urban centre by airline distance. In this way the area, or population, served by each centre can be measured. The indicator of the location dimension of polycentricity is then the squared sum of deviations of the areas or popu-

lations served by each centre from the average area or population served by a centre in the whole country. The smaller the squared sum of deviations, the more polycentric is the urban system. Instead of airline distance also the logsum of the travel times and/or travel costs by road and rail (and at higher levels of the hierarchy also by air) could be used. Alternatively, also the mean travel time and/or travel cost, again multimodal, by which each centre can be reached by the population in the areas served could be taken as indicator. Figures 5 and 6 show the subdivision so derived for Germany, the Netherlands and Poland.

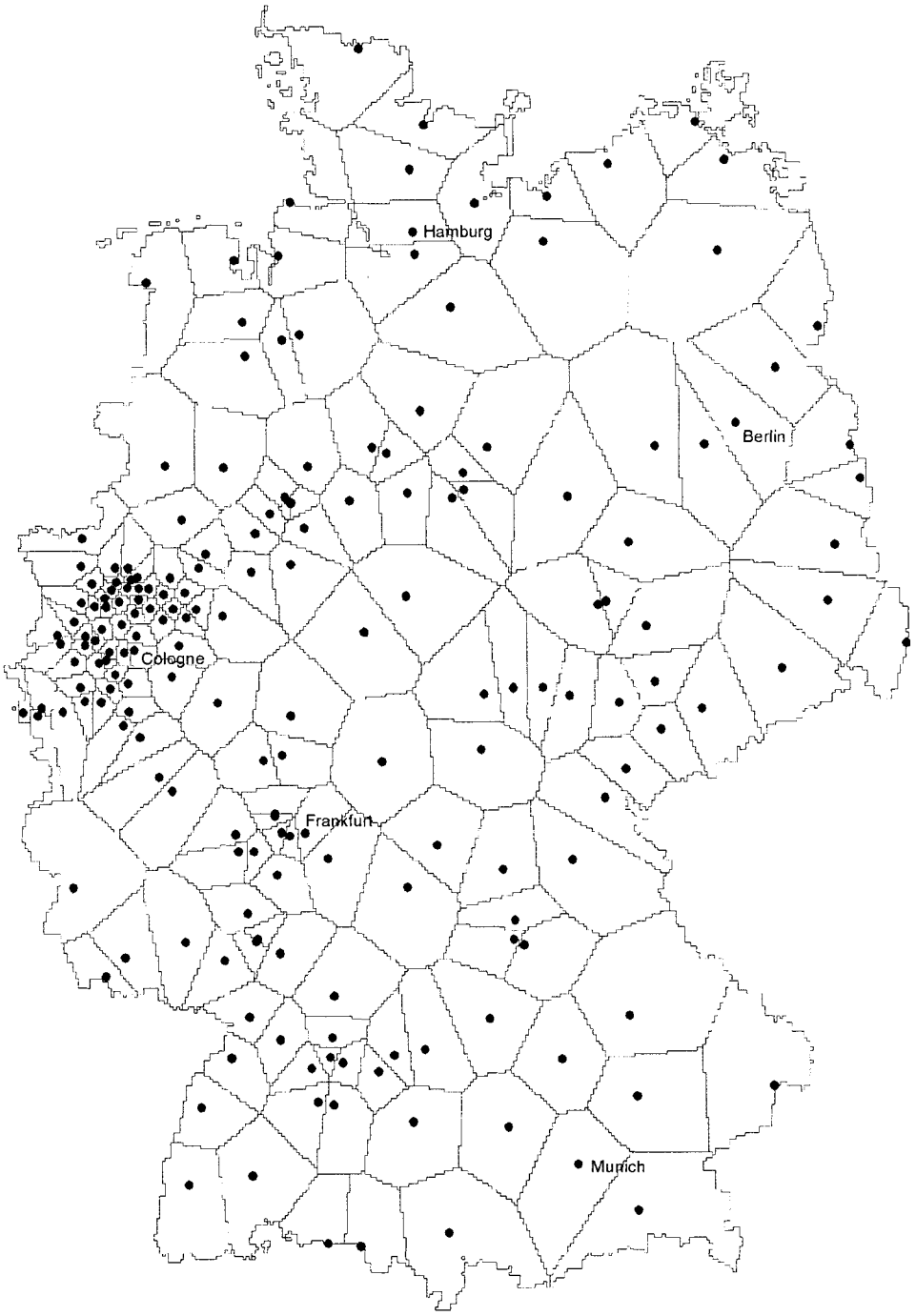


*Figure 5. Catchment areas of cities over 50,000 population in Germany*

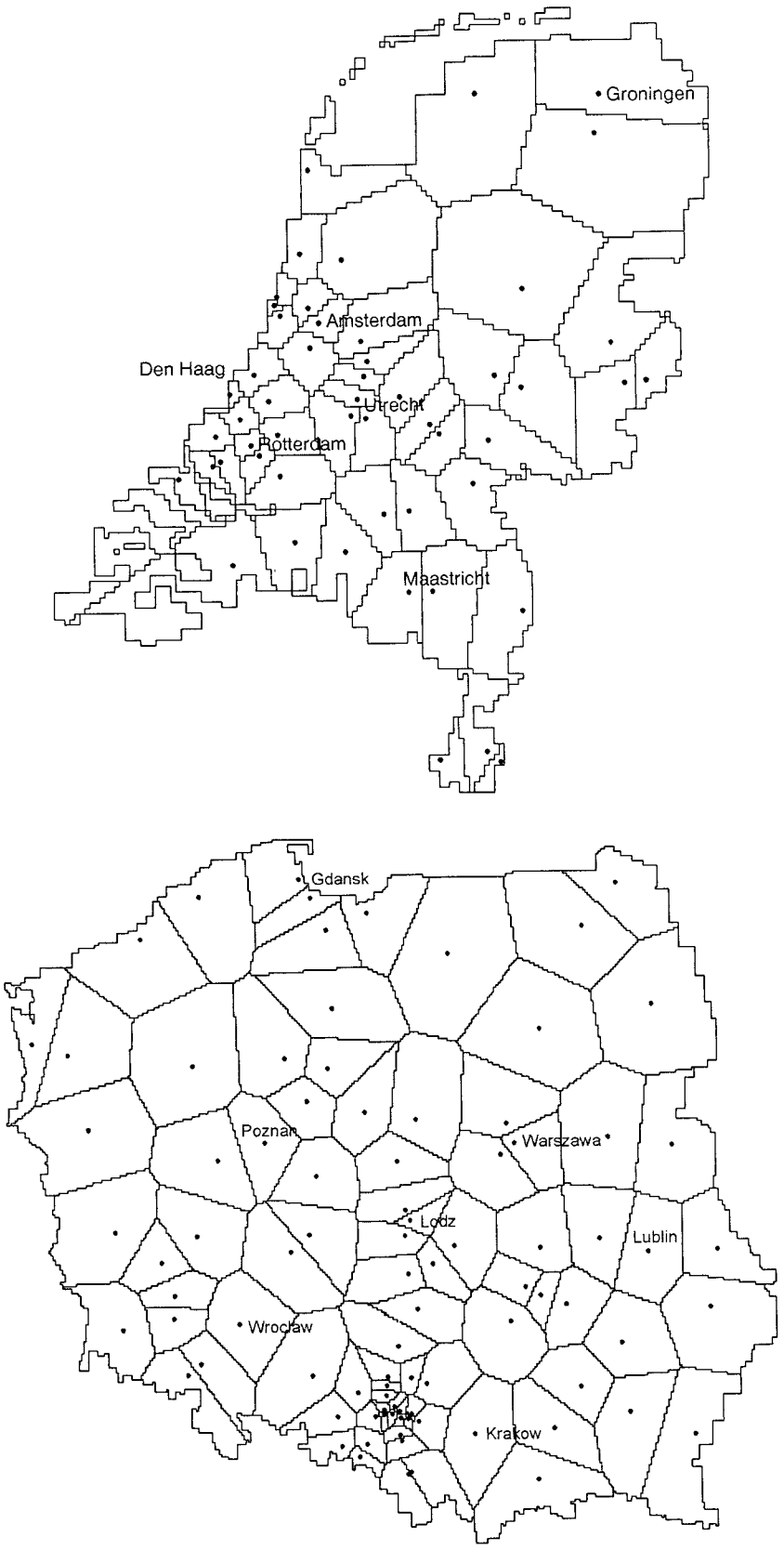


*Figure 6. Catchment areas of cities over 50,000 population in the Netherlands and Poland*

*Connectivity*

A third property of polycentric urban systems is that there is functional division of labour between cities, both between higher-level centres and the lower-level centres in their territory and between cities at equal levels in the urban hierarchy. This implies that the channels of interaction between cities of equal size and rank but in particular between lower-level and higher-level cities are short and efficient. It is obvious that this requirement may be in conflict with the postulate that cities of equal size and rank should be equally spaced on the territory.

There principally two ways to measure connectivity. One is to measure actual interactions. Ideally, the analysis would reveal functional relationships between cities of equal size or rank and between cities of different size or rank in the urban hierarchy. Appropriate indicators of such interactions would be flows of goods or services, travel flows or immaterial kinds of interactions, such as telephone calls or e-mails. At the level of municipalities, information on such interactions is rarely available or considered an economic asset, as in the case of travel flow data held by private transport carriers or telecommunications data held by private telecommunications operators.

The second possibility is to measure the potential for interactions. Measures of interaction potential could be infrastructure supply, i.e. the level of road connections (motorways, roads) or the level of service of rail (number of trains) or air (number of flights) connections. Another way is to simply measure proximity between centres, because if two centres are close to each other, the probability and feasibility that functional division of labour is implemented is higher than if the two centres are distant from each other.

Figure 7 is a very simple analysis of connectivity as proximity. The map shows the same cities in Europe with a population of more than 50,000 population used for Figure 3. Each city is represented by a circle the area of which is proportional to its population. In addition, each city is connected by a line to the nearest city with larger population. Figures 8 and 9 show excerpts from the same data for Germany, the Netherlands and Poland. It can be seen that, with few anomalies, the historically grown urban hierarchy in Europe emerges.

Here airline distance was used. However, the analysis could also be repeated with travel time and/or travel cost via networks and so measure not only geographical proximity but also the quality of infrastructure supply.

In a further step, the travel times and/ travel costs between cities so derived could be used to calculate hypothetical interactions, such as commuter flows, business trips or tourist visits. If the same behavioural parameters are applied all over Europe, countries and regions could be compared with respect to the efficiency and ease of spatial interactions, for instance in terms of average speed.

What could be an appropriate indicator of connectivity derived from these results? Simply to give a premium to high speeds and large volumes of traffic between cities would be misleading as it would ignore equity and sustainability objectives. It will be necessary to develop a connectivity indicator which recognises the need for a balance between efficiency, equity and sustainability.

*Figure 7. Cities in Europe over 50,000 population connected to the nearest larger city*

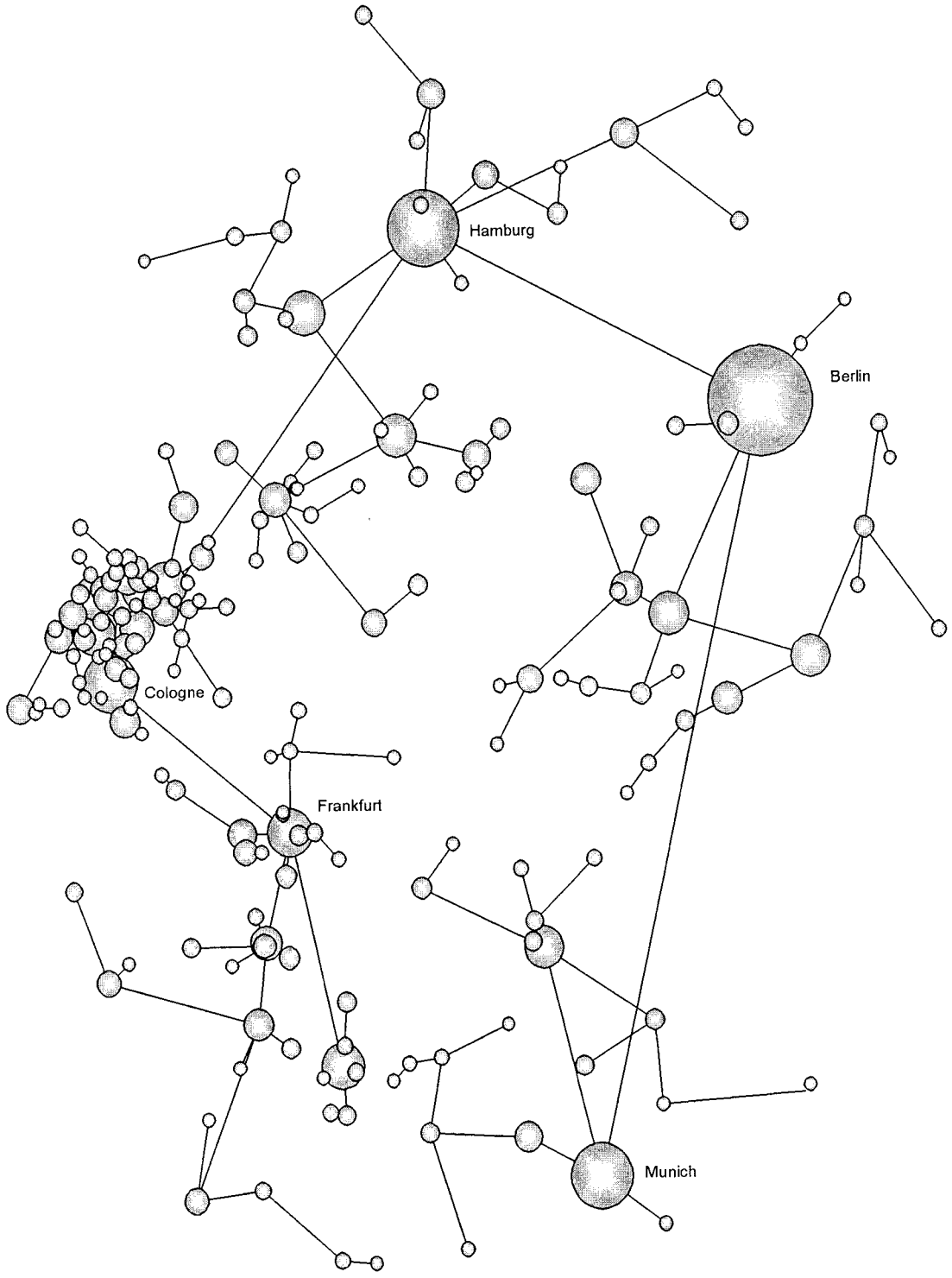


*Figure 8. Cities in Germany connected to the nearest large city.*

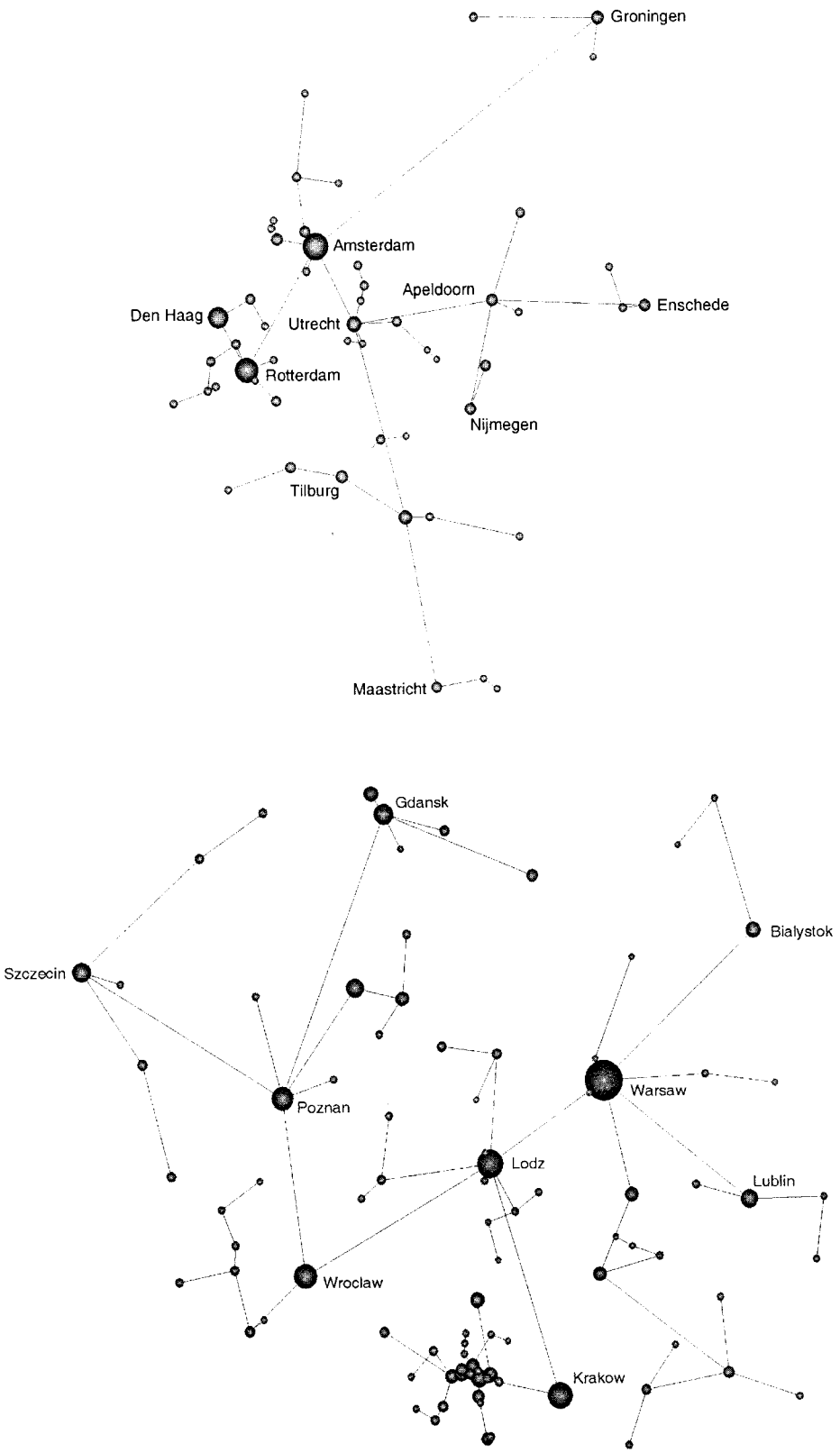


*Figure 9. Cities in the Netherlands and Poland connected to the nearest large city.*

With these three partial indicators of polycentricity, size, location and connectivity, a comprehensive indicator of polycentricity can be constructed.

The proposed method is, in principle, independent of spatial scale. It can be applied both at the national and at the European level; in fact it should be attempted to link the two levels.

The proposed method differs from normative approaches to polycentricity in which a system of central places in a country, e.g. taken from a national planning document, is taken as given; instead the polycentric urban system is a *result* of the analysis.

### 3.2 A Typology of Urban Areas

There are innumerable ways of developing typologies of urban regions. Cities may be classified by their size, their location (coastal cities, port cities, border cities, etc.), their administrative function (national capitals, regional capitals, etc.), their economic function (global cities, financial centres, industrial cities, etc.) or by their function in the transport network (railway nodes, airport hubs, etc.). All of these typologies are of interest for certain purposes.

However, for spatial planning the most interesting aspect for the classification of cities is their position in the multilevel polycentric urban system.

The three partial indicators of polycentricity proposed in Section 3.1, size, location and connectivity, can be aggregated to a comprehensive indicator of polycentricity. The indicator will classify each country on a continuous scale of polycentricity and at the same time assign each city a place and level in the national and European urban hierarchy. It may also be possible to apply cluster analysis to verify and validate the polycentric urban system so derived.

The method can also be used to forecast the likely future development of polycentricity in Europe for different scenarios of urban growth and linkages between cities taking account of macro trends such as the enlargement of the European Union, further integration of the world economy and intensification of the competition between regions and cities and the development of energy cost, transport technology and the further diffusion of telecommunications.

Scenarios of the socio-economic development of NUTS-3 regions in the European Union and the accession countries and Norway and Switzerland can be obtained from the results of ESPON 2.1.1 "Territorial Impacts of EU Transport and TEN Policy".

## 4. Policy Applications

The indicator of polycentricity and the typology of urban areas can be used in various policy contexts.

One significant application would be to use the typology for the assessment of future TEN transport and telecommunications policies. The underlying hypothesis is that in a well developed and balanced polycentric urban system the interactions between higher-level centres are more intense and cover greater distances than those between lower-level centres or between higher-level centres and their subordinate lower-level centres, and that therefore higher-level centres should be connected by higher-level and faster transport and telecommunications links

than lower-level centres. In the absence of true interaction data, the quality of the links can be used as proxies for the intensity of interaction; in this case the analysis contributes to the identification of polycentrism. In reversal of the argument, the analysis can be used to examine whether the polycentric hierarchy of centres is supported by a corresponding hierarchy of networks.

On a more advanced level, the analysis of polycentricity can be used to determine the optimal degree of polycentricity with respect to policy goals such as efficiency (competitiveness), equity (cohesion) or environmental sustainability under different scenarios of macro trends such as the enlargement of the European Union, further integration of the world economy and intensification of the competition between regions and cities and the development of energy cost, transport technology and the further diffusion of telecommunications. It is to be expected that the optimum degree of polycentricity will depend on the constellation of these macro trends.

It is particularly here that co-operation with ESPON 2.1.1 will be important. ESPON 2.1.1 will develop model-based forecasts of the socio-economic development in terms of population and economic activity in 1,321 NUTS-3 regions in the European Union and the accession countries and Norway and Switzerland under different assumptions about the macro trends indicated above.

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