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Towards urban *un*-sustainability in Europe? An indicator-based analysis

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Abstract

In Europe, during the period 1980-2000, urban land has expanded by 20% while population has increased only by 6% (EEA, 2002). This is one of the consequences of unsustainable development patterns in some European urban agglomerations. This paper analyses the relationship between urban land use development and population density in fifteen European urban areas.

The results were achieved using five indicator sets which shed light on built-up areas, residential land use, land taken by urban expansion, population density and how the population takes up the built-up space. These complementary indicators show that the built-up areas have grown considerably in all studied cities: the most rapid growth dates back to 1950s and 1960s, afterwards 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, which demonstrates the de-centralisation trend of urban land uses. It is a question of taste whether to call it urban sprawl or urban dispersion.

The analysis closes by discussing on the one hand the common urban land use and residential population density trends and on the other hand detecting differences between the studied cities, dividing them in three groups: compact, with lower densities and cities in the midway between the extremes.

Keywords: Urban development, urban population, urban sprawl, indicators, European cities.

1. Introduction

The aim of this paper is to examine and compare urban land use patterns and population density development trends 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 large scale land use data stored in the MOLAND[1] database.

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 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. Edmonston et al., 1985; Parr, 1985; Batty & Kim, 1992; Balchin et al. 2000; Batty et al., 2003) and *compactness/degree of sprawl* of urban areas (see e.g. Torrens & Alberti, 2000; Williams et al., 2000; Longley & Mesev, 2001; Camagni et al., 2002; Hasse & Lathrop, 2003a). These two research interests are converging since they study only slightly different aspects of the same phenomenon.

North American cities have inspired a lot of research, mainly because urban sprawl is major policy issue there (e.g. Hasse & Lathrop, 2003a; Ewing et al., 2002; Filion, 2001). Abundant are studies on rapidly growing Asian cities (e.g. Sorensen, 2000; Lin, 2002; Deng & Huang, 2004). Cities in the developing countries have also started to gain terrain among urban geographers (Lopez et al., 2001; Sutton & Fahmi, 2001; Barredo et al., 2003) 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 (Champion, 1992; CEC¸ 1992; Cheshire, 1995; Antrop, 2004). Even at the level of individual countries the number of publications on urban research is quite

[1] The MOLAND (MOnitoring LANd use/cover Dynamics) database is collected and maintained by the Joint Research Centre of the European Commission in support of EU policies. It contains more than 50 urban areas and regions. The datasets are derived from high resolution satellite imagery, more information is available at: http://moland.jrc.it.

modest (e.g. Germany: Gans, 2000; Ott, 2001; France: Guérin-Pace, 1995; Ireland: Lutz, 2001). The probable reasons for this issue 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 exist but they have to be collected from various sources.

2. Methods and Datasets

2.1. Methods

In order to analyse urban land use and population density development trends over the past 50 years an indicator framework composed of five sets of indicators is adopted (Table 1).

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 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 Growth of residential areas	Growth rate of residential area in percentage	1950s, 1990s
2.2 Ratio of continuous residential areas of all residential areas	Percentage of continuous residential area over all residential area	1950s, 1990s
2.3 New discontinuous residential areas	Percentage of discontinuous residential area over all new residential area	After 1950s
3. Land taken by urban expansion		
3.1 Loss of natural and agricultural land	Lost agricultural and natural land in sq. km	1950s-1990s
4. Population density		
4.1 Residential density	Population/residential areas	1950s, 1960s, 1980s, 1990s
5. Population in the built-up space		
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/inhabitant	Available built-up area/inhabitant in sq. m/inhabitant	1950s, 1960s, 1980s, 1990s

Table 1: Summary of urban land use indicators developed in this study.

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 most fundamental character of urban land use patterns is the ratio between built-up and un-built areas.

The first indicator set called 'built-up areas' measures issues linked to the extent and growth of built-up areas: ratio of built-up and un-built areas and the break-down into shorter time periods from the mid-1950s until the end of 1990s to show how the growth rate has evolved in time.

The second set of indicators gets more into the details by breaking up the built-up land use into residential areas and commercial-industrial-transport areas. This indicator set describes: the type of built-up land (residential, commercial, industrial etc.) and the respective growth rates of these subclasses, the continuity and intensity of residential land use by dividing it into continuous and discontinuous residential classes (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) and the growth rate of the continuous and discontinuous residential land use classes.

With the aid of *the third indicator* we examine the land taken by urban expansion, calculating how much agricultural and forest land has been lost because of urban development between the mid-1950s and the late 1990s.

For what concern *the fourth indicator,* the focus shifts from the land use to population density. Although population density indicator gives relatively good general information about the character of the city, it is not an unambiguous or easily interpretable concept. In most cases this indicator 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 (Frey, 1999; Masnavi, 2000). This traditional figure is very sensitive to the size of the city (Buckwalter & Rugg, 1986) and one must be cautious when comparing the net population densities in various cities, since the administrative areas of cities vary so considerably. To overcome this problem we have estimated the 'residential density', calculated by distributing the total population to the area occupied by residential housing.

The *fifth indicator set* focuses on how the population occupies the available built-up space. 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 database contains detailed land use and transport network data at the scale of 1:25 000 of more than 50 urban areas in Europe (EEA & JRC, 2002). They have been recorded at four dates: mid-1950s, late 1960s, mid-1980s and late 1990s and complemented by population data in order to widen analysis possibilities.

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.

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	351,000	770,000	119.4	Spain
Bratislava	432	184,000	450,000	144.6	Slovak Republic
Brussels	1301	1,275,000	1,642,000	28.8	Belgium
Copenhagen	648	1,038,000	1,232,000	18.7	Denmark
Dresden	1240	871,000	789,000	-9.4	Germany
Dublin	659	637,000	1,000,000	57.0	Ireland
Helsinki	790	407,000	932,000	129.0	Finland
Lyon	302	770,000	1,030,000	33.8	France
Milan	322	1,533,000	1,800,000	17.4	Italy
Munich	791	1,127,541	1,680,000	49.0	Germany
Palermo	223	535,000	739,000	38.1	Italy
Porto	193	544,000	671,000	23.3	Portugal
Prague	788	1,022,000	1,270,000	24.3	Czech Republic
Tallinn	1048	287,000	482,000	67.9	Estonia
Vienna	822	1,706,000	1,648,000	-3.4	Austria

Table 2: Basic information on the studied urban areas.

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.

In the MOLAND database in order to avoid this difficulty urban areas have been delimitated by using as a starting point the continuous built-up area (A) in the late 1990s. This area has been buffered, 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. For example in Milan the buffer is dominated by built-up areas, in Bratislava it is clearly dominated by natural and agricultural areas and the built-up areas are fairly scattered (Figure 1). Therefore 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. This study tried to use as little absolute indicators as possible to avoid comparability problems.

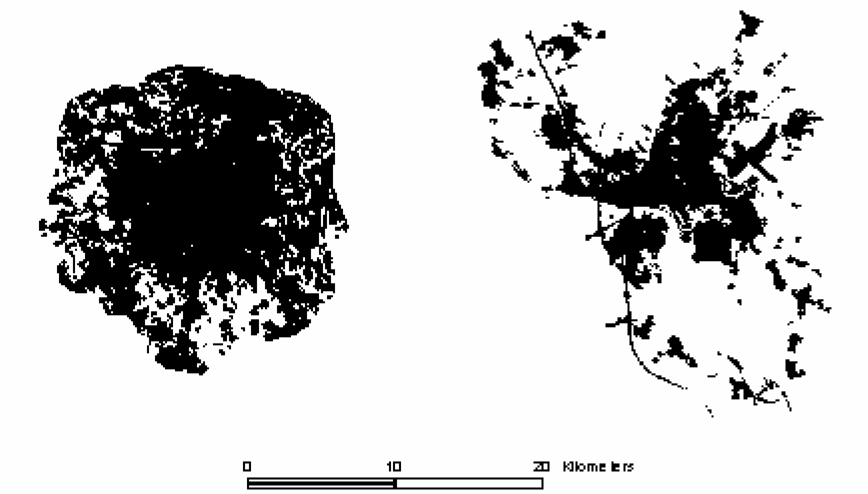

Figure 1: Built-up areas (in black) in Milan, Italy and Bratislava, the Slovak Republic in the late 1990s.

3. Results

3.1. Indicator set: Built-up areas

The ratio between built-up[2] and un-built areas gives a fairly good overall image of the character of the city. As Figure 2 shows in most studied cities between 30 and 40 percent 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%. On the basis of the available data it is clear that the core areas of Southern European cities are surrounded by very dense 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 (Cheshire, 1995; Dura-Guimera, 2003; Munoz, 2003).

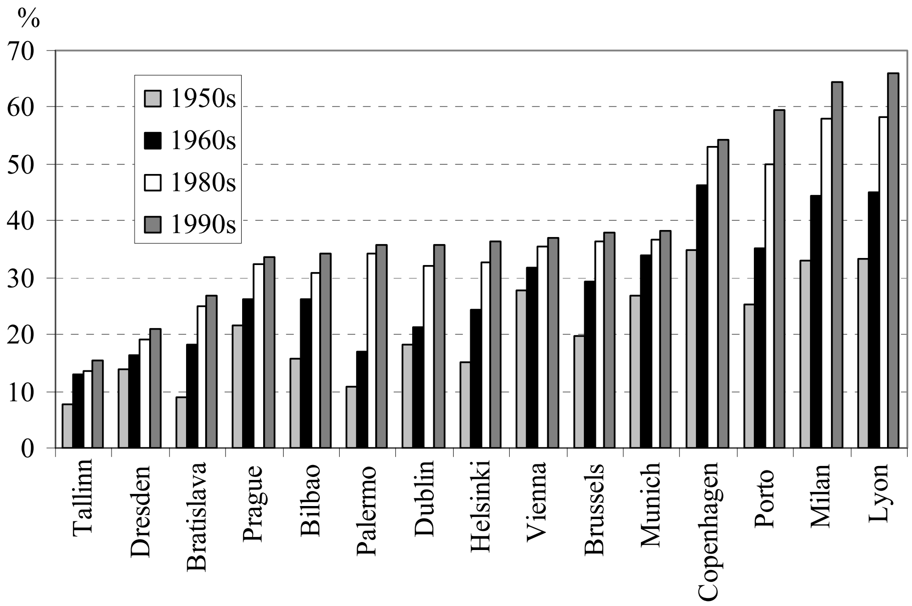

Figure 2: Percentage of built-up areas in the studied cities in mid-1950s, late 1960s, mid-1980s and late 1990s.

In order to analyse more thoroughly the growth pattern, in Figure 3 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.

[2] 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.

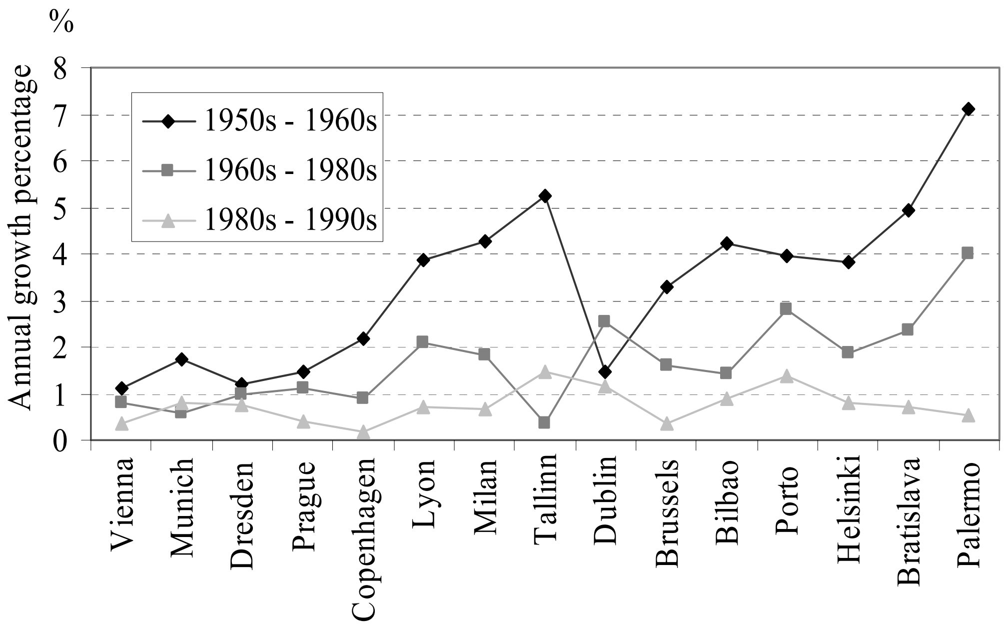

Figure 3: Annual growth percentages of built-up areas in the studied cities from the mid-1950s to the late 1990s.

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 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. 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.

During the study period both residential and industrial-commercial-transport land use classes have grown rapidly (Figure 4). In all cities except Dublin and Palermo the average growth rate for industrial-commercial-transport is the double if compared to the growth of residential land use. The most rapid growth 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.

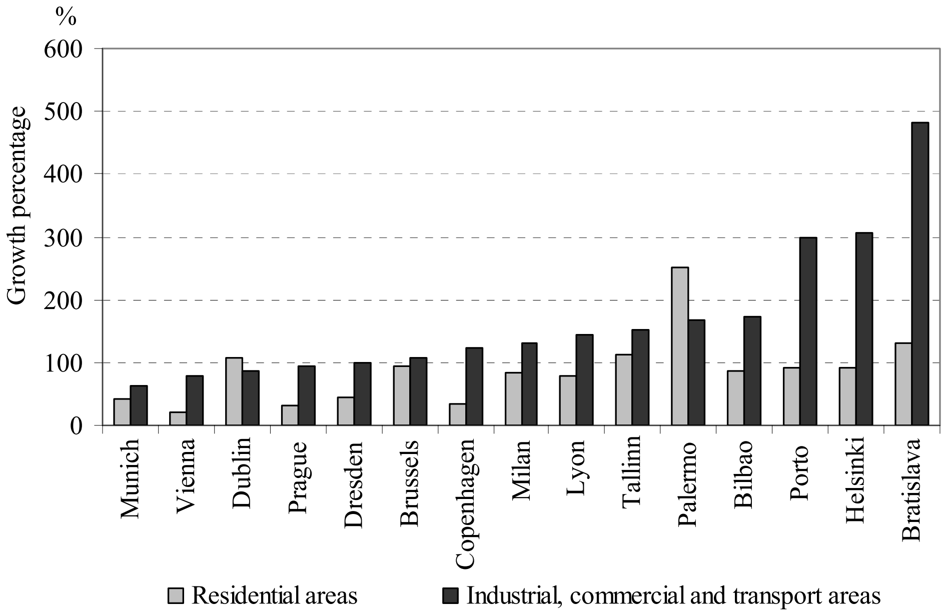

Figure 4: The growth rate of residential areas and industrial-commercial-transport areas in the studied cities from the mid-1950s to the late 1990s.

Another interesting indicator characterizing urban landscape is the land use intensity of residential areas. By intensity we refer to the degree to which the built structures cover the available land. 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%.

Figure 5 shows the percentage of continuous residential land of all residential land. The studied cities are indeed very diverse: Palermo is without comparison in its compactness, almost 90% of all residential areas are continuous. At the other end are Dublin, Dresden, Brussels, Helsinki and Copenhagen where 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 much less continuous, dotted by gardens and small parks.

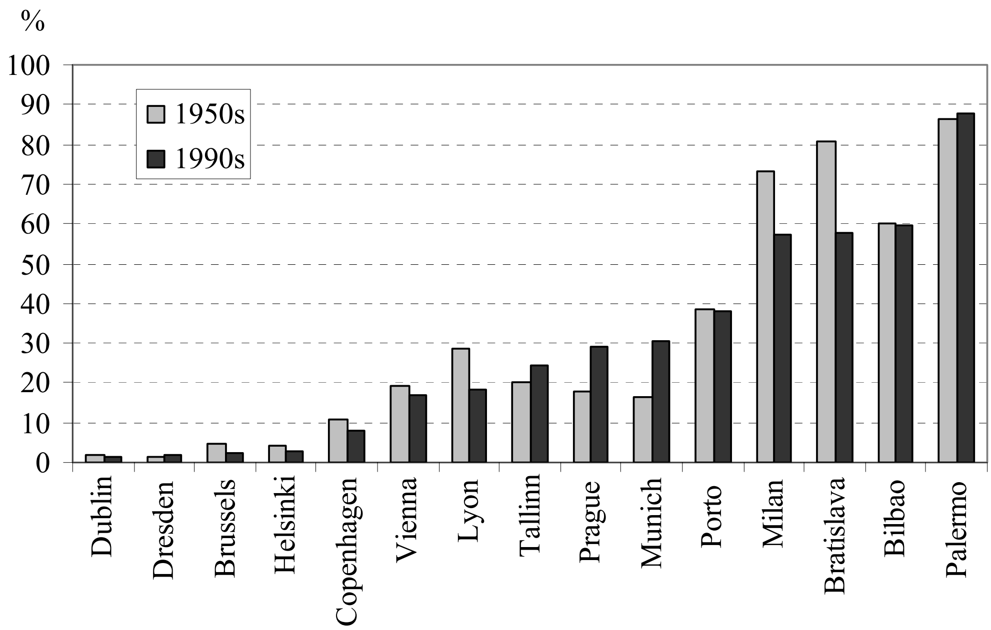

Figure 5: Proportion of continuous (buildings and related structures cover more than 80% of the surface) residential areas of all residential areas in the studied cities in the mid-1950s and in the late 1990s.

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 (Figure 6). In all other cities the growth of 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).

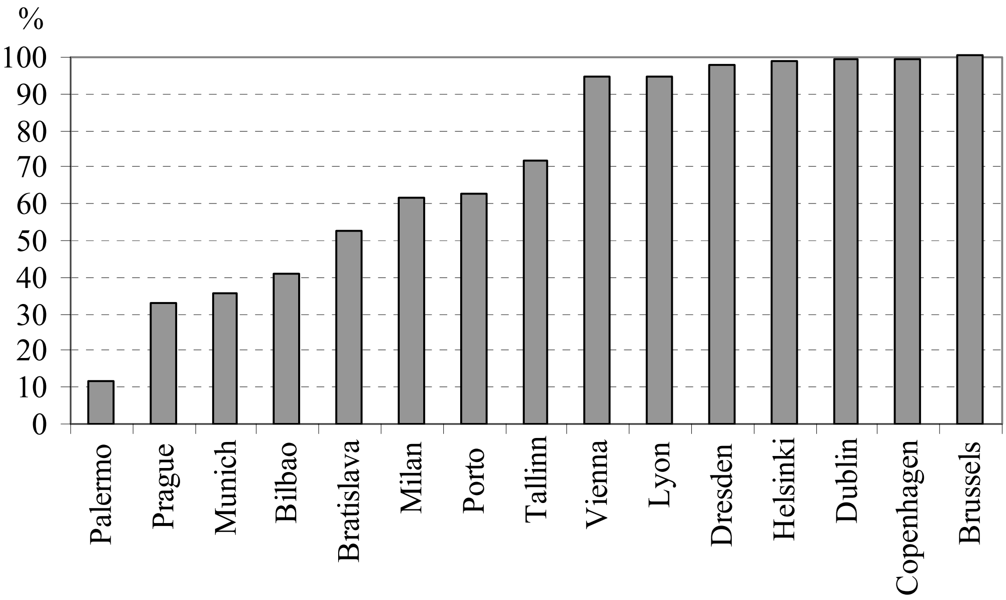

Figure 6: Share of discontinuous residential areas of all residential areas built after the mid-1950s in the studied urban areas.

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 doesn't seem to have reached yet the land use dynamics. Making cities more compact has already for a while been at the top of national (Williams, 2000) and European policy agendas (CEC, 1990; CEC 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 area grows, other land uses are on the losing end. It is interesting to note that in most cities the growth of the built-up area has taken place mostly on previous agricultural land (Figure 7). Only in Helsinki and 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 Figure 6. 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).

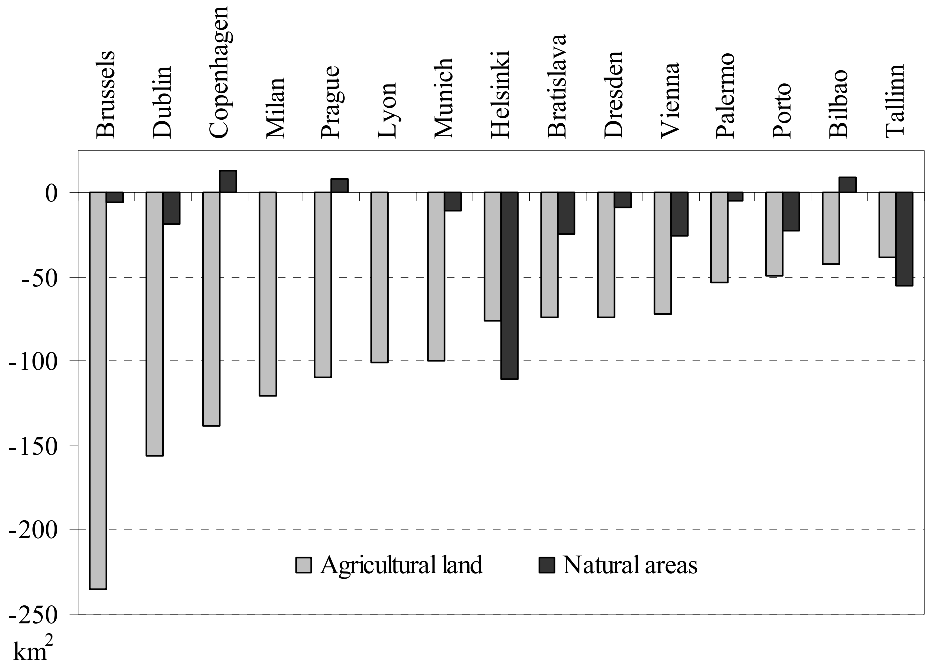

Figure 7: Natural and agricultural land (in km2) lost due to urban development in the studied cities between the mid-1950s and the late 1990s. (NB. The sizes of studied areas vary, see table 2).

3.4. Indicator: Urban 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.

The net population density (inhabitants/area) is an indicator very sensitive to the size of the city, therefore it 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 5,000 and 10,000 inhabitants per residential km^2 (Figure 8). 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 observation period. The drop has been remarkably big in the studied Italian cities: in Palermo the residential density has decreased by 60 % (from 30,000 to 12,000) and in Milan by 36 % (from 25,000 to 16,000).

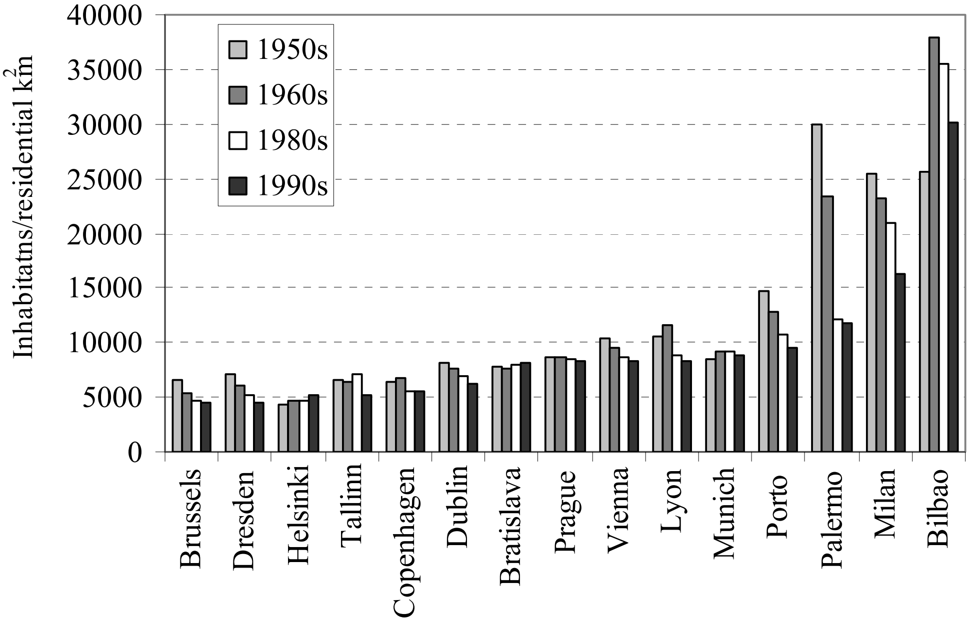

Figure 8: The residential population density in the studied European cities from the mid-1950s to the late 1990s (measured as inhabitants per residential km2).

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 blocs, which are predominant in city centres.

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). Residential density refers to land use: it indicates how much land is used to provide the citizens with housing while housing density refers to the availability of floor space per inhabitant.

3.5. Indicator: Population in the built-up space

The population data has been cross-tabled with the growth rate of built-up areas. In the resulting scattergram (Figure 9), 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.

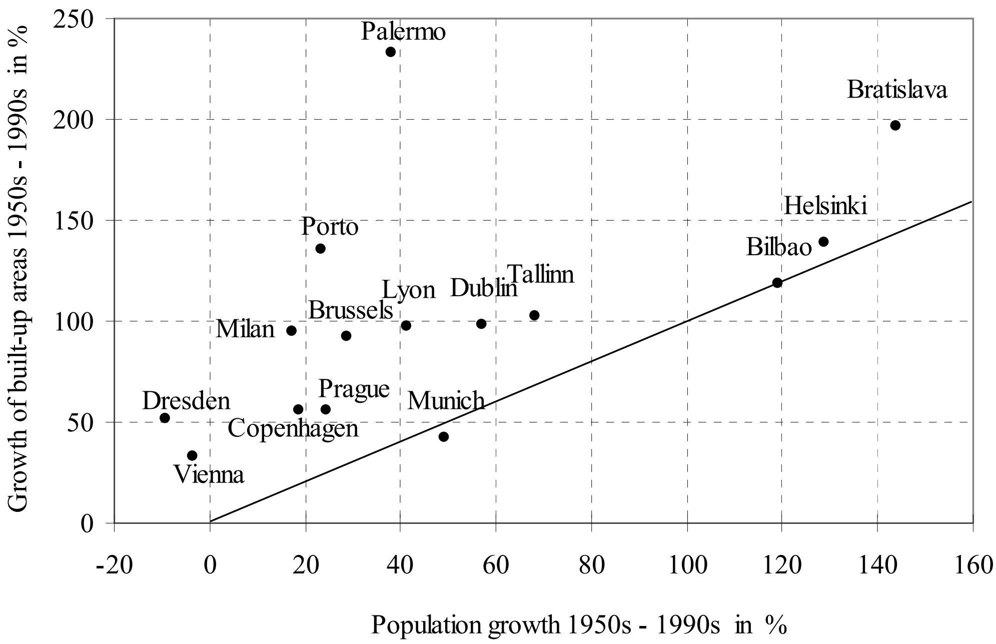

Figure 9: A comparative perspective into the population growth and growth of built-up areas in the studied cities from the mid-1950s to the late 1990s.

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 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.).

Analysing the availability of built-up area per person, the results are not surprising (Figure 10). In the cities in Southern Europe, the built-up area per person is much smaller than elsewhere. The trend seems to be the further north you go, the more built-up areas per person there are in urban areas. In the 1950s, in the most 'spacious' city, Helsinki, there was almost 7 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 big.

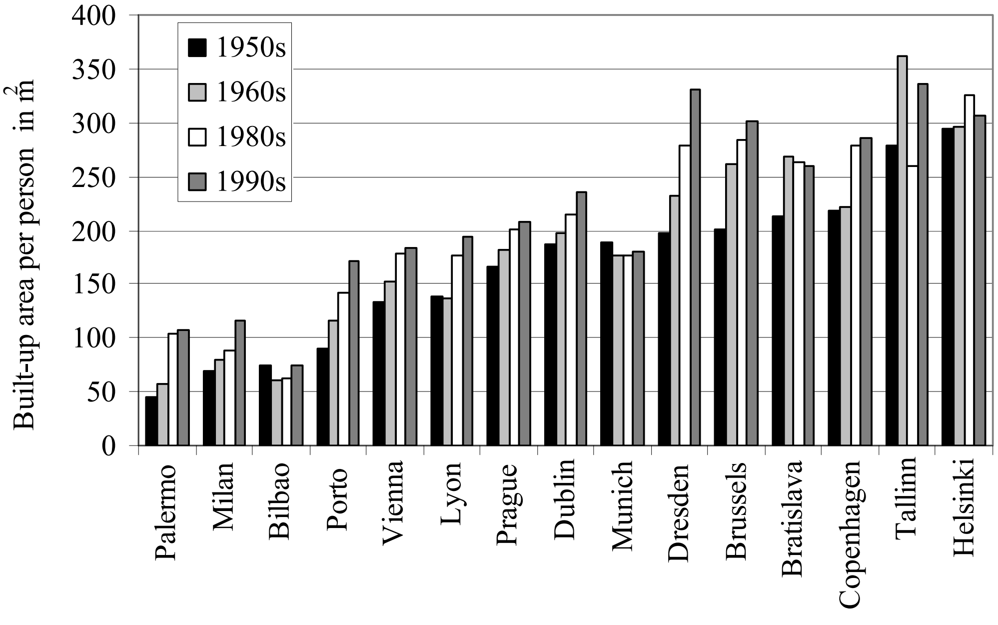

Figure 10: Available built-up area per person in m^2 in the mid-1950s, late 1960s, mid-1980s and late 1990s in the studied cities.

4. Discussion

In the light of the presented analysis, it is clear that European cities are very different from the point of view of population densities and land use patterns. However development dynamics among the studied European cities are converging: the built-up areas have grown rapidly in all studied cities from 1950s to 1960s, afterwards the annual growth rate has slowed down and the gap in growth paces between various cities has narrowed.

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 inhabitant 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 the compactness of urban structures and population densities are not always parallel to each other, and where the individual cities are changing positions in time.

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 inhabitant 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.

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 20^{th} 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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