CHANGING LAND USE DYNAMICS IN EASTERN EUROPEAN CITIES

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ABSTRACT

The objective of this work is to analyse and model urban growth dynamics of Eastern European cities and regions in the past and in the new Europe. This work is a part of the on-going research in the field of urban and regional development, carried out in the Joint Research Centre (JRC) of the European Commission.

After the collapse of communist regimes cities and regions in Eastern and Central Europe have entered into a new phase of urbanisation, which has changed dramatically land use patterns. The liberalization of economy and the membership in the EU have led to the growing impact of the European market and EU development schemes (e.g. TEN/T, ERDF, etc.). The continuous growth of urban areas is one of the major socio-economic consequences of this development. What shapes urban sprawl will take and will it cause new threads to sustainability remains to be seen.

In this paper we focus on the Dresden – Prague transport corridor in Germany and in the Czech Republic. The MOLAND urban and regional growth simulation model, which is based on "cellular automata" (CA), is the key instrument in forecasting land use development. This model allowed us to integrate urban land use patterns with environmental, socio-economic and institutional aspects of territorial development. The impact of diverse socio-economic trends was simulated through several scenarios in order to model the spatial pattern of urban land use. The scenarios offer a useful approach to analysing and understanding urban land use dynamics and they can also support landscape management at the local and regional scales, complementing existing policies and programmes.

Key words: urban sprawl, regional development, modelling of development scenarios.

INTRODUCTION

SETTING UP THE STAGE

Eastern European cities experienced similar and very turbulent historical and political development during the 20th century. It was clearly shown in Kasanko et al. (in press) that after the WWII the expansion of urban areas in medium-sized European cities reached the peak in the 50's and the 60's and it slowed down towards the end of the century. Although the urban expansion has been comparable in Western and Eastern European cities, the driving forces are different (Table 1). After the communist regimes where established the political efforts towards continuous industrialization of economy and centralisation of agricultural production in collective farms led to high urbanization of population in the Eastern block. In our study cases percentage of people living in the cities reached 75% in the mid 80's. The policies during the communist period with planned economy have clearly been reflected in the land use pattern development with large industrial sites and districts of block houses. In contrast to Western European cities, extent suburbs and satellite cities were built only on a limited scale. In addition, no or very few commercial zones and commercial centres were built in suburban areas and transport network around cities was much less developed. Main features of suburbanisation in the 80's were continuing flow from centres to periphery, since in Western Europe population moved out from the cities. On the other hand, in the Eastern block suburbanisation was connected to a great extent to the development of big collective agricultural units which in addition to agricultural production included technical infrastructures, services and compact residential areas.

Table 1. Main driving forces for urban development

From the 50s to the 90's	From the 90's up to present
Economy	
• Planning economy • Emphasis on heavy industry and mining	• Market economy • Foreign investments • Emphasis on modern high-tech industries, commerce and services • Construction boom
Population/urbanization	
• Slowing population growth since the 70's • Migration to the cities due to industrialisation	• Decrease and ageing of population • Migration of rural population into the cities compensates natural decrease of population in cities • Emigration to the Western Europe for better jobs (Saxony)
Housing and planning policy	
• Limited market for residential and land properties • Land price was not considered in planning process, dominance of political decisions • Construction of vast areas of block houses for industry workers (especially CZ)	• Open market for residential and land properties • Private sector interests competing with public interests in planning process • Low land prices outside cities and people's preference to move in one-family houses
Infrastructure	
• Emphasis on public transport and rails	• Growing importance of motorways

With the collapse of communist regimes cities and regions in Eastern Europe have entered into a new phase of urbanisation, which has changed dramatically land use patterns. The adaptation into the market economy caused many dramatic changes in traditional economic structures, decrease in GDP and a high rate of unemployment. Towards the end of 90's gradual but sustainable recovery of the economy started and political and social reforms took place. The membership in the EU has led to the growing involvement in the European market and EU development schemes (e.g. TEN/T, ERDF, etc.). In spite of the expected decrease of population in the new EU countries the average gross domestic product is projected to triple and the number of households is projected to double between 2000 and 2030 (EEA, 2005/4). All these changes have created completely new driving forces for urban development (Table 1). At the very moment when political and economical reforms are mostly completed, their manifestation in urban landscape pattern has just only started to take its shape. It is a question of the forthcoming decades if the new developments will be environmentally sustainable.

MOLAND DATA

Urban and regional cases discussed in this paper have been mapped in the frame of MURBANDY/MOLAND[1] project applying methodology and legend especially designed to meet requirements of urban studies.

[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 European policies. At the moment it contains more than 50 urban areas and four larger regions. The data is derived from very-high resolution satellite images and for historical dates mainly from aerial photos. For more information, visit the website http://moland.jrc.it/

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). The data has also a temporal dimension. The land use data have been recorded for most areas at four dates: mid-1950s, late 1960s, mid-1980s and late 1990s. Land use information has been complemented by population data in order to widen analysis possibilities.

The data is derived mainly from very-high resolution satellite images (such as IRS images with 5.8m 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 the 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

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 territories included into the current analysis are the city of Dresden (480 000 inhabitants, 2004) and its agglomeration (800 000 inhabitants), the city of Prague (1 172 000 inhabitants, 2005) and the transport corridor connecting them. The corridor is defined by the motorway D8 (CZ)/ A17 (D), which is part of the Trans-European Network (TEN) Corridor IV. (Kasanko et al, 2003)

METHODS

EXAMINE PAST TRENDS - URBAN GROWTH INDICATORS

A set of urban and use and population indicators has been created as part of the MOLAND project (Kasanko et al, in press). The full set comprises 13 indicators. So far it has been applied to more than 20 urban areas in Europe. For the purpose of this study a subset of 6 indicators was selected.

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 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.

MODELLING THE FUTURE - MOLAND MODEL APPLICATION

In order to facilitate the forecast of urban land use dynamics, we used urban development scenarios generated by means of a cellular automata (CA)-based spatial model, named MOLAND model (Barredo et al., 2003, Lavalle et al., 2004). The model consists of "cells" which represent continuous space and can evolve from one "state" to another according to "spatial transitional rules". The model operates at two levels. At the microlevel, the CA-based model determines the state of individual cells based on the type of the activities in their neighbourhood. Unlike conventional CA, this model is defined with large neighbourhoods and more cell states representing built-up land uses and natural land cover (Barredo et al., 2003). At the macrolevel, various additional factors such as overall land use demand, effects of the transportation network as well as legislative, environmental and institutional characteristics (e.g. environmental protection, zoning) constrain the behaviour of the CA-model. This approach allowed us to integrate '"physical", environmental as well as institutional aspect of territorial development.

The model requires as input digital maps of actual and historical land use, accessibility maps derived from the transportation network, and maps of inherent suitability for different land use states. Optionally, if available, zoning status (i.e. legal constraints) and socio-economic (e.g. population, income, production, employment) variables are used to fine-tune the model.

Two steps of modelling process are required: (1) Calibration of the model by means of defining appropriate values for each cell's transitional rules, and (2) Simulation of future development for the scenario-period. For model calibration historical and reference land use/land cover maps are used. They are reclassified into land use 'states' of three types - "active" urban classes which participate in urban expansion; "vacant" land uses, representing areas where expansion takes place, such as agricultural and natural land; and "fixed" classes where development is restricted. Statistics of changes obtained for different land use in calibration period served as basis for land use demand at micro model level. Different transitional rules are tested in order to reach as similar as possible urban pattern as occurred in reference data set. Model calibration is interactive process where understanding land cover dynamics plays a central role. At this stage the analysis of land use indicators helps to balance different model components. The resulting maps of the calibrated model were compared with the actual land use from reference data set. They were tested by using accuracy analyses - firstly by statistical and then by spatial metrics (Engelen, 2004).

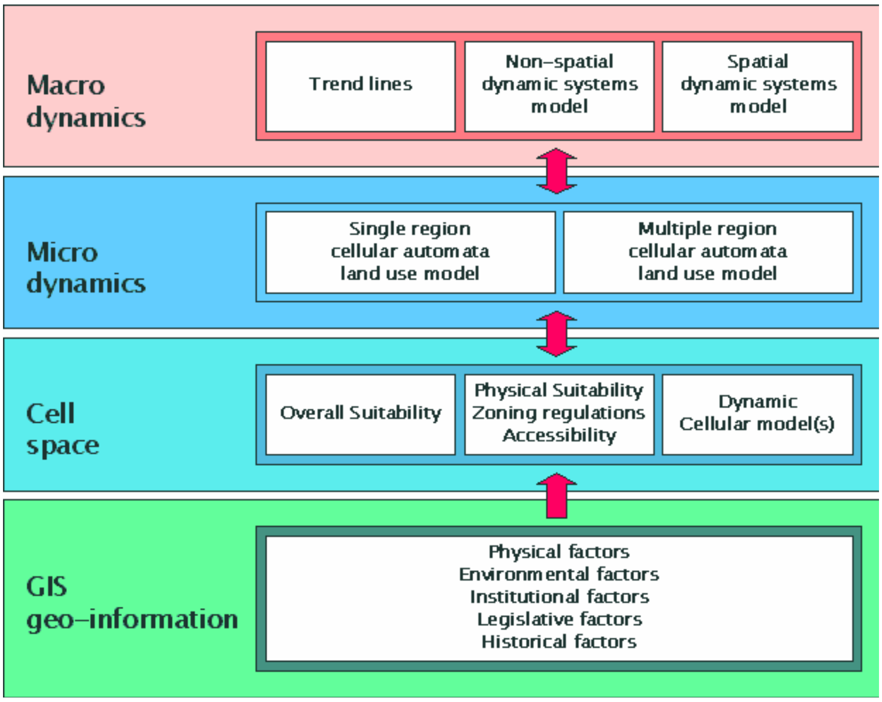

Figure 1. Scheme showing the role of cellular automata land-use model's core elements linking socio-economic and environmental developments operating at different geographical scales in the MOLAND model. Source: Lavalle et al., 2004

Model parameters defined in the calibration process are used for simulating the development scenarios. Main lines of how land use can evolve in the future are obtained from general econometric scenarios through selected key drivers. Among such drivers are policies and socio-economic conditions which are translated into residential, industrial and commercial land demands. Demographical projections and changes in housing preferences also play an important role. On the other hand, increase in mobility and accessibility are vital elements for the development of different land use classes. All mentioned key drivers can be transformed into model parameters. By re-enforcement of one of the model's main components -land demand, accessibility, neighbourhood effect, suitability or stochastic parameters - alternatives of future landscape development can be simulated in order to visualise and evaluate impacts of different drivers.

RESULTS

PAST DEVELOPMENT TRENDS

The city of Dresden (480000 inhabitants, 2004) and its agglomeration (ca 800 000 inhabitants) are classical examples of historically developed multi-central urban pattern. It is also a part of the metropolitan area of the Saxon Triangle with a population of 3.2 millions. Dresden is surrounded by four major municipalities - Pirna, Coswig, Radebeul and Frietal- all of which have a population higher than 25 000. Population density in Saxonian rural municipalities is also quite high (150-200 inhabitants/km^2). City itself, unlike many large German cities, which normally have a clearly defined inner city, has several important centres of economic and social activity which are spread into the different parts of the city. In contrary the city of Prague is an example of mono-centric development. With 1 170 000 inhabitants it dominates over the Central Bohemian Region. The average size of its closest satellites – Ricani, Brandys nad Laben, Kralupy– is a little bit over 15 000 inhabitants.

Figure 2 shows changes in urban pattern for agglomeration of Dresden and the city of Prague from the 50's to the late 90's. In terms of built-up area growth rate for overall after-WWII period was moderate for both cities – 39% for Dresden and 50% for Prague – and is comparable with such cities as Munich and Copenhagen (Kasanko et al, in press).

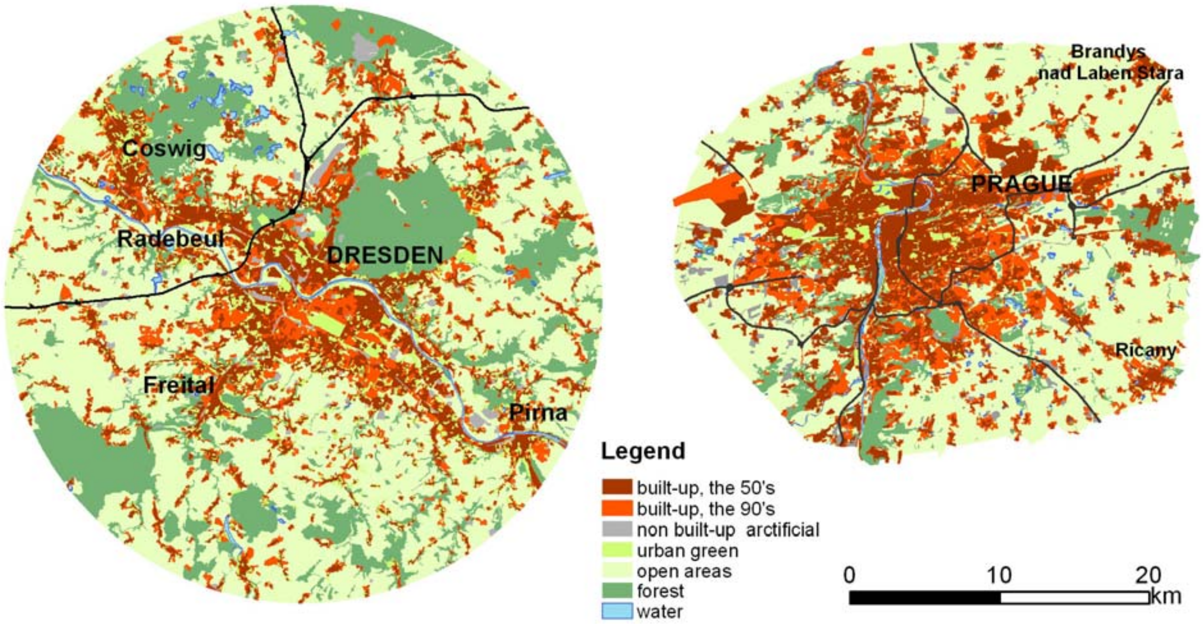

Figure 2 Changes in urban pattern for agglomeration of Dresden and the city of Prague from the 50's to the late 90's

In case of Dresden the main urban development inherits its pattern from times when navigable River Elbe was the main development axis. It is located in the widening of the Elbe valley, bounded by 200 meter high hills. By comparing the extent of built-up area in the 50's and 90's one can clearly see how different urban clusters have grown together within the past 50 years. The development has been influenced by main roads and rails passing through old urban centres. Annual growth rate was mainly constant, around 2.0 km per year for the overall period (Table 1). It is surprising that built-up areas continued to grow at the same speed also in the 80's and 90's although the population of the region declined considerably in that period. In the course of political and economic transformation since 1989 the city lost over 70% of its industrial employment which caused a 10% population decline (IÖR, 1997). Immigration to the Western Germany for better job opportunities led to considerable ageing of population. On the other hand, the city of Dresden as all Eastern Germany started to benefit from public programmes and investments to the economic and residential sector. (Arving and Herfert, 2001).

Table 2. Annual growth of built-up areas in km^2 in the studied cities. (NB: the figure indicates the average yearly growth)

	1950s-1960s	1960s-1980s	1980's-1990's
Dresden	2.1	2.0	1.9
Prague	2.5	2.3	1.1

The historical core of Prague was formed long time before the period under investigation and is characterised by high density of built-up areas. During the last 50 years urban growth has moved from the centre towards peripheries over predominantly agricultural landscapes of valley of river Vltava and its tributaries. The capital status has helped the city to gain population even during the years of transitional period (Sykora & Ourednicek, 2006; Kupková, 2002). Employment in industry dropped by almost half, whereas the service sector grew and currently accounts for 75% of employment. But in spite of this fact, last decades are characterised by considerable slowing of urbanisation pace for the city of Prague (Table 2) –'wait-and-see' attitude and low investments in construction are the main features of the beginning of the 90's. The recent construction boom in the districts of Smíchov, Karlín and some suburban areas speaks for the start of a new urbanization phase.

Besides of their historical value the cities of Dresden and Prague were advanced industrial cities before the WWII and successfully continued in this status during second part of 20th century due to communist policy towards industrialization of economy.

When entering in a more detailed way into the development of urban areas in Dresden and Prague, one can find a lot of similarities but also differences. Both cities have almost doubled the size of the built-up area since the mid-1950's (Table 3). Urban landscape is quite similar in that respect that residential areas form from 58 % (Prague) to 67 % (Dresden) of all built-up areas. Since the mid-50's in both cities industrial, commercial and transport areas have almost doubled their size and residential areas have grown on a more moderate pace.

The main difference between Dresden and Prague is the denseness of residential areas. In Prague the continuous residential areas cover one fourth of all residential areas and in Dresden almost all residential areas are discontinuous, less densely built. One third of new residential areas built after the mid-50s are continuous in Prague which is also on European scale a very high figure (Kasanko et al, in press).

Table 3. Urban growth indicators

Indicators		1950's	1990's	1950's-1990's
Overall growth of built-up area, %				
	Dresden			39
	Prague			50
Ratio of residential areas / other built-up (combined industrial-commercial-transport), %				
	Dresden		67/27	
	Prague		58/34	
Growth of residential areas / other built-up area, %				
	Dresden			44/99
	Prague			30/95
Proportion of continuous residential areas, %				
	Dresden	2	2	
	Prague	18	25	
Share of new discontinuous residential areas				
	Dresden			98
	Prague			33

The development of motorway D8/A17 connecting two cities was decided and planned a long time ago, but the construction started only in the late 90's with partial financing from the EU funds. From Prague to Ustin-nad-Laben (CZ) it follows mainly already existing roads, which already existed. The fact that in Northern Bohemia (CZ) and in Saxony (D) motorway line is a newly constructed road raised many environmental debates in both countries. The biggest urban settlements in the D8/A17 corridor are located in Northern Bohemian Basin. Cities of Teplice

(52 000), Usti nad Laben (97 000) and Decin (53 000) are industrial centres, the development of which has been for centuries strongly connected to the nearby brown coal mines and navigable commerce along River Elbe. Built-up area growth rate of 6% for period 1980's-1990's shows dynamic evolution around the cities of Northern Bohemia. New residential and industrial areas have been also built. The growth of commercial sites (33%) has taken mainly place in towns' centres and outskirts, which demonstrate slow expansion and re-structuring of urban space.

FUTURE DEVELOPMENT ALTERNATIVES

For Dresden-Prague study case historical (1986/1989) and reference (1998/2000) land use maps were used, so the calibration period is approximately 12 years. Due to complicated economical and demographical background and differences in the policies in the simulation period the trends of land use evolution were very controversial and did not occur at the same rate during calibration period. For each scenario the simulation was made for a 20 years period from 2000 to 2020. Three different land use scenarios were developed.

The 'Business-as-usual' scenario is based on moderate growth. It continues trends observed during calibration period and can be taken as urban development baseline. In addition, two alternative scenarios –'Built-up expansion' and 'Motorway impact' – explore the development alternatives brought by more dynamic socio-economic development. The reunification of Germany and adhesion of the Czech Republic to the EU led to growing involvement in the European Market. Socio-economic reforms are mostly finished and the basis for sustainable economic growth is established. New investment perspectives have opened and the area also benefits from EU Cohesion and Structural funds. So the 'built-up expansion' scenario elaborates the socio-economic projections of the European Environment Agency (EEA, 2005). On average for new EU countries (EU-10) the gross domestic product expected to triple and the number of households is projected to double between 2000 and 2030. But in contrary to the economic growth the demographic trends for EU-10 will show dramatic decrease of 7% during the same period.

Figure 3 presents the simulation results for all three scenarios. In '**Business-as-usual**' scenario the land demands develop according to the trends of late 90's. Industrial land use is not foreseen to grow in the area and in fact, abandoned vast industrial lots can be re-developed and used by new commercial and service activities. The importance of motorway and — accessibility to certain land use classes such as industry and commerce — has not increased yet considerably. As a result (Figure 3.A), the land use pattern of the cities will not change dramatically. Development in the two main cities occurs on the outskirts of the cities where moderate residential development takes place. Industrial and commercial activities move from the core areas to more peripheral areas. In Dresden de-centralisation and in case of Prague edge-development types of urban expansion can be found. Minor urban developments can be spotted around the cities of Northern Bohemia. In predominantly rural countryside the striking feature is the absence of changes.

In '**Built-up expansion'** scenario (Figure 3.B) we assumed that economic growth results in 50% growth of demand for low and medium dense residential land. For commerce and services the land demand even doubles and importance of fast transit links grows. As a result in old core centres new development gradually turns to the appearance of commercial and service clusters. Around Dresden new residential districts are adjacent to the existing ones and process of melting together of former clusters continues. Hand-by-hand with projected population decline it leads us to conclusion that urban growth will be mostly characterised by term 'sprawl' which indicated the growth of low density residential areas. The simulation results for Prague show a very different, more clustered and compact type of development. New urban clusters start to grow around old villages or along the transport links. Growing building activity on the outskirts of big and medium size cities stimulates also an increase in commerce and services land uses. Development in rural areas remains moderate.

In '**Motorway scenario'** construction of the new motorway A17 which goes around the city of Dresden from west to south becomes a new development axis for commercial and industrial areas. On the other hand, the radial network of motorways around Prague connecting it to different destinations does not allow us to conclude the central role of D8 motorway in land use pattern change – all of them attract the development of commercial zones and produce more clustered pattern. The municipalities located in direct vicinity of Prague experience intensive residential development and hence it can be assumed that high pressure and demand for new housing will remain strong. But further to the north the particular impact of D8 motorway can be seen around municipalities of Neratovici and Kralupy nad Vltava.

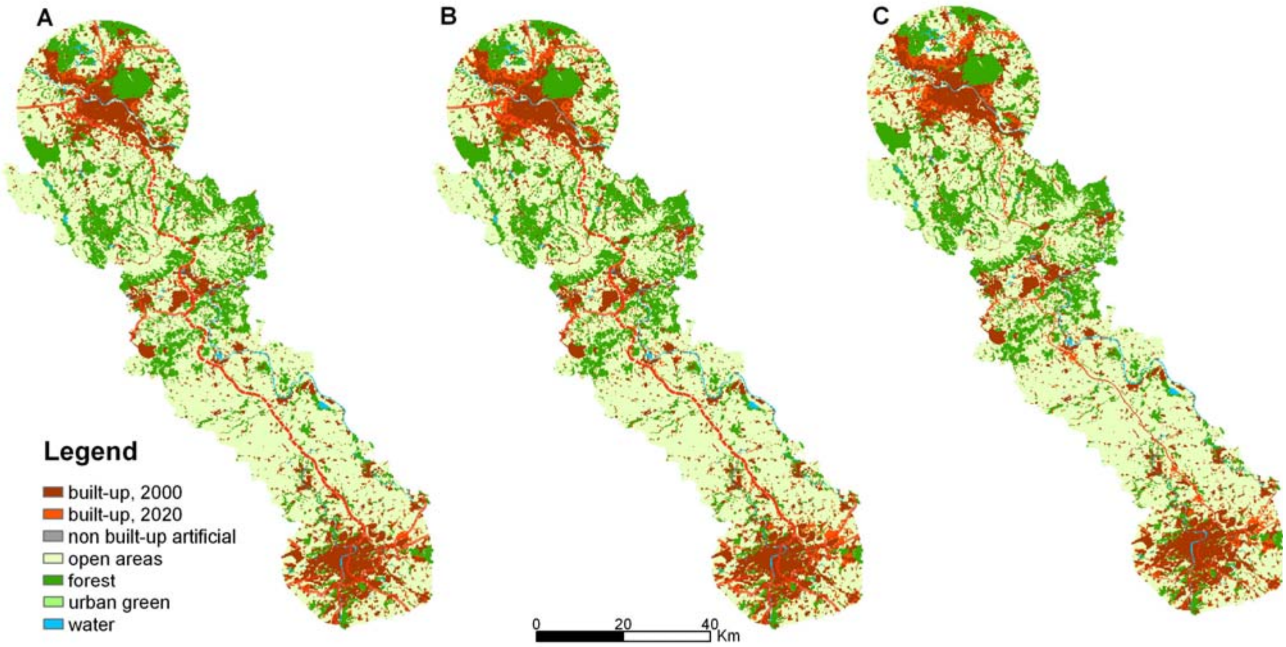

Figure 3. Scenarios of urban land use development for the corridor Dresden-Prague. A – 'Business as usual' scenario shows a moderate urban growth according to trends of the 90's . Scenarios B (Built-up expansion scenario) and C (Motorway impact scenario) are examples of more intensive development. In the scenario C the role of the motorway is reinforced.

A minor urban development can be seen around the industrial towns of Northern Bohemia (Teplice, Usti nad Labem and Decin) in the central part of motorway corridor. No major changes are foreseen in predominantly rural countryside where decrease of population and economic activities are likely to take place ('Build-up expansion' scenarios). Despite that the motorway A17/D8 can reinforce regional development and can lead to the setting up of commercial and service sites in the surroundings of bigger settlements and towns. However the positive regional development still highly depends on the general economic situation and how economic growth will be distributed between centre and peripheries.

COSTS OF URBAN GROWTH

Urban development is not an isolated process – it gets impulses from population and economic trends and sends its feedbacks further to people and the environment. Alongside with positive changes in living standards and mobility towards more prospering society we may face with negative byproducts of progress. Thus if we have a tool to evaluate alternatives of land use development, we can estimate its consequences in number in various contexts.

The urban expansion always consumes land which is a finite resource. In most cases the growth of built-up area takes place mostly over previously agricultural land, and cities of Dresden and Prague are not exceptions. Figure 4 illustrates these processes in the last decades and their probable extent according to land use simulation. It can be seen that main pressure will remain on agricultural and natural areas around cities.

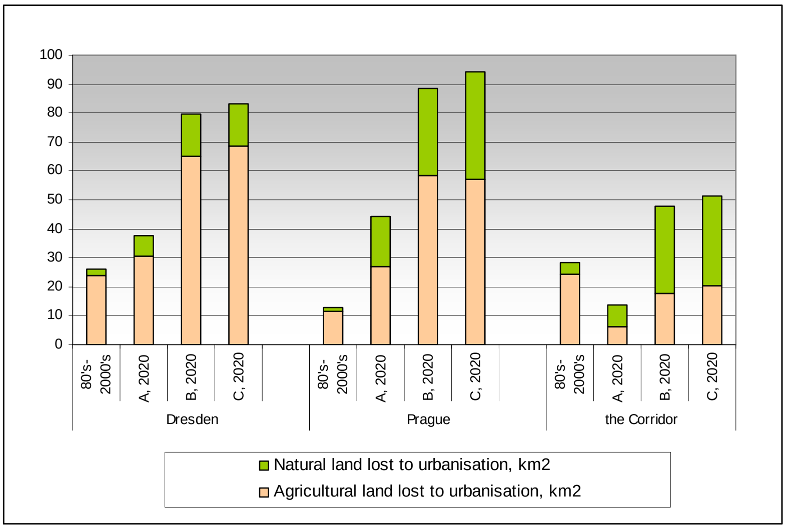

Figure 4. Land lost to urbanization. A –'Business as usual' scenario shows a moderate urban growth according to the trends of the 90's. Scenarios B (Built-up expansion scenario) and C (Motorway impact scenario) are examples of more intensive development. In the scenario C the role of the motorway is reinforced.

One of the most important geographical features in the region are Elbe and Moldau rivers. Due to the fact that both rivers are navigable, they have always been very important transport routes and main development axes. However, those rivers represent also a threat in form of floods for settlements located on the flood plain. In August of 2002 and in April of 2006 severe floods hit the area. Demographic and socio-economic trends manifesting them-selves in urban sprawl play a key role in increasing the society's exposure to flood damage. The modeling of urban dynamics allows us to represent spatially these components of risk. The results of above-mentioned analysis were used in hazard risk assessment study (Genovese, 2006) together with potential flood hazard maps generated by LISFLOOD[2] model (De Roo, 2002, Barredo et al., 2005). The study shows that beside more frequent extreme flood events urban sprawl contributes considerably to increase of net damages (Figure 5).

[2] *http://natural-hazards.jrc.it/activities_lisflood.html*

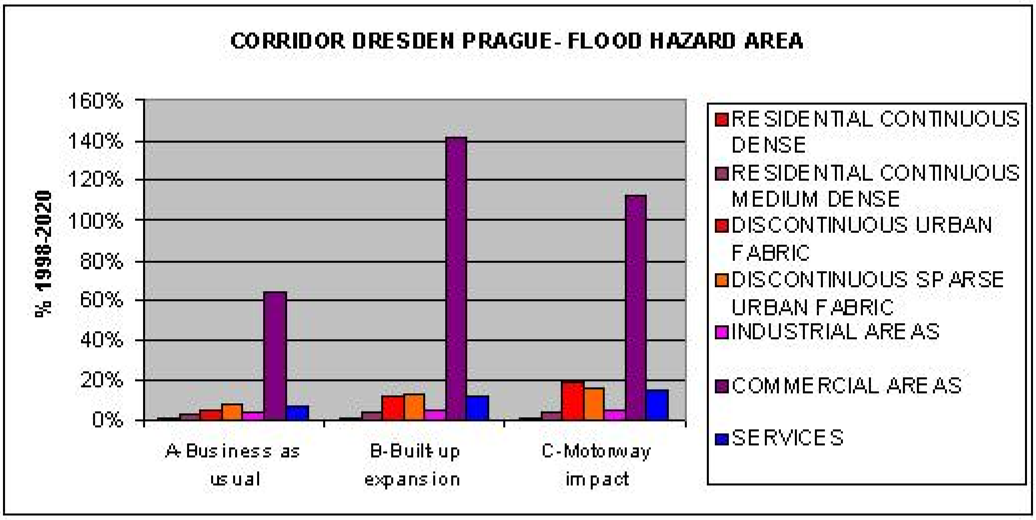

Figure 5. Built-up areas exposed to floods on the basis of three growth scenarios in the period 2000-2020. Changes are in percentage. Source: Genovese, 2006

In case of moderate growth (A scenario) built-up in flood hazard areas is expected to rise by 11 km^2 in the future; but following the B and the C scenario, it can increase from 21 km^2 to the maximum value of 24 km^2. Total residential growth trend, which is estimated in a new urban area exposed to floods equal to can double. Higher damages can also be expected in newly constructed commercial and services in potential hazard zones. In particular the commercial areas grew more than three times bigger than in the historical period and it will very likely lead to high damage expectations for businesses. Consequently, the reduction of urban areas in this hazard zone should focus here in planning and adaptation measures.

CONCLUSIONS

Analysing and understanding urban land use dynamics is an extremely challenging task even in one urban agglomeration not to mention at national or European level. As European cities are very diverse in terms of compactness and land use patterns, the approach of indicators shows us that there are doubtless some common trends. This comparative study shed light on general development of two cities in the Centre of Europe where similar history and current trends have produced completely different spatial patterns. We were looking for answers to the question how similar or different the future developments of Dresden and Prague will be. The three scenarios show that urbanisation in the Dresden-Prague corridor area will most likely take place around the main cities. In case of Dresden, a spread and diffuse development style can contribute to real urban sprawl. Around Prague, a more concentrated and clustered urban pattern is devised. The influence of transport network will be higher in the immediate vicinity of the developed centres then in predominantly rural areas. The role of motorway A17/D8 as new development axis can reinforce the urban development in countryside, but real changes will strongly depend on general economic situation and/or special policies and regional projects. However the regional development still highly depends on the general economic situation and how economic growth will be distributed between centre and peripheries. The adopted scenario approach allows us to address the topics of broad range of consequences of development alternatives. The intuitive hypotheses can be tested and expressed in real numbers showing the range of positive and negative impacts.

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