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Modeling the suburbanization of the Budapest agglomeration (Hungary) with GIS methods the aspect of the sustainable development

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Abstract. Urban growth and increase of urban population depends on several socio-economic (and environmental) factors and today is a global phenomenon. In developed countries the primary reason for urban growth is the suburbanization while in less developed areas urbanization is responsible for the same phenomenon. Similarly to the US and Western European trends, a new urbanization process that is characterized with distinct suburbanization was observable in Eastern European countries. In this respect, Budapest, the capital city of Hungary is a representative urban agglomeration for all large cities in the countries of former socialist regime. Suburbanization has numerous socio-economic impacts, thus process and future prediction analyses are essential from the viewpoint of sustainable development.

In the present study we evaluated the social geographical factors of the suburbanization processes of the Budapest agglomeration by employing GIS tools. The objective of the current paper is to create a GIS-based model to monitor and predict the future (sub)urbanization processes for large agglomeration. Since the suburbanization is the key factor for the development of any agglomeration, this method helps to identify that group of settlements where development is likely being sustainable, while additional analysis of social and environmental factors of these settlements may provide crucial basis for the development plans for the Budapest agglomeration.

Our results is in good correspondence with the environmental policy of the European Union. The urban population of the EU is 72.2 % today but this rate will likely increase to 80% by 2030 (UN 2007). Our results provide additional examples and development schemes for the international trend of suburbanization, and may provide useful model tools for sustainable urban development.

Keywords: suburbanization, modelling, sustainable development, Budapest agglomeration, GIS trend analysis

1. Introduction

Conditions of urban development dramatically changed in Eastern Europe over the first years of the 1990s, leading to pronounced suburbanization and growth of suburban areas. Recently, suburban analysis is a popular topic of urban studies. Studies in Hungarian research institutes primarily focus on the exploration of the contributing socio-economic factors (Bajmócy 1999, Barta and Beluszky 1999, Hardi T and Nárai M 2005, Sági and Trócsányi 1998, Timár 1994; Timár and Váradi 2001; Tosics 2006, Tóth 2006). The impact of natural physico-geographical factors are hardly studied in Hungary, although some papers discuss them in limited details (Czigány and Gyenizse 2006). Questionnaire-based surveys, interviews and statistical analyses are the primary methods in these papers, while the number of state-of-the-art GIS based studies, at least compared to international publications, is minimal (Akbari et al. 2003, Fragkias and Seto 2007, Jensen et al. 2007, Kahn 2006, Sabins F F 1996, Weng and Quattrochi 2006).

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The process of suburbanization is a characteristic process in all large cities of Hungary, however its dominance and consequences are more pronounced in the Budapest agglomeration. In the present study, we summarize the major characteristics of the post-1990 development of the Budapest residential agglomeration (Timár and Váradi 2001). Former studies, due to the lack of sufficient elapsed time since 1990, usually focused on short urban development periods. Presently, however, ample data is available for temporal analyses, comparison and model development to predict future urban growth tendencies.

2. Materials and methods

As suburban sprawl is a spatially heterogeneous process in the Budapest agglomeration, areas of most intense development need to be studied with means of GIS tools and appropriate databases. Databases used in the current short paper included residential population, number of passenger vehicles, number of residential properties (using Hungarian Central Statistical Office statistics) and Corine Land Cover CLC90, CLC2000 and CLC2006 land use databases. These parameters properly represent the temporal tendency and location of suburban sprawl and its environmental and socio-economic consequences (e.g.: air pollution, congestion, traffic problems, etc.). GIS methods also point out the most dynamically developing new suburban hubs of the broader agglomeration. Temporally, the post-1990 period is divided into two periods, as development rate is different in these two periods. The changes in development rate and location of local hubs may provide valuable information for the prognosis of future suburban development and help to determine those settlements where the development seems to be sustainable. Further analysis of the social and environmental factors of these settlements may help to understand the necessary conditions of the sustainable development in the agglomeration.

3. Major characteristics of the Budapest suburbanization

Budapest is one of the major agglomeration areas of Eastern Europe. One fourth of the total population of Hungary (2.5 million people) lives here, while one third of the gross national production originates from here. The total land area of the agglomeration covers 2,538 km^2, population density reaches 1,000 people per km^2, while it exceeds 3,200 people per km^2 in the central core of Budapest. Administrative borders are thus smeared in several places and administrative units have been merged in several instances (Tóth 2006).

Intense development of the agglomeration and the surrounding settlements began in the second half of the 19th century, when the rapid economic and industrial development of the area was associated with a sudden population growth. Today, the agglomeration contains 81 administratively independent settlements and is divided into six sectors. The most spectacular feature of the post-1990 development of Budapest is the rapid development and population growth of the suburbs. Some temporal delay is clearly observable between the migration of residents and economic entities between the central and peripheral areas of the agglomeration. The current study, however only focuses on the spatial and temporal pattern of residential migration (Tosics 2006, Sági and Trócsányi 1998).

3.1. 3.1 Suburbanization in numbers

Following the change of the political system in 1990, market positions, rapid property privatization, and legal policy changes resulted in new migration processes in Budapest. At that time, suburbanization was a novel and unexpected phenomena, as positive population balance characterized Budapest in 1990. Nonetheless, over 1991 and 1992 the population balance suddenly became negative for Budapest, suddenly growing to a decline of more than 10 thousand people annually by the mid-1990s (Dövényi and Kovács 1999).

Population of the Hungarian capital totalled 1.7 million people in 2008, which reflects a 16% decrease compared to the early 1990 census (Fig. 1). This negative population data originated from both the negative migration balance and from the nationwide natural population decline beginning in 1993. Demographic features pronouncedly differed between the central and peripheral areas. Positive migration balance became significant in the outer agglomeration zone since 1994, producing a population growth of 51% (200,000 people) in a 20-year period. Significant differences are observed among the suburban settlement: 45% (equals to 20,000 people) and 431% (2,700 people) population growth was observed in Érd and Telki,

respectively. On the other hand, Sződ and Vác experienced a 7% (270 people) and 2% (720 people) population decrease, respectively.

Onehundred-seventy-thousand residential properties were built in Budapest over the period of 1990 to 2008 that equals to an increase of 17% compared to 1990. About 50% of all housing estates were built in Budapest itself, which equals to a 10% increase of all housing, while, at the same time, a 53% housing increase was registered in the agglomeration ring.

Suburbanization considerably changed transportation type in the broader agglomeration over a few year period following 1990. The number of passenger vehicles totalled 886,000 in 2008 (which equals to 33% of all passenger cars of Hungary). 594,000 vehicles (67%) were registered in Budapest, and 289,000 in the suburbs. Under the same 18-year period the total number of vehicles increased by 15% in Budapest and by 121% in the agglomeration ring.

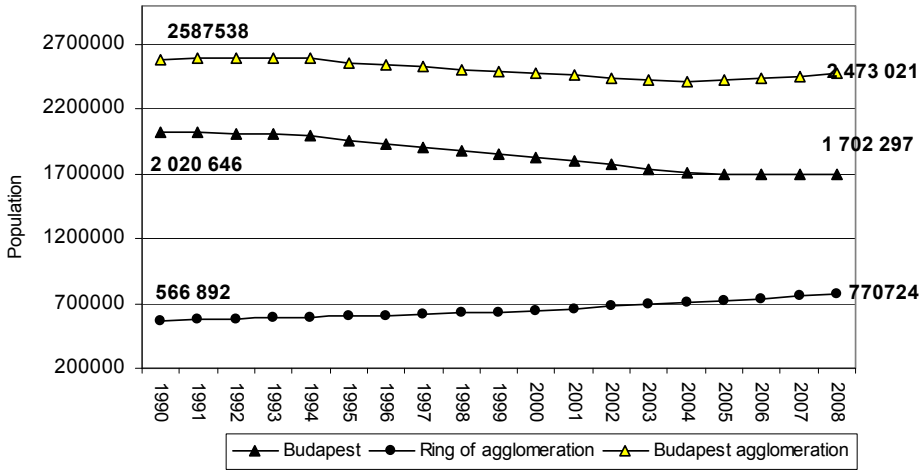

Figure 1. Demographic trends in Budapest and the agglomeration between 1990 and 2008

3.2. Land use analysis of the Budapest agglomeration with GIS tools

Surfaces of urban development were selected for further analyses from the CLC database using ArcGIS 9.2. For each administrative unit we determined the growth of built-in and developed (artificial) areas for the period of 1990 to 2007.

Largest growth of developed areas was observed in the immediate vicinity of Budapest. Two exceptions are observable in the western and north-eastern part of the agglomeration, where growth of urban areas was above average. Largest growth exceeded 10%, while the average growth was 1.4% over this period. The average growth reached 2.4% for the period between 2001 and 2007, while maximum growth rate reached 13%. Largest growth was still observed the north-eastern part of the agglomeration, however the southern and south-eastern part also showed a pronounce increment of developed areas. Growth of developed areas exceeded 10% in 13% percent of all settlements of the agglomeration.

3.3. Spatial and temporal changes of the suburban sprawl in the Budapest agglomeration

Population growth exceeded 50% in 9% of all agglomeration settlements between 1990 and 2000, while the average population increase for all settlements reached 26%. The number of housing estates showed a similar trend for the period of 1990 to 2001 as in the case of the population growth. Thirteen per cent of all settlements showed a housing estate growth more than 50%, while the average growth reached 30%. For the entire 1990 to 2007 period the average population increase reached 53% in the agglomeration ring (Fig. 1).

The total number of vehicles showed a much larger increase (121%) than the population growth (51%) and the number of housing estates (53%) in the agglomeration ring. This discrepancy among the three indices is explained by the larger demand for mobility today than over the early 1990s.

The extreme growth of the number of vehicle generated not only by the suburbanization, but in one hand the motorization, and other hand the demands of the high living standard participants.

4. Conclusions

To describe the complex growth and tendency of suburban sprawl in the Budapest agglomeration we defined the so-called combined growth index that includes land use, population, number of vehicles and number of housing estates (Fig. 2). These quantitative parameters were combined and weighted accordingly to obtain the combined growth index. Six categories were established to quantify the magnitude of suburban changes, one for decline (negative growth index), while five classes were established to categorize growth rates (positive values).

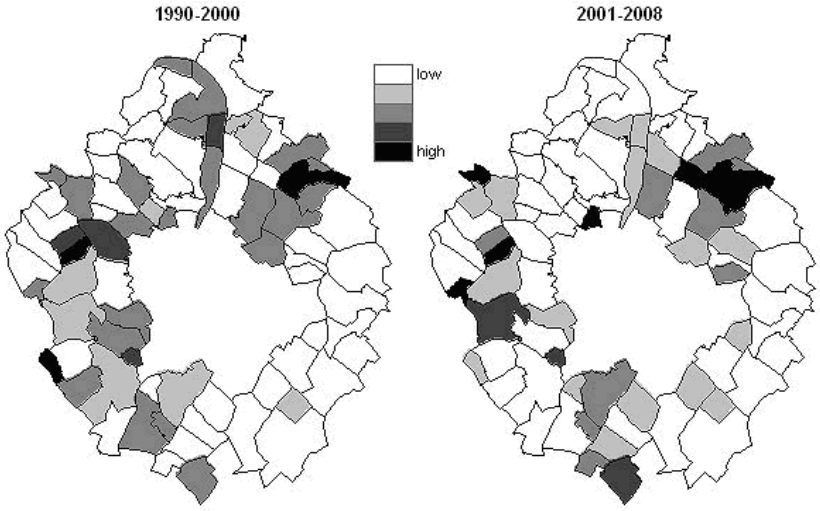

Figure 2. Combined growth index in the Budapest agglomeration (1990-2000, 2001-2008)

Largest growth indices are observable in the north-east part of the Budapest agglomeration. Likely, the growth of the north-eastern areas will show a similar trend in the next decade (i.e. growth rate will remain steady), as well. However, based on the long-term analyses, the growth rate of the north-west part of the agglomeration will likely slow down in the near future, while in the south-west and southern parts of the agglomeration will show an increasing growth rate in the very near future. Further analysis of the north-west part may help to point out the factors that obstruct sustainable/constant development.

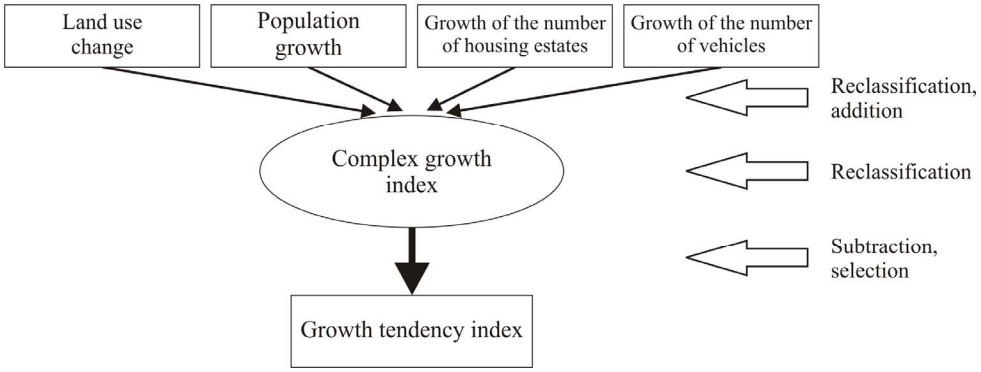

Figure 3. The process of the analysis

From the magnitude of the complex growth index, we may estimate the spatial differentiation of suburban growth. The growth tendency index is derived from the combined growth index determined for both suburban sprawl periods by subtracting the complex growth index of the 2001 to 2007 period from that of the 1991 to 2000 period. Consequently, the growth tendency index may also be either positive or a negative value. Negative values indicate slower growth rate in the second study period, while positive numbers indicate larger growth rate between 2001 and 2007.

Positive growth indices do not necessarily reflect above-average urban growth rate and potentially impacts the short-term spatial and quantitative properties of the suburbanization process. To determine and select the settlement that are characterized with above-average growth rate we need to consider those settlements where the growth tendency index shows a much higher growth rate in the second period than during the first period. This list of settlements of this type is obtained by superimposing the complex growth index, the growth tendency index and the polygon database on the same layer, then the obtained data needs to be reclassified. Reclassification will then provide the list of settlement that are characterized by above-average development rate, and based on their present day growth trend steady-state growth is predicted in the future as well (Fig 4). Here, with GIS tools we verified and validated the results obtained formerly by other methods to quantify the suburbanization process of the Budapest agglomeration. Results and analyses are further refined by dividing the entire suburbanization periods into two shorter intervals. This way, with the application of function analysis tools the obtained trends and processes are efficiently analyzable, so it is possible to find those settlements where the development is constant or growing.

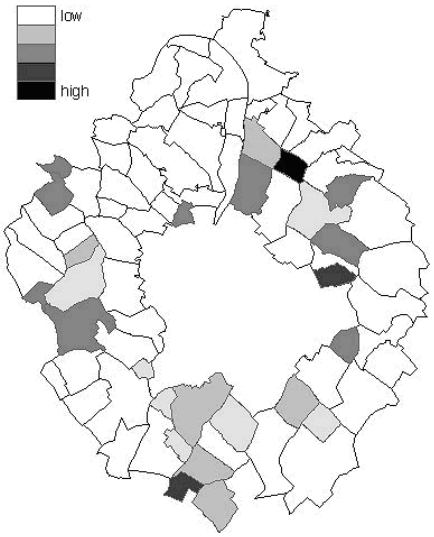

Figure 4. Spatial distribution of the growth tendency index in the agglomeration ring of Budapest (1990-2008)

By analyzing additional other statistical parameters, the accuracy of the presented results could be increased and more accurate picture could be obtained about the spatial and temporal processes occurring in the Budapest agglomeration. The results of our study may help to create a GIS model to determine the qualitative and quantitative conditions required for sustainable development.

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