

Analysis of Influence of Different Factors on the City Spatial Development with Using GIS

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Abstract In this paper, using GIS software, the spatial development of the city of Prague was analyzed, as well as factors that promoted this: the population change; motorization level and its impact on the environment. The author analyzes land use changes in Prague using ArcGIS 10.1 software and available master plans. Land use changes analysis in GIS will allow to assess the dynamics of urban development, and also to identify the relationship between changes of different classes of territories in certain time periods.

Keywords spatial development, land use, population change, motorization level, environment

1. INTRODUCTION

The main principle of sustainable urban development is to ensure a stable socioeconomic growth as well as environmental health and safety. The main objective of sustainable development assumes a reasonable use of the social, natural and economic potential of the area and also the balance between the use of the environment and population growth. In the modern world as a result of a number natural factors (population growth, high mobility of labour and financial resources), the urbanization and intensive development of city territories is occur. However, due to the inefficient use of urban land or because of uncontrolled expansion of urban areas it contributes occurrence of negative economic, environmental and social implications for people.

Land is a nonrenewable resource, the amount of which is limited, therefore we must ensure its reasonable using (Liu, 2011). Because of the intense urbanization, the modern cities face a number of problems such as environmental problems, problems of unhealthy living environment of the population — the noise, air pollution, consolidation of built up area, transport problems, etc. On the other hand urbanization is an unavoidable process, since it is primarily based on economic interests of different stakeholders. Developers invest in residential and commercial construction and municipal authorities support this as a way of local budget replenishment. At the same time, seeking to gain economic benefits, we should not forget about environmental issues. In this context it is important to control and guide urban development processes, since decisions made now will affect the future structure of the city and the living conditions in it.

As an example of such influence we can analyze urbanization processes in the United States. In the 1950's the US federal

government began to subsidize the construction of one- or two-storey single family houses. The system of mass construction of identical houses on the standard lots was developed and was accompanied by the construction of highways that connected suburbs and cities. It was very popular when the family lived in a quiet suburban area, with monofunctional land use, location of jobs were in the downtown and the car was the best way to get to the place of people activity. With the development of the suburbs, more and more people abandoned the city. This process is called urban sprawl. The public transport service area could not cover the sprawled cities and the use personal cars became a necessity. And now there is a great concern among scientists and experts which is caused not only by environmental pollution but also high urban transport energy consumption.

In this paper, using GIS software, the spatial development of the city of Prague was analyzed, as well as factors that promoted this: the population change; motorization level and its impact on the environment.

2. SPATIAL DEVELOPMENT OF PRAGUE

Spatial development is a gradual process caused by changes in the socio-cultural or material environment by different stakeholders within the boundaries of local urban areas. Spatial analysis is one of the basic functions of geographic information systems. It represents a way of exploring spatial patterns of objects and phenomena, their interactions and development. One way to understand urban development is to analyze changes in land use. Land use can be considered as a dynamic process that is subject to constant change. Land use changes analysis in GIS will allow to assess the dynamics of urban development, and also to identify the relationship between changes of different classes of territories in certain time periods.

The main document outlining the concepts of urban development and land use is master plan. Using a set of master plans, we can perform the urban development analysis, with regard to the changes and stability of functional areas and we can also control the processes of urbanization and suburbanization.

In this paper ArcGIS 10.1 software was used for the land use changes analysis. Analysis was performed using four vector land use maps for the years: 1986, 1994, 1999 and 2012 (Figure 1). These maps were provided by Prague Institute of Planning and Development as a shape file, at scale 1:10 000. These vector maps

represent a database in which stores information about polygons that are the closed sequence of lines. Each of the polygons represents a certain class of land use and contains attributes characterizing its property, color, type, name, etc. (Kostin, 2013).

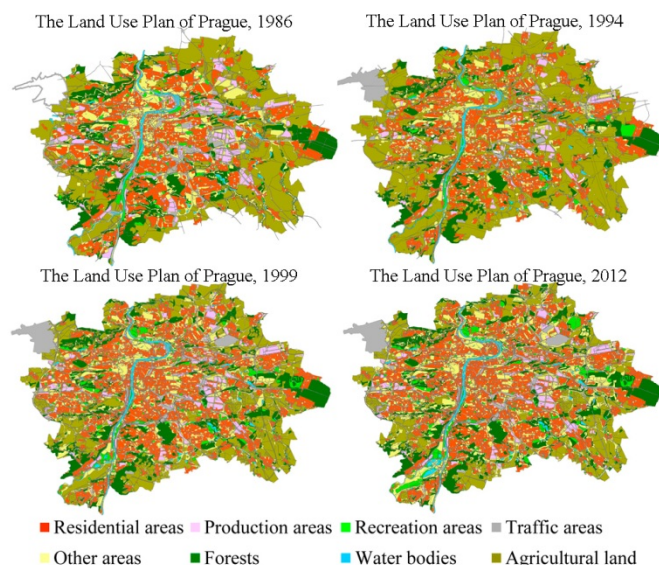


Figure 1. The land use plans of the city of Prague

Because of different classification level of land use plans at four periods, the unified legend of land classification was created, which contains the following eight categories of land use: residential areas, production areas, recreation areas, traffic areas, other areas, forests, water bodies, agricultural land.

Analysis of land use change was performed using “overlay” tool in ArcGIS 10.1 software. Overlay analysis is one of the most powerful and commonly used analytical methods in GIS environment. This tool is based on the overlay of two or more different cartographical layers and the creation of derived objects arising at their geometrical overlay. In particular the overlay analysis allows to identify the major “sources” and “destinations” of appearing and disappearing land (Delden, 2008). ArcGIS 10.1 offers several overlay operations at working with polygons. In this paper the “union” operation is used, which computes a geometric intersection of the input features. All features will be written to the output feature class with the attributes from the input features, which it overlaps.

Overlay analysis was performed sequentially between periods: 1986–1994; 1994–1999; 1999–2012. The results of overlay analysis are shown in tables 1, 2, 3.

In these tables columns show the sum of land use areas for older year, and row show the sum of areas for the modern year. On a diagonal specified value of the areas which have remained without changes during studied period. The historical structure of city center doesn't allow the further development of territories, so the main land use changes occurred in the outer zone of the city.

To understand and describe the changes in land use that occurred during the studied periods, the following factors were analyzed: the population change; motorization level and its impact on the environment.

3. CHANGES IN POPULATION OF PRAGUE SINCE 1986

Currently in Prague live 1,243,201 inhabitants, 90% of which are citizens of the Czech Republic (Czech Statistical Office, 2014).

Population changes in the city from 1986 to 2012 are shown in Figure 2.

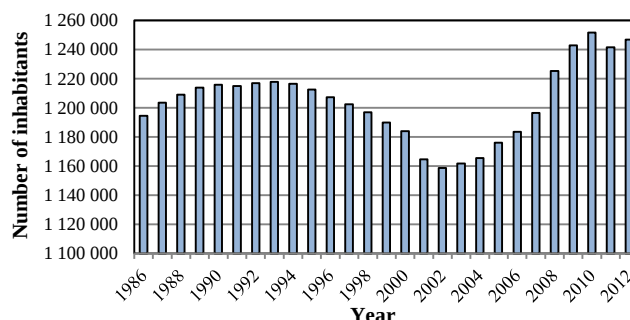


Figure 2. Development of the Prague's population from 1986 to 2012

In terms of time appears uniform population growth till 1993, which was influenced by the influx of immigrants from all over Czechoslovakia. However, from 1993 to 2001 downward trend is appearing. According to the census, in 2001 the number of inhabitants was even lower than in 1980, which was caused by natural movement (Bradova, 2008). In those years there was no construction of large housing areas in Prague. The numbers of emigrants from Prague exceeded the number of immigrants that is possibly related to suburbanisation processes in Prague and its surroundings. Only from 2002 the population growth appears again, mainly due to a positive migration balance of people from abroad.

The population development in relation to the city districts was not proportional (Figure 3). Since 1992 there was a decrease in the number of permanent residents of the central part of the city (Prague 1 and 2), and also some city districts related to the inner city (Prague 3, 4, 6, 7, 8, 9, 10).

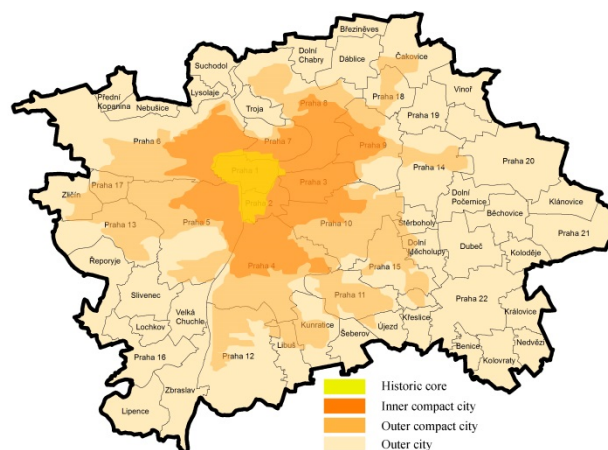


Figure 3. Prague city districts

At the same time, there was population growth in that period at the city periphery or in the outer city area. This can be explained by the beginning of suburbanization process within the city and by completion of construction of the major residential areas. Development of mortgage market in 2000 caused population increase in the city periphery (Bradova, 2008).

Development of residential areas corresponds to an increase of the city population (Figure 2) during the periods 1986–1994 and 1999–2012. Significant changes seen in the increase of residential areas with the primary 11 468 ha in 1986 to 13 660 ha in 2012, that makes increase on 2192 ha. Most of the residential areas in the 90s

were concentrated in a compact city, which includes the large housing estates, forming a large part of the North, South and Southwest City. After 1989, there were some developmental transformations within the city. The processes of restoration of the historical center and other parts of the city were started together with the beginning of privatization and the development of commercial construction (Szentesiöva, 2010).

All these factors led to the construction boom. Therefore, the total increase in residential areas in the period between 1986 and 1994 was 1612 ha (Table 1).

Between 1994 and 1999, there was period of suburbanization processes and Prague population decrease. Therefore, the total increase of residential areas was only 72 ha (Table 2).

Since 2002, the city population began to increase which led to an increase in residential areas on 508 ha (Table 3). New residential areas were often implemented at the edges of the compact city and the individual settlements, or between existing buildings. As the negative consequences of such residential areas development can be considered appearance of monofunctional zones, without public amenities and traffic growth.

4. MOTORIZATION AND THE ENVIRONMENT

The next important factor that affects the urban development is the level of motorization and development of traffic areas.

Increase in number of motor vehicles in Prague started in 60s of the 20th century. The first traffic problems began to appear because of the insufficient number of main intersections in the city center. The significant growth of road transport was in the 90s of the last century, when the socioeconomic conditions changed, the development of a market economy started, the lifestyle has changed and became associated with greater mobility of the population and the car has become an affordable commodity. This in turn required a decision on further long term development of the transport network of the city. Increase of road traffic intensity and transport problems with specific conditions of Prague (relief of the city, housing density) indicated, that the situation in Prague road network does not help only the reconstruction or maintenance of existing roads (Bradova, 2012).

In first period from 1986 to 1994, the increase of traffic areas amounts to 224 ha (Table 1). In this period there was an increase in population of the city. The outer city zone had the potential to not only development of residential areas but also the construction of shopping centers. This in turn required the development of transport infrastructure that would have linked these areas of outer zones with the city center. During 80s and 90s thanks to the implementation of separate plots of Prague City Ring and his connections with Prague Ring there is became possible to carry part of the inner city transport relations primarily in districts which located near Prague Ring.

The renewal of country transport networks especially has become even more relevant with the accession of the Czech Republic to the European Union. In the third period from 1999 to 2012 traffic areas have increased by 335 ha (Table 3).

One of the main problems in Prague is shortage of parking spaces. This problem is caused by the historical structure of the city and compact planning, which practically does not allow to develop of new parking areas. This problem is partially solved by converting of unused production areas. As a whole the reduction of production areas is 734 ha.

However, the development of transport infrastructure has negative consequences on the environment. Figure 4 shows the development of number of registered vehicles in Prague since 1981. Statistical data were taken on web page of the Czech Statistical Office (2014).

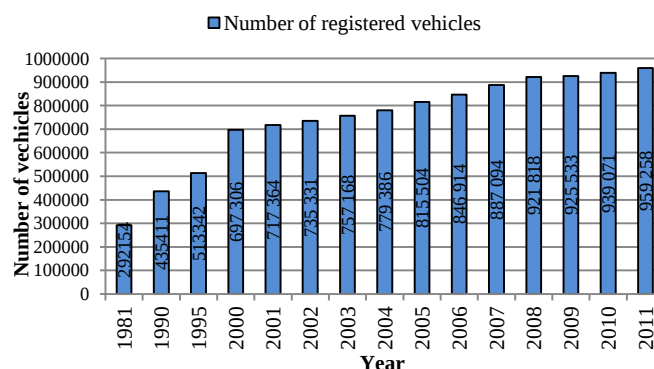


Figure 4. Number of registered vehicles in Prague since 1981

As seen in Figure 4, the number of cars in Prague is steadily growing. This is due to the modern way of life, high mobility, the car has also ceased to be a luxury. Another reason is the rapid growth in city population over the past 10 years. In general, the number of registered private cars in Prague has increased by 70% over the last 30 years.

The next step was to analyze the transport emissions to assess the effect of increase in the number of vehicles on the environment (Figure 5).

As the main pollutants are considered three substances: nitrogen oxides (NOx) is released during the combustion of fossil fuels such as gasoline, fuel oil, natural gas, etc.; carbon monoxide (CO) is a common pollutant in the air, his amount depends on the road transport intensity; sulphur dioxide (SO2) is highly toxic to plants. The statistical data on amount of emissions considered substances from transport were used as initial data for the analysis (Czech Statistical Office, 2014). Data on emissions of harmful substances in Prague are available only from 2000 to 2010.

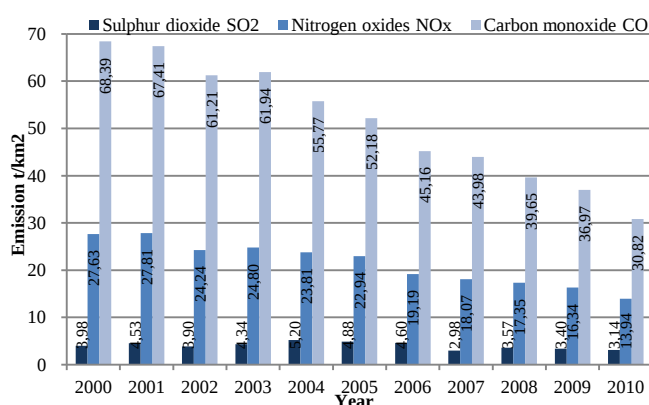


Figure 5. Emission of harmful substances into the atmosphere from transport in Prague

As seen in Figure 5 the reducing of harmful emissions from road transport during the considered period is observed. Minor fluctuations occurred in the period from 2002 to 2004, but in general there is a tendency to reduce emissions. This is a paradoxical situation, there is a reduction of emissions of harmful substances into the atmosphere against the background of intensive growth of the number of vehicles in the city, which every year becomes more

and more. However, this discrepancy can be explained by the following factor. First of all, the composition and quantity of transport emissions depends mainly on the condition of the vehicle fleet. Policies of the European Union which aimed at reducing of emissions tightens requirements for automobile companies, mainly, due to technological improvements of engines and exhaust filtration systems. Therefore, analyzing on figure 4 increasing of number of cars in the city, it should be noted that about 70% of personal vehicles are comply with the standard EURO 3 or higher. More than 40% of personal vehicles are comply with the standard EURO 4 or higher. On the other hand, during the period from 2001 to 2009, the number of cars that do not even comply with the standard EURO 1 reduced from 25% to 4%.

5. CONCLUSION

The analysis carried out in this work is allowed to reveal the dynamics of land use changes in Prague and factors that promoted this. Two main periods of urban development are allocated: 1986—1994 and 1999—2012. During these periods, there was an increase in population of the city, which caused the development of residential areas (total increase is 2192 ha). Development of residential and commercial construction, in turn, contributed to the development of transport infrastructure. The development of road network in Prague is primarily due to the construction of its main traffic arteries: outer Prague Ring and inner City Ring. Construction of these objects will reduce the transport load in the central parts of the city and also to improve transport accessibility in the developing residential areas located near the city border. This will also increase the interest from investors in land lots which adjoining to Prague Ring. Carrying out of overlay analysis allowed to reveal negative aspects of urban development, that require special attention from urban planners and local authorities. As a result of ongoing development of urban areas, there is a reduction of agricultural lands (total decrease is 4205 ha), which located in the outer zone or near the city borders. Fragmentation of natural areas, which violated the integrity of ecosystem, is also negative factor of urbanization.

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Table 1. Changes in land use for the period 1986—1994 (ha)

Areas	Res	Pro	Rec	Tra	Oth	For	Wat	Agr	1994
Res	10033	130	101	351	966	106	4	603	13080
Pro	28	2043	58	138	144	9	0	57	2477
Rec	10	9	623	12	168	227	9	91	1150
Tra	145	59	35	2777	278	55	4	124	3477
Oth	1092	223	534	314	6236	374	52	667	9490
For	72	13	21	65	470	4960	8	194	5802
Wat	13	6	13	14	153	22	850	32	1103
Agr	75	12	60	31	484	272	34	12241	13207
1986	11468	2495	1445	3701	8899	6025	961	14009	

Note: Res=Residential areas, Pro=Production areas, Rec=Recreation areas, Tra=Traffic areas, Oth=Other areas, For=Forests, Wat=Water bodies, Agr=Agricultural land.

Table 2. Changes in land use for the period 1994—1999 (ha)

Areas	Res	Pro	Rec	Tra	Oth	For	Wat	Agr	1999
Res	12132	167	11	117	519	31	8	64	13152
Pro	19	1548	0	72	134	3	0	4	1780
Rec	28	18	1223	5	364	28	3	55	1725
Tra	283	43	11	3648	182	25	10	18	4219
Oth	432	197	93	213	8592	205	107	444	10283
For	40	6	100	22	216	5699	23	134	6241
Wat	6	2	12	4	51	14	948	32	1069
Agr	140	12	45	26	316	135	12	10559	11244
1994	13080	1993	1495	4109	10374	6139	1112	11311	

Note: Res=Residential areas, Pro=Production areas, Rec=Recreation areas, Tra=Traffic areas, Oth=Other areas, For=Forests, Wat=Water bodies, Agr=Agricultural land.

Table 3. Changes in land use for the period 1999—2012 (ha)

Areas	Res	Pro	Rec	Tra	Oth	For	Wat	Agr	2012
Res	12959	80	29	49	250	11	1	281	13660
Pro	25	1638	0	22	31	2	1	43	1761
Rec	13	4	1618	1	80	6	16	375	2114
Tra	76	18	9	3932	268	18	3	116	4439
Oth	69	39	32	83	9536	49	16	409	10234
For	1	4	5	7	59	6142	1	258	6477
Wat	0	0	22	1	21	2	997	82	1126
Agr	9	0	7	9	62	4	1	9711	9804
1999	13152	1782	1722	4104	10308	6234	1036	11276	

Note: Res=Residential areas, Pro=Production areas, Rec=Recreation areas, Tra=Traffic areas, Oth=Other areas, For=Forests, Wat=Water bodies, Agr=Agricultural land.