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Are European cities becoming dispersed? A comparative analysis of 15 European urban areas

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Abstract

In this paper we analyse the relationship between urban land use development and population density in 15 European urban areas. Five indicator sets are used to shed light on built-up areas, residential land use, land taken by urban expansion, population density and urban density. The built-up areas have grown considerably in all studied cities. The most rapid growth dates back to 1950s and 1960s. The annual growth pace has slowed down in the 1990s to 0.75%. In half of the studied cities over 90% of all new housing areas built after the mid-1950s are discontinuous urban developments. When putting these findings into the context of stable or decreasing urban population, it is clear that the structure of European cities has become less compact. In most cases it is mere a question of taste whether to call it urban sprawl or urban dispersion. Although most studied urban areas have experienced dispersed growth, as a result of the analysis we divide the cities in three groups: compact southern cities, northern and eastern cities with looser structures and lower densities mainly located in northern and eastern parts of Europe, and central and western cities in the midway between the extremes. However it has to be borne in mind that groupings are always to some extent artificial, forcing strict boundaries on phenomena which are continuous by nature.

Keywords: Urban development; Urban population; Urban sprawl; Indicators; Europe

1. Introduction

This paper analyses urban land use and population development in 15 medium-sized and large European urban areas from the mid-1950s until the late 1990s. The cross-European comparisons combined with a long time-horizon is made possible by the availability of detailed land use data stored in the MOLAND database. The database is collected and maintained by the Joint Research Centre of the European Commission. The main aim of this paper is to examine urban land use patterns and population density development trends in European cities during the past 50 years. The second objective is to compare land use development

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and population development in the form of urban densities. In order to meet these objectives five indicator sets measuring various aspects of urban land use and population density are used.

Urban land use and population density have always inspired researchers working in the fields of urban planning, geography and urban/regional economics. The discussion has evolved and fragmented both contextually and theoretically considerably during the past decades. Lately the research has focused among other topics on *land use intensity* which combines urban land use with population densities often in the form of various density gradients and density indices (e.g. Batty et al., 2003; Balchin et al., 2000; Batty and Kim, 1992; Edmonston et al., 1985; Parr, 1985) and *compactness/degree of sprawl* of urban areas (see e.g. Hasse and Lathrop, 2003a; Camagni et al., 2002; Longley and Mesev, 2001; Torrens and Alberti, 2000; Williams et al., 2000), which has gained terrain during the past decades. These two research interests are converging since they study only slightly different aspects of the same phenomenon. In this paper we focus on analysing intensity of urbanisation from the point of view of land use and population development and how they have changed over time.

Research on urban densities has mainly focused on three types of cities. North American cities have inspired a lot of research, mainly because low density and resulting urban sprawl are major policy issue there (e.g. Hasse and Lathrop, 2003a; Ewing et al., 2002; Filion, 2001). More and more abundant are studies on rapidly growing Asian cities (e.g. Deng and Huang, 2004; Lin, 2002; Sorensen, 2000). Cities in the developing countries have also started to gain terrain among urban geographers (Barredo et al., 2004; Lopez et al., 2001; Sutton and Fahmi, 2001) due to the rapid and much more unpredictable growth patterns than experienced in the cities in industrialised countries.

European urban land use and population trends have inspired less research during the past years (Antrop, 2004; Cheshire, 1995; CEC, 1992; Champion, 1992). Even at the level of individual countries the number of publications on urban research is quite modest (e.g. Ireland: Lutz, 2001; Germany: Ott, 2001; Gans, 2000; France: Guérin-Pace, 1995). The probable reasons for the relatively low interest in urban comparisons at European level are numerous. European cities might be considered too stable and hence of little interest as research topics. Another plausible explanation is the relatively low visibility of urban issues and the weakness of urban policy at the European level. Clear and focused national policies are much stronger drivers for research than weak European interests. A third explanation could be the difficulty of collecting comparable data (Antrop, 2004). The data exists but it has to be collected from various sources. This paper provides analysis on urban land use and population trends from a European perspective on the basis of the data from 15 European cities located in 13 countries.

2. Methods and datasets

2.1. Methods

In order to analyse urban land use and population density development trends over the past 50 years a stepwise indicator approach is adopted. The indicator framework is composed of five sets of indicators measuring various aspects of urban land use and population density (Table 1). Hasse and Lathrop (2003b) have suggested that the first step in assessing the existence and degree of urban dispersion is to evaluate land use changes and their relation to population density. The indicator framework has been devised so that it leads from basic land use indicators to population density measurements and finally to a combined analysis of population densities and land use intensity.

The most fundamental character of urban land use patterns is the ratio between built-up and unbuilt areas. The first indicator set called 'built-up areas' measures issues linked to the extent and growth of built-up areas. The following aspects are measured: ratio of built-up and unbuilt areas, growth rate at which built-up areas have expanded form the mid-1950s until the end of 1990s and the break-down into shorter time periods to show how the growth rate has evolved in time.

The second set of indicators enters more into the details of urban land use by breaking up the built-up land use into residential areas and commercial-industrial-transport areas. This indicator set is composed of four subindicators. The first one describes the type of built-up land (residential, commercial, industrial, etc.). The second one illustrates the respective growth rates of these subclasses. The third subindicator characterises the continuity and intensity of residential land use by

Table 1
Summary of urban land use indicators

Indicator	Description	Time horizon
1. Built-up areas		
1.1 Ratio of built-up and unbuilt areas	Percentage of built-up area of total land area	1950s, 1960s, 1980s, 1990s
1.2 Overall growth of built-up areas	Growth of built-up area in percentages	1950s compared to 1990s
1.3 Annual growth of built-up areas	Estimation of the annual growth rate of built-up area	1950s–1960s, 1960s–1980s, 1980s–1990s
2. Residential land use		
2.1 Ratio of residential areas and other built-up areas	Percentage of residential area of total built-up area	1990s
2.2 Growth of residential areas	Growth rate of residential area in percentages	1950s, 1990s
2.3 Ratio of continuous residential areas of all residential areas	Percentage of continuous residential area over all residential area	1950s, 1990s
2.4 New discontinuous residential areas	Percentage of discontinuous residential area over all new residential area	After 1950s
3. Land taken by urban expansion		
3.1 Type of unbuilt land available	Percentage of agricultural and natural areas over all unbuilt areas	1950s
3.2 Loss of natural and agricultural land	Lost agricultural and natural land in km^2	1950s–1990s
4. Population density		
4.1 Traditional population density	Population/area	1950s, 1960s, 1980s, 1990s
	Change of population density	1950s–1990s
4.2 Residential density	Population/residential areas	1950s, 1960s, 1980s, 1990s
5. Urban density		
5.1 Population growth in contrast with the growth of built-up areas	Growth of built-up areas in percentage/population growth in percentage	1950s–1990s
5.2 Available built-up area/person	Available built-up area/person in m^2/person	1950s, 1960s, 1980s, 1990s

dividing it into continuous and discontinuous residential classes. The parameter used to measure the continuity/discontinuity in this study is how large portion residential buildings and related artificial land fills out of total area available. If residential structures cover more than 80% of the land, it is deemed to be continuous. If the coverage is less than 80% the area then falls into the discontinuous class. The threshold of 80% which divides the continuous and discontinuous classes is a European standard derived from the CORINE land use classification and agreed upon among the European countries. It has been determined to be the best fit for the very heterogeneous reality of European built-up areas. The last subindicator details the growth rate of the continuous and discontinuous residential land use classes.

With the aid of the third indicator set we examine the land taken by urban expansion. We start by analysing the type of surrounding unbuilt land available for building activity in the 1950s. In the next phase we calculate how much agricultural and forestland has been lost because of urban development between the mid-1950s and the late 1990s.

In the forth indicator set the focus shifts from the land use to population density. We start with estimating the traditional population density. Although population density is quite a simple indicator of urban development, it gives relatively good general information about the character of the city, particularly if combined with land use information. However, population density is not an unambiguous or easily interpretable concept.

In most cases population density is calculated as inhabitants/km^2 and the whole land area of the city is taken as the reference point (called also a net density, see Frey, 1999 or overall population density, see Masnavi, 2000). In that case the changes in population density depend solely on the number of inhabitants since the administrative area of the city usually remains more or less stable over time. The traditional population density figure is very sensitive to the size of the city (Buckwalter and Rugg, 1986) and one must be cautions when comparing the net population densities in various cities, since the administrative areas of cities vary so considerably. In some cases administrative cities are large and they comprise broad forest and/or agricultural areas in the border zones. In other cases administrative cities are very small including only the city centre. To overcome this problem we have estimated also the 'residential density' as the second subindicator. It is calculated by distributing the total population to the area occupied by residential housing.

The fifth indicator focuses on how the population occupies the available built-up space. This we call urban density. Firstly we plot together the population growth and the growth of built-up areas. The second subindicator describes the available built-up area per person and how this ratio has developed over time.

2.2. Datasets

The MOLAND (MOnitoring LANd use/cover Dynamics) database is collected and maintained by the Joint Research Centre of the European Commission in order to support European policies. The MOLAND database contains detailed land use and transport network data, population data and a large number of statistical indicators (statistical part covers only part of the database) at the scale of 1:25,000 (EEA and JRC, 2002). At the moment the MOLAND database contains more than 50 urban areas and four larger regions in Europe. The data has also a temporal dimension. The land use data have been recorded at four dates: mid-1950s, late 1960s, mid-1980s and late 1990s.

The data is derived mainly from very-high resolution satellite images (such as IRS images with 5.8 m resolution), and for historical dates mainly from aerial photos. Maps and field trips have also been used as support for photo-interpretation. The photo-interpretation rules and procedures have been adopted from the CORINE land use classification which is the European Commission standard land cover/use classification (European wide coverage at the scale 1:100,000, see more information EEA, 2000). When necessary the CORINE rules have been applied to meet the needs of more detailed scale of MOLAND.

The MOLAND land use classes have as well been derived from the European standard CORINE classification. Two more detailed levels of land use classes have been added to the MOLAND land use legend in order to make a match with the more detailed scale of MOLAND (For more information, visit the website http://moland.jrc.it and consult EEA and JRC, 2002). The same land use classification has been used in all study areas. Naturally not all classes are present in all study areas. The main differences lie in natural and agricultural classes due to different climate conditions. The same photo-interpretation rules and similarly defined land use classes make comparisons between various study areas reliable. All datasets have been accurately assessed and validated by the research group responsible for the MOLAND database in the Joint Research Centre of the European Commission in order to guarantee full comparability between study areas.

The main selection criterion for choosing areas to be included in the MOLAND database was the overall representativeness of the sample of the cities. The considered attributes were geographical location (country and physical location), size, and development dynamics. For the purpose of this study 15 European cities were selected from the MOLAND database. As indicated in Table 2, the sizes of the cities vary quite considerably in three respects: size of the land area, size of population and population growth rate from the mid-1950s to the late 1990s. This heterogeneity has to be borne in mind when interpreting the results. Among the cities are capitals and other major European cities. Three of the cities are located in Central and Eastern Europe.

Land use statistics are often gathered by cities themselves and they follow in most cases the administrative borders of cities. This often hampers the comparisons between various cities, as the sizes of administrative cities vary to a considerable extent in various European countries. Therefore, in the MOLAND database in order to avoid this difficulty urban areas have been delineated by using as a starting point the continuous built-up area (A) in the early 1990s which was taken from the CORINE land cover maps. In CORINE continuous urban fabric has been defined as areas where 80% or more of the land is covered by buildings, transport structures and other artificially surfaced areas (EEA, 2000). This area was then buffered with a zone

Table 2
Basic data on the studied urban areas

City	Total land area in km^2	Population in the mid-1950s	Population in the late 1990s	Population change mid-1950s–late 1990s in %	Country
Bilbao	166	351000	770000	119.4	Spain
Bratislava	432	184000	450000	144.6	Slovak Republic
Brussels	1301	1275000	1642000	28.8	Belgium
Copenhagen	648	1038000	1232000	18.7	Denmark
Dresden	1240	871000	789000	−9.4	Germany
Dublin	659	637000	1000000	57.0	Ireland
Helsinki	790	407000	932000	129.0	Finland
Lyon	302	770000	1030000	33.8	France
Milan	322	1533000	1800000	17.4	Italy
Munich	791	1127541	1680000	49.0	Germany
Palermo	223	535000	739000	38.1	Italy
Porto	193	544000	671000	23.3	Portugal
Prague	788	1022000	1270000	24.3	Czech Republic
Tallinn	1048	287000	482000	67.9	Estonia
Vienna	822	1706000	1648000	−3.4	Austria

which is based on the same idea as Longley and Mesev's (2001) urban field although the strict definitions are not completely identical. In the MOLAND database the width (W) of the buffer is calculated as follows:

$$W = 0.25\sqrt{A}$$

Even this delimitation method could not completely overcome the difference between compact Southern European cities and cities with more extensive land use in Central and Northern Europe. This distinction is still noticeable in the sizes of the study areas (Fig. 1). For example in Milan the buffer is dominated very much by built-up areas. In Bratislava the built-up areas are fairly scattered and the buffer is clearly dominated by natural and agricultural areas. Although this method to delineate the study area has its own weaknesses which are mainly due to the heterogeneity of European cities, its strengths (the size of the study area is delineated by using the same methodology which is based on land use intensity and does not follow often very arbitrary administrative borders) overweight its weaknesses. It is also relatively cost-effective because by using the above-described delineation the size of the study area

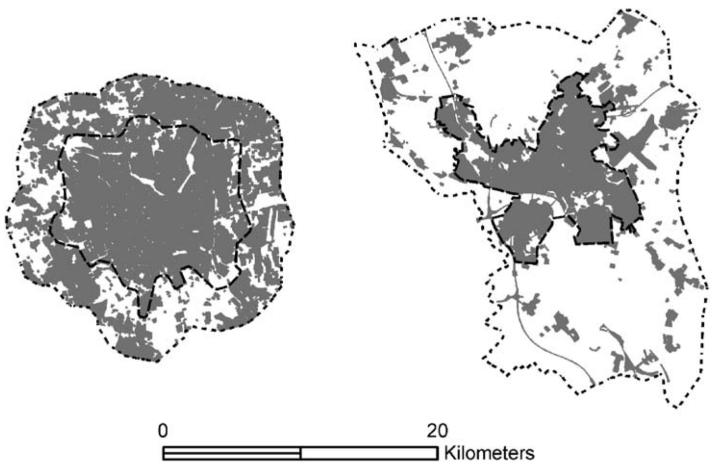

Fig. 1. Built-up areas (in grey) in Milan, Italy and Bratislava, the Slovak Republic in the late 1990s (the buffer for Bratislava does not follow the formula because of close by state border and the inclusion of an artificial lake on Danube).

is limited to the immediate surroundings of urban areas. Taking into account the large sample of urban areas (more than 50) this aspect has to be borne in mind. Although most of the buffers are quite large, one has to bear in mind that urban dynamics have an impact on land use also outside the buffer area. The conclusions presented in this paper are based on the development within the study area.

The population data was collected form local and regional authorities' statistical yearbooks which were either available on the official web sites of the local and regional authorities or if not available electronically, paper copies of the statistics were requested directly from them. All population statistics were collected following the administrative boundaries. The merge with the MOLAND study areas was done by overlaying the European municipality boundaries database (from the Geographic Information System for the European Commission GISCO-database, see at http://eusoils.jrc.it/gisco_dbm/) with the extent of the MOLAND study areas. Then the population figures were assigned to respective municipalities. If the municipality fell completely within the MOLAND study area, then the whole figure was taken into account. If part of the municipality was outside and part inside the MOLAND study area, then the population figure falling inside the study areas was reduced proportionally from the total figure. In the end the total population was summed up for each study area.

Some land use indicators are very sensitive to the size of the study area. In particular those indicators which measure absolute values of various land use classes are not very comparable across cities, as they are easily influenced by the size of the total area studied. In this study we have tried to use as little absolute indicators as possible to avoid comparability problems.

3. Results

3.1. Indicator set: built-up areas

The ratio between built-up and unbuilt areas gives a fairly good overall image of the character of the city. Built-up areas include residential areas, industrial and commercial areas, transport areas, dump sites, construction sites and mineral extraction sites. They do not include green urban areas. As Fig. 2 shows in most studied cities between 30 and 40% of the land area is covered by artificial structures (buildings, roads, etc.) in the late 1990s. In four cities the ratio is over 50% and in only three the ratio is below 30%. The average figure between 30 and 40% of built-up areas of total urban area seems to be quite typical for European cities (e.g. the Greater Manchester area in Ravetz, 2000). As a general rule the cities with a high proportion of built-up areas are located in Southern Europe and cities where the surroundings are strongly dominated by natural and agricultural areas are more common in Western, Central and Northern Europe. On the basis of the available data it is obvious that the core areas of Southern European cities are surrounded by built-up areas if compared to their more northern counterparts, although there is evidence that also Mediterranean cities have started to spread out and have thus become less compact in structure (Dura-Guimera, 2003; Munoz, 2003; Cheshire, 1995).

In all selected cities the built-up area has grown considerably over the study period from the mid-1950s to the late 1990s. The growth ranges from 28% in Vienna to 220% in Palermo. On average the growth of built-up areas has been 87% (Fig. 3). This means that the built-up area in the studied cities has almost doubled during the past 50 years. Clement and Guth (1995) have analysed urban growth in 22 French cities between 1975 and 1990. French cities had doubled their built-up areas in only 15 years.

In order to analyse more thoroughly the growth pattern, in Fig. 4 the overall growth has been divided into three periods (1950s–1960s, 1960s–1980s and 1980s–1990s) and into annual growth percents. The most rapid growth of built-up area has taken place from the 1950s to 1960s. Dublin is the only exception to this rule. The development in Dublin has been exceptional due to the rapid economic growth which took place later than in most European countries where the economies were prospering soon after WWII (Ellis and Jong, 2001; Lutz, 2001). The absolute growth figures of built-up areas (km^2) are collected in Table 3.

In most studied cities the land use dynamics have slowed down considerably towards the end of the study period. During the first period the average yearly growth rate was 3.3%. It then dropped to 1.7% and when coming to the 1990s down to 0.75%. The growth rates of built-up areas in the studied cities converged towards the end of the study period. The standard

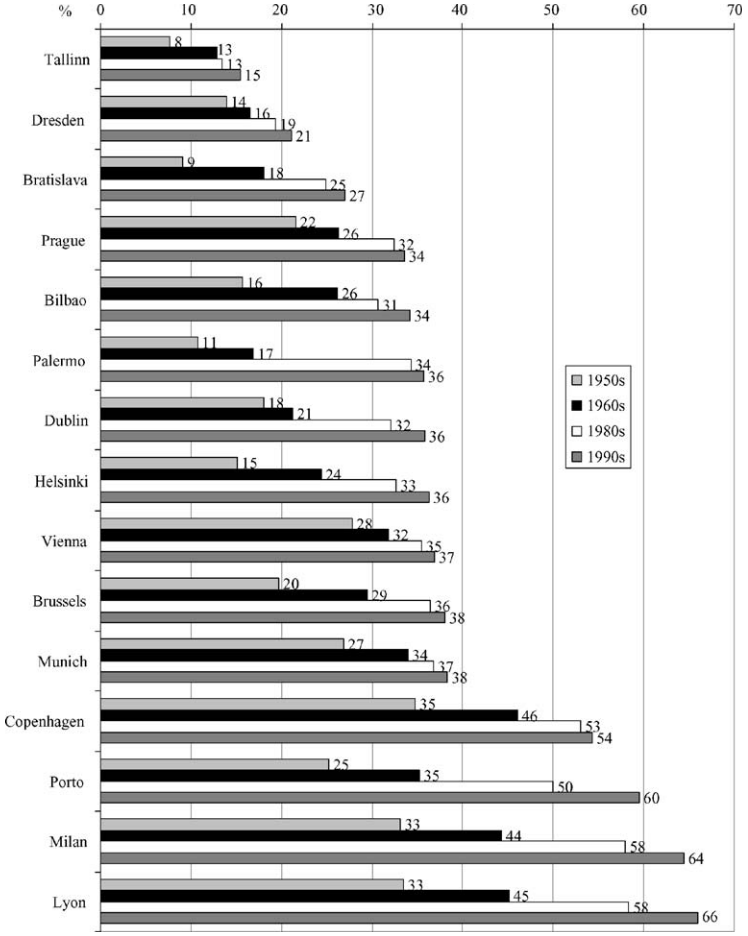

Fig. 2. Percentage of built-up areas in the studied cities in mid-1950s, late 1960s, mid-1980s and late 1990s.

deviation dropped from 1.76 (1950s–1960s) to 0.37 (1980s–1990s).

Taking into account the relatively good representativeness of the studied cities, it can be assumed that urban land use dynamics have reached a certain degree of maturity in Europe because the yearly growth rate has dropped down drastically in all studied cities. It can also be noted that cities with a population of 0.5 million or more seem to have reached a rather similar phase of development in respective to the dynamics of urban expansion measured by changes in built-up area. On the basis of the available data the spurt in the growth of built-up land dates back to 1950s and 1960s. Although the growth has slowed down after that, the average yearly growth of 0.75% at the end of the 1990s is quite high and means that urban spread continues although at a slower pace.

3.2. *Indicator set: residential land use*

Each of the various built-up land use classes (such as residential, industrial, commercial, transport) has its own development dynamics and drivers. For that reason it is necessary to split up the built-up land use into more detailed subclasses. In this context we decided to take a closer look into two classes: residential land use and the aggregation of industrial, commercial and transport land use.

The share of residential areas of all built-up areas shows surprisingly big variation across cities (Fig. 5). It

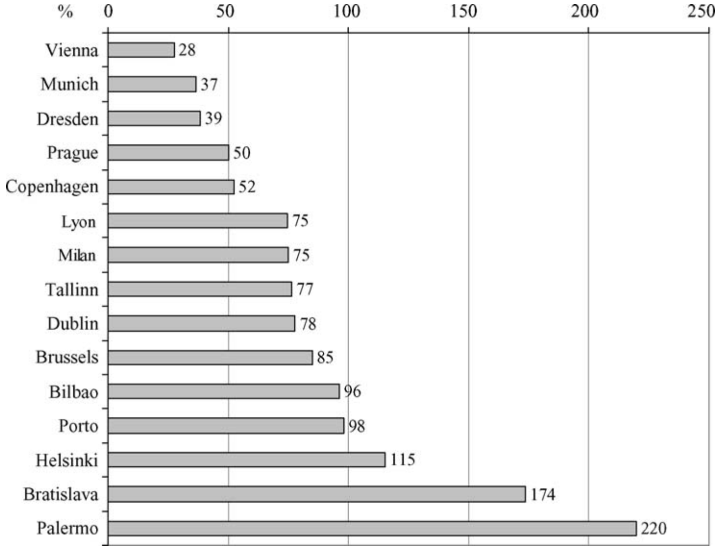

Fig. 3. Growth rate of built-up areas in the studied cities between the mid-1950s and the late 1990s.

varies from only 45% (in Bilbao) to 79% (in Palermo). Part of the variation depends on the amount of mixed land use in commercial/residential areas. In cities such as Palermo and Brussels there are a lot of small shops in the ground floors of residential buildings. In these cases the land use has been classified in the MOLAND database according to the dominant land use (residential). In the cities where mixed residential/commercial land use is the prevailing type of commercial services the amount of land classified under commercial land use is to some extent underestimated. Taking into account the inaccuracies caused by mixed land use it can be stated that the share of residential land of all built-up areas is in the region of 60–70% in more service-oriented cities and between 50 and 60% in cities where industries are in a more dominant position in the economy.

During the study period both residential and industrial–commercial–transport land use classes have grown rapidly (Fig. 6). In all cities except Dublin and Palermo the growth rate of industrial–commercial–transport land use has outpaced clearly the growth of residential land use. The average growth

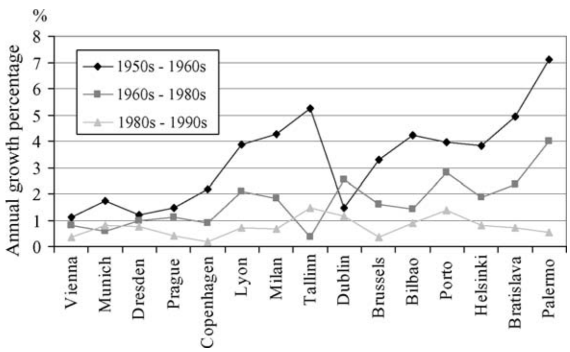

Fig. 4. Annual growth percentages of built-up areas in the studied cities from the mid-1950s to the late 1990s.

Table 3
Annual growth of built-up areas in km^2 (N.B. The figure indicates the yearly growth)

	1950s–1960s	1960s–1980s	1980s–1990s
Bilbao	1.1	0.6	0.4
Bratislava	1.9	1.8	0.8
Brussels	8.4	6.1	1.7
Copenhagen	4.9	2.6	0.7
Dresden	2.1	2.0	1.9
Dublin	1.8	3.6	2.5
Helsinki	4.6	3.6	2.1
Lyon	3.9	2.9	1.3
Milan	4.5	2.6	1.2
Munich	3.7	1.5	2.4
Palermo	1.7	1.5	0.4
Porto	1.9	1.9	1.3
Prague	2.5	2.3	1.1
Tallinn	4.2	0.5	2.1
Vienna	2.5	2.0	1.1

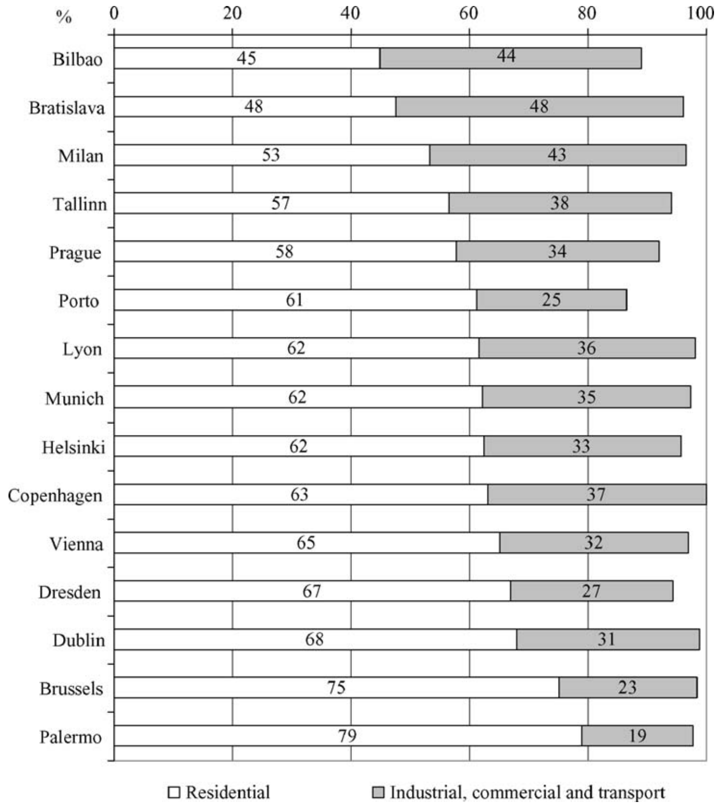

Fig. 5. Share of residential and industrial, commercial and transport land use of the total built-up area in the late 1990s in the studied cities. (N.B. The two land use classes do not sum up to 100% because there are other artificial areas such as dump sites, construction sites, etc.)

rate for industrial–commercial–transport is the double if compared to the growth of residential land use. The most rapid growth in industrial–commercial–transport areas dates back to 1950s and 1960s. Towards to the end of the study period the growth pace slows down. In this respect the trends in residential and industrial–commercial–transport areas follow the same pattern.

Another interesting indicator characterizing urban landscape is the intensity of land use and in particular the land use intensity of residential areas. By intensity we refer to the degree to which the built structures cover the available land. Compactness is another definition used commonly when referring to composition of built-up and unbuilt patches in urban landscape. Compactness is measured in general by spatial metrics which is such a vast branch of urban landscape research that we had to leave it outside the scope of this study.

In the MOLAND database the residential areas have been classified into two main classes, continuous and discontinuous. The main difference between the classes is the intensity of land use: in the continuous class buildings and related structures cover more than 80% of the total surface and in the discontinuous class the coverage varies between 10 and 80%.

The studied cities are indeed very diverse when it comes to the intensity of residential areas. Fig. 7 shows the percentage of continuous residential land of all residential land. Palermo is without comparison in its compactness: almost 90% of all residential areas are continuous. At the other end of the continuum are Dublin, Dresden, Brussels, Helsinki and Copenhagen where discontinuous residential areas dominate (over 90% of all residential areas are discontinuous). In Southern Europe continuous seems to dominate over discontinuous and in Western, Central and Northern Europe residential areas are

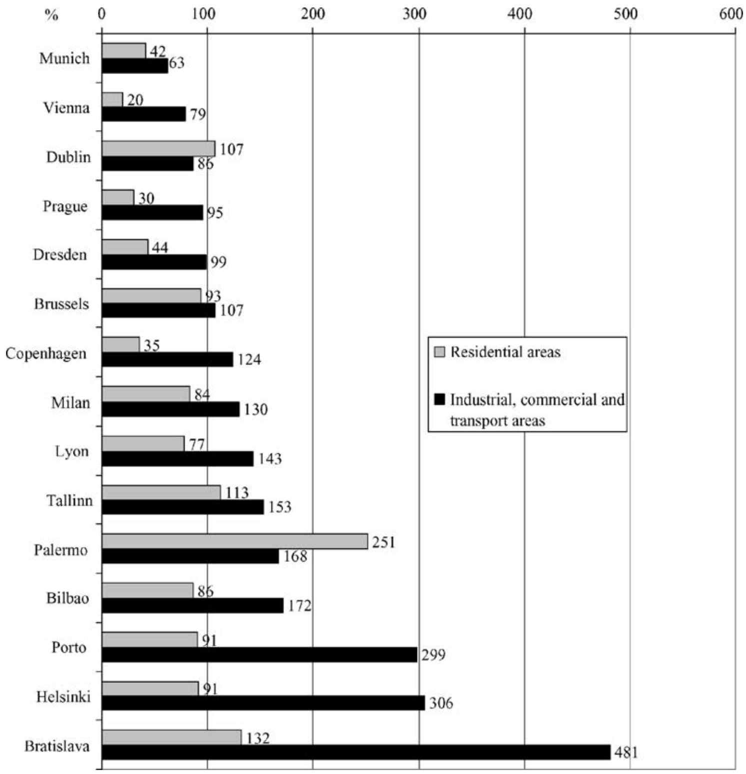

Fig. 6. The growth rate of residential areas and industrial–commercial–transport areas in the studied cities from the mid-1950s to the late 1990s.

much less continuous, dotted by gardens and small parks.

The general trend over the 50-year long study period shows a clear trend towards less intensive residential areas. Only in Palermo, Prague, Munich and Bilbao more than 50% of new residential development has been continuous (Fig. 8). In all other cities the growth of discontinuous, less intensive residential development has clearly outpaced the growth of continuous housing areas.

In half of the studied cities over 90% of all new housing built between the 1950s and the end of 1990s is discontinuous. This is linked to the rapid decentralisation trend which has characterized urban development in Western Europe since WWII (Breheny, 1996; Cheshire, 1995). Although there is some evidence that the decentralisation has slowed down, stopped and even turned into recentralisation in the 1980s in Northern Europe, if measured by population development (Cheshire, 1995), it does not seem to have reached yet the land use dynamics. Making cities more compact has already been for a while at the top of national (Williams, 2000) and European policy agendas (CEC, 1990, 1996). However, these policy efforts have not seemed to have yielded yet visible results in the light of continuing growth of discontinuous residential areas in most European cities.

3.3. Indicator: land taken by urban expansion

As land is a finite resource, if built-up areas grow inevitably agricultural and natural areas shrink. The studied cities vary very much from each other in respect to the surrounding land use (Fig. 9). In the mid-1950s Milan was quasi-completely surrounded by agricultural land and in Helsinki only 1/3 of the surrounding land was agricultural and 2/3 natural areas. For most cities more than half of the surrounding land was in agricultural use (arable land, pastures, etc.).

It is interesting to note that in most cities the growth of built-up area has taken place mostly on previously agricultural land (Fig. 10). Only in Helsinki and

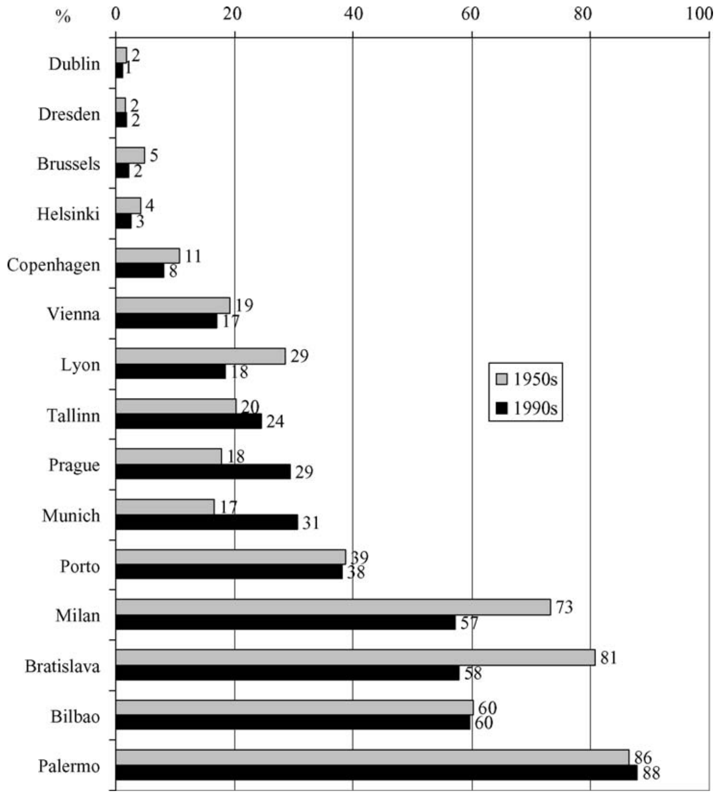

Fig. 7. Proportion of continuous (buildings and related structures cover more than 80% of the surface) residential areas of all residential areas in the studied cities in the mid-1950s and in the late 1990s.

Tallinn, where most of the surrounding land is natural, has most of new building activity been channelled into previously natural areas. In all other cities there is a clear dominance of new building development in previous agricultural land. This is due to several factors. Firstly most of the available land for urban growth is agricultural, as shown in Fig. 9. Secondly, agricultural land is in most cases technically more suitable for construction than forest areas both topographically and in economic terms. Thirdly, natural areas are often considered as valuable recreational areas and hence cities have protected them from building activities (e.g. Tyrväinen, 2001; Pirnat, 2000).

A large study conducted in the state of New Jersey, USA, shows that due to urban sprawl over 61,000 ha previously undeveloped land was converted into built-up areas between 1986 and 1995. Only 38% of the land was before in agricultural use and the rest either forests or wetlands (Hasse and Lathrop, 2003b). In our sample of 15 European cities almost 90% of all land lost because of building activity between the mid-1950s and the late 1990s was agricultural. There are several likely explanations to the different pattern in the studied cities in Europe and in New Jersey. Firstly in New Jersey the study area covered the whole US state and in our study only urban areas and their surrounding buffers. It is very likely that the land use patterns far away from urban centres differ considerably from land use patterns in their immediate vicinity. The time span is shorter and starts later in New Jersey. As agricultural land is technically easier to construct on than natural (mainly forests) areas, it is likely that the earlier expansions of urban areas have already consumed available agricultural land and most of the remaining land in the potential expansion area of urban areas are forests and wetlands. Local land use policies (or lack of them) play also a major role in pointing a direction to further urban expansion and whether it takes over natural or

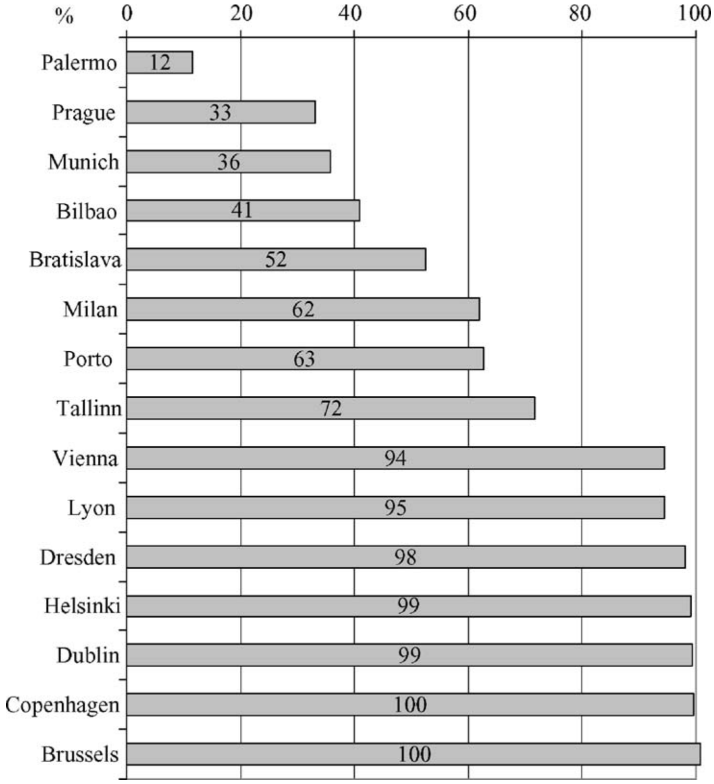

Fig. 8. Share of discontinuous residential areas of all residential areas built after the mid-1950s in the studied urban areas.

agricultural land. A sustainable strategy for urban development should focus on the recycling of previously developed sites (e.g. brownfield land) while maintaining and enhancing areas of green space (EEA, 2002).

3.4. Indicator: population density

In order to understand the reasons explaining the considerable differences in the growth rate of built-up areas, it is essential to combine the land use data with data on population development. Population density has been calculated by dividing the total population by the study area composed of the core area + the buffer around it (for the delimitation of the buffer, see Section 2).

In the studied cities the population density differs to a considerable extent (Fig. 11). In the mid-1950s the most densely populated city – Milan – was 17 times denser than the most sparsely populated, Tallinn. There is a clearly discernible difference in population density in north and south. The population density is much higher in the cities in the Southern Europe than in the north. However, one has also to bear in mind the limitations of population density when comparing cities as stated in Section 2.

During the 50-year long study period the population, and hence also the density, have grown in all other cities except in Dresden and Vienna. In most cities the population growth and densification development have reached the peak between the mid-1950s and the mid-1980s. During the past 15 years the growth has slowed down drastically, stopped or even turned into decrease. The average population change among the selected cities is −2.8% for the period from the mid-1980s to the end 1990s.

There are three cities where the population density has more than doubled during the study period. In spite of doubling their population Helsinki, Tallinn and Bratislava remain still relatively sparse cities. Bilbao was already at the beginning of the reference period

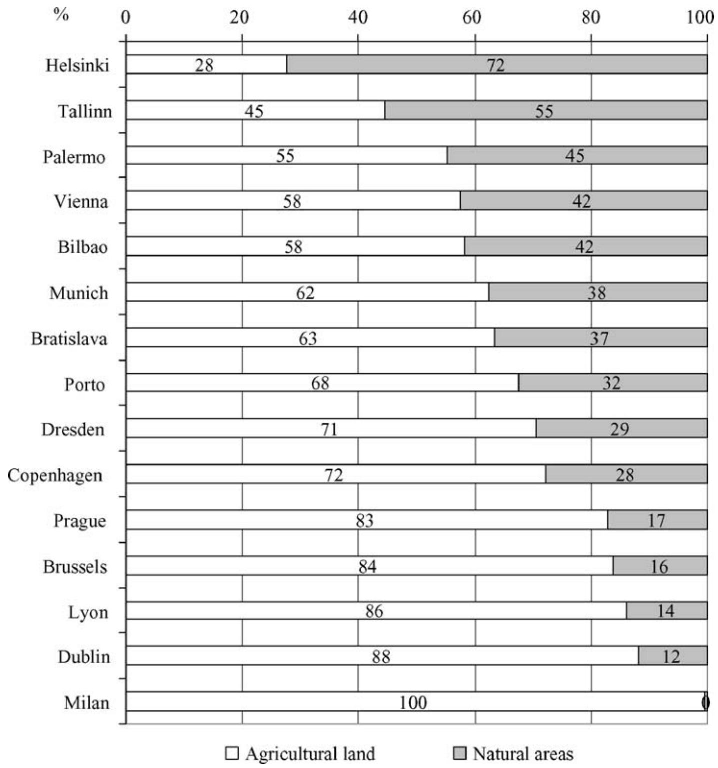

Fig. 9. Dominating land use classes for unbuilt areas in the mid-1950s in the studied cities.

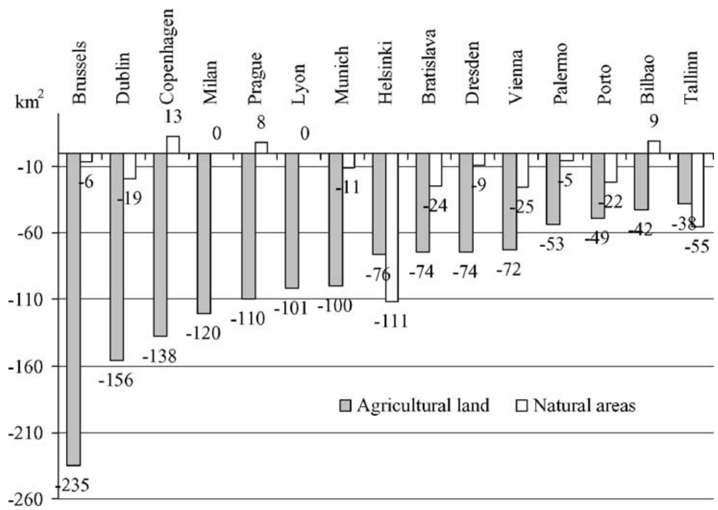

Fig. 10. Natural and agricultural land (in km^2) lost due to urban development in the studied cities between the mid-1950s and the late 1990s. (N.B. The sizes of studied areas vary, see Table 2.)

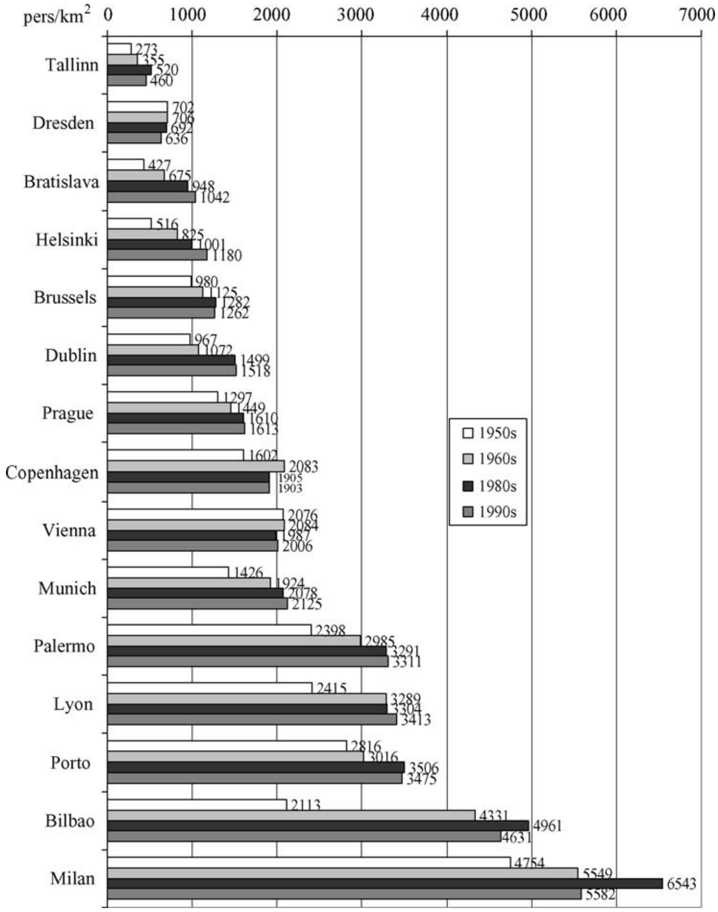

Fig. 11. Population density (inhabitants/km^2) in the mid-1950s, late 1960s, mid-1980s and late 1990s.

relatively dense and it became the second densest city among the studied cities.

As indicated above the net population density (inhabitants/area) has some limitations in particular when comparing cities with each other. To overcome the comparability problems, another type of density figure was calculated. As the surface of residential areas is known in the MOLAND database, it was possible to compute the residential density, which is the number of inhabitants per residential km^2. This figure is a more reliable, and above all more comparable, indicator of urban densities.

In most cities the starting level in the mid-1950s was between 5000 and 10,000 inhabitants per residential km^2 (Fig. 12). In Palermo, Milan and Bilbao the density was much higher, over 25,000 inhabitants per residential km^2. In all cases except in Bilbao, Helsinki, Munich and Bratislava, the density figure has dropped during the 50-year-long observation period. The drop in residential density has been remarkably large in the studied Italian cities. In Palermo the residential density has dropped by 60% (from 30,000 to 12,000) and in Milan by 36% (from 25,000 to 16,000).

Drop in the residential density means that the growth pace of residential areas has outpaced the population growth. It also indicates that new residential areas are built more sparsely than the existing ones. At the outskirts of cities, where new areas are generally located, the dominating housing types are detached or semi-detached houses. The suburban blocks of flats normally tend to be free-standing and are hence more space-consuming than the closed

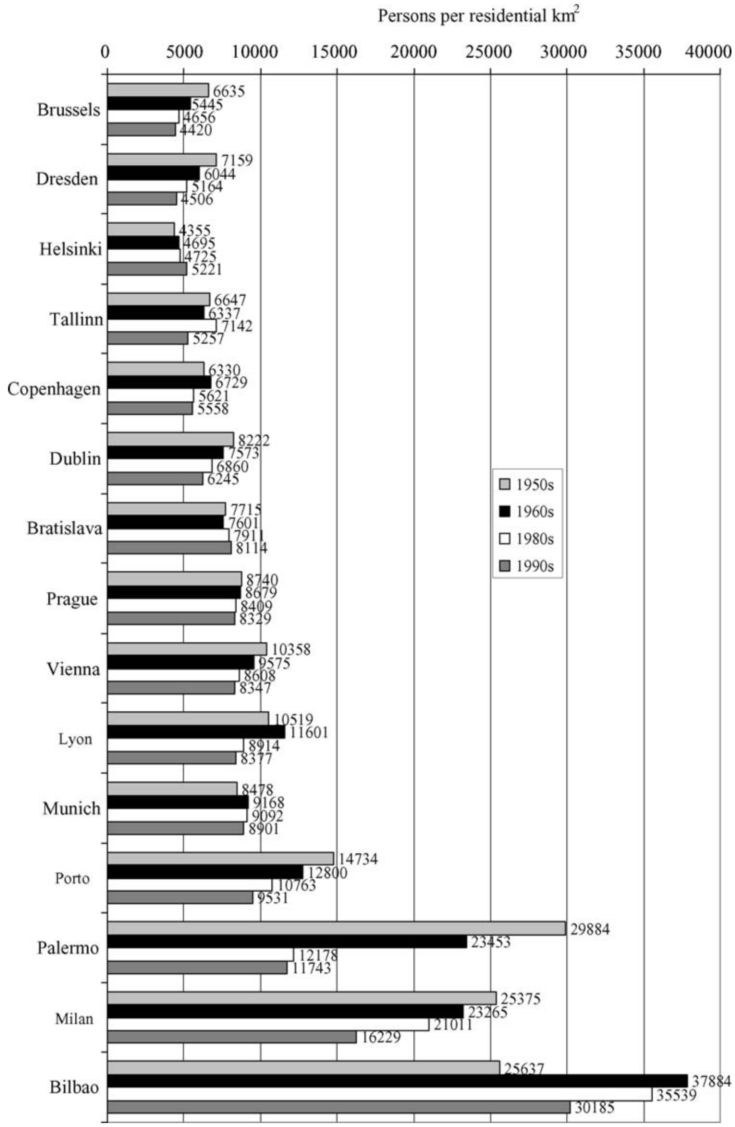

Fig. 12. The residential population density in the studied European cities from the mid-1950s to the late 1990s (measured as inhabitants per residential km^2).

blocs, which are predominant in city centres. In Bilbao, Helsinki, Munich and Bratislava the new housing areas have increased the residential density which means that they are denser than the already existing ones and therefore have increased the residential density.

The concept of residential density is a separate one from housing density, which refers to the floor space available per person. In all EU-countries the housing density has decreased drastically during the past 50 years (Housing Statistics, 2002). For example in the city of Helsinki in 1960 each person had approximately 16.5 m^2 floor space at his disposal. By 2000 the space had doubled to 33 m^2 (Facts about Helsinki, 2003). Although there seems to be a mismatch between decreasing housing density and increasing residential density in Helsinki the contradiction is only ostensible. Residential density refers to land use. It indicates how much

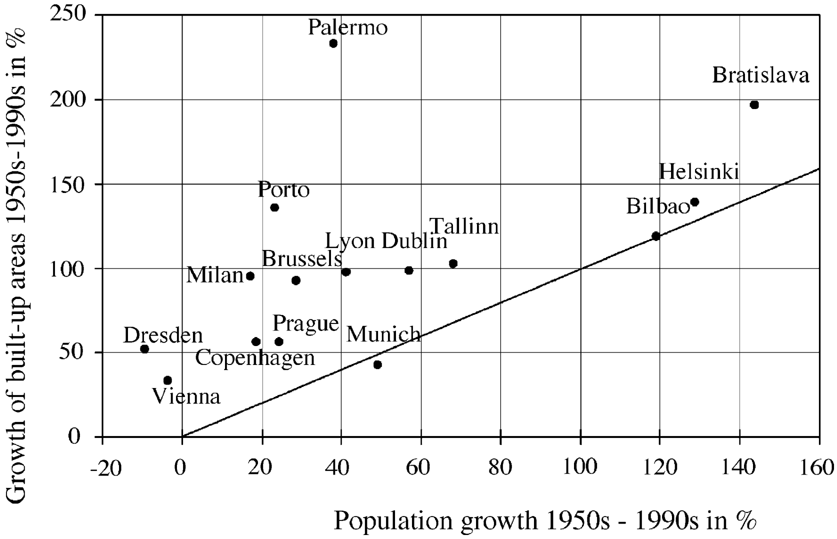

Fig. 13. A comparative perspective into the population growth and growth of built-up areas in the studied cities from the mid-1950s to the late 1990s.

land is used to provide the citizens with housing while housing density refers to the availability of floor space per inhabitant.

3.5. Indicator: urban density

The population data has been cross-tabled with the growth rate of built-up areas. In the resulting scattergram (Fig. 13), the population growth rate (in %) is plotted on *X*-axis and the growth rate of built-up areas on *Y*-axis. The diagonal line shows the even growth line i.e. population and built-up areas have grown at the same rate. The linear growth line divides the cities in two groups: all cities above the line have experienced faster growth of built-up areas than of population and in the cities below the line the population growth has outpaced the growth of built-up areas. The farer away the city is located from the line, the bigger the difference in the two growth rates.

In Helsinki, Bilbao and Bratislava the rapid growth of built-up areas is explained by equally or almost equally rapid population growth. Only in Palermo and Porto, which are among the cities where built-up areas have grown much faster than in the average cities, the growth has not been accompanied by equally rapid population growth. In these cases the built-up area per inhabitant has grown fast. This can be an indication of urban sprawl or of lower than average starting level, in which case they have been catching up with the overall trend.

The other reasons for the growth of built-up areas are manifold and can be identified with rising living standards (more space per person), developing commercial and transport services (which require more buildings), changing living preferences (single houses preferred over blocks of flats) and changing land use policies (attitude towards compact/sprawled city ideal, etc.).

Out of the above-mentioned possible explanations for rapid growth of built-up areas only the availability of built-up area per person is possible to analyse with the available data. The results are not surprising (Fig. 14). In the cities in Southern Europe, the built-up area per person is much smaller than in cities in Western, Central, Eastern and Northern Europe. The trend seems to be the further north one goes, the more built-up areas per person there are in urban areas. In the 1950s, in the most ‘spacious’ city, Helsinki, there was almost seven times more built-up area per person than in the most ‘concentrated’ city Palermo. During the following 50-year period the gap has narrowed, but still in the late 1990s the difference between Palermo (107 m^2 per person) and Tallinn (337 m^2 per person) was considerably large.

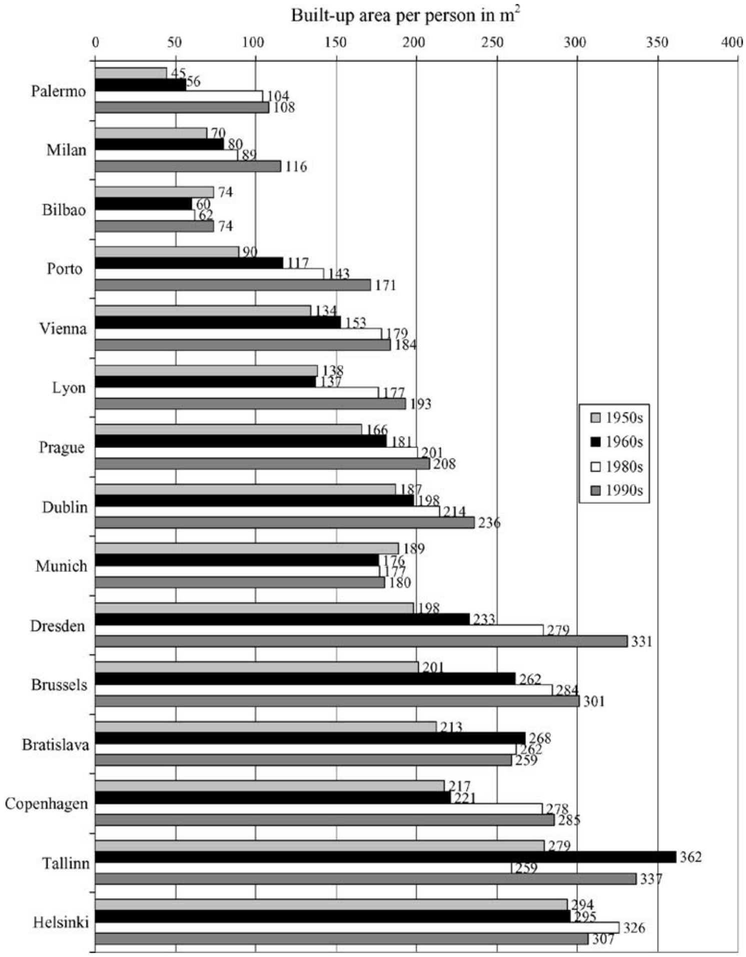

Fig. 14. Available built-up area per person in m^2 in the mid-1950s, late 1960s, mid-1980s and late 1990s in the studied cities.

4. Discussion

In the light of the presented land use and population development data, it is clear that European cities are very different from the point of view of population densities and land use patterns. However, there are some common trends. The built-up areas have grown considerably in all studied cities. The most rapid growth dates back to 1950s and 1960s. The annual growth rate has slowed down in the 1990s to 0.75% and the gap in growth paces between various cities has narrowed. This indicates that development dynamics among the studied European cities are converging.

In the 15 studied cities the annual growth rate of 0.75% in built-up areas has to be put into the perspective of population development. During the 12 years from the mid-1980s to the late 1990s the urban population has declined by 2.8% and built-up areas have grown by approximately 9%. This mismatch indicates that a phenomenon referred in the US literature as urban sprawl is also reality in Europe. Another feature suggesting potential urban sprawl is the strong growth of discontinuous residential areas. In half of the studied cities over 90% of all new housing areas built after the mid-1950s are discontinuous. On the basis of these findings it is mere a question of taste whether to call it urban sprawl or urban expansion.

Although the size of the sample was limited (15), there are enough grounds to subdivide the cities into three groups according to the results of the combined population density and land use analysis. The studied cities in Southern Europe – Palermo, Milan, Bilbao and Porto – form a clearly distinguishable group. In particular until the 1960s they were very compact in structure and very densely populated. Still at the end of 1990s they are the most compact and dense of all studied cities, but the difference between them and the other cities has shrunk. Our research findings confirm that Southern European cities have started to experience rapid urban expansion but that they still are very compact if compared to other European cities, in particular to those in Northern Europe.

Another group which stands out clearly are cities with low densities and looser structures. Helsinki, Tallinn, Brussels, Copenhagen, Bratislava and Dresden belong to this group. Most of these cities are located either in northern or central parts of Europe with the exception of Brussels. These cities are characterised by low population densities and discontinuous residential structures. The amount of built-up area per person is clearly higher than in the other studied cities.

The rest of the studied cities belong to a sort of a middle group. Vienna, Munich, Lyon, Prague and Dublin are more compact and dense than their northern counterparts but not as dense as the cities in Southern Europe. This type of urban development seems to be the most common one in Western and Central Europe. This group is the most ambiguous one, since not all the used indicators point to the same direction. For example the city of Dublin has the highest rate of discontinuous residential areas among the studied cities but the other density variables indicate higher densities than in the northern cities. This only tells that on one hand the compactness of urban structures and on the other hand population densities are two continua which are not always parallel to each other, and where the individual cities are changing positions in time. Groupings are always to some extent artificial, forcing strict boundaries on phenomena which are continuous by nature.

The observed diversity of urban development in Europe is a result of various factors. Firstly geographical surroundings where the studied cities are located are very different. Coastal or mountainous location creates very different development options than location on a plain or along a river. Secondly, historical onset of urbanisation process marks very clearly the present outlook of cities. Those cities which have been found 2000 years ago look very different from those which only have a history of a couple of hundreds of years. More recently land use policy and the nature and follow-up of the application of zoning restrictions have profound implications of urban development. Population development moulds also the physical development of urban areas. All these factors have fostered the very diverse urban development trends in different parts of Europe although some common characteristics have been identified. European urban development is hence not as uniform as often thought.

Are there cities among the studied ones which seem to have succeeded in fighting against excessive urban expansion? Considering all the indicators used in this study two very different cities can be brought up in this context: Bilbao and Munich. They are the only two cities where the available built-up area per person has been either stable or decreasing. In all other cities it has grown considerably. They are very different cities in size, density, location and land use set-up but despite their differences both have obviously managed to implement land use and transport policies which control efficiently the outward spread of urban structures. It would be very interesting to analyse more in depth the practiced urban policies in these two cities.

5. Conclusions

Analysing and understanding urban land use dynamics and population development is an extremely challenging task even in one urban agglomeration not to mention at national or European level. This comparative study has shed light on general urban land use and population trends in 15 European cities during the latter half of the 20th century. The results show that analysing urban land use development necessitates the use of complementary indicators. Not a single indicator used in this study is capable of portraying the whole picture of urban land use and population evolution. All used indicators have their strengths and weaknesses but when used in parallel they enable a thorough analysis. In order to get a more comprehensive understanding of urban land use dynamics, and in particular of the extent of urban sprawl or fragmented land use dynamics more indicators capable of processing data related directly to urban forms – such as gradients, mean distances, form of land use patterns, etc. – are needed.

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