# INVESTIGATION OF THE INTERNAL STRUCTURE CHANGES OF ULAANBAATAR CITY USING RS AND GIS

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**ABSTRACT:**

This paper describes the changes occurred in the internal structure of central part of Ulaanbaatar, the capital city of Mongolia, since the fall of communism in Mongolia. Currently, Ulaanbaatar is encountering increasing urban development problems, similar to many cities in developing countries. In the city, different problems had been accumulated during the communist era. These problems have been accelerated by the reforms of the entire political and economic systems, unregulated market development and the rapid population growth caused by migration from rural areas. Actually, in the country there are missing urban-oriented research and surveys as well as thoroughly conducted and creative activities, based on the modern urban geographical theory and methodologies used in the developed countries. One of the methods that can be used for this purpose could be the application of the modern remote sensing (RS) and geographical information system (GIS) techniques and technologies for rapid urban-related planning and management. In this study, we wanted to detect the changes occurred in between 1990 and 2002 in the central part of Ulaanbaatar city using RS and GIS techniques. For this purpose, the urban land use has been selected within the city business district (CBD) area of the capital city and for the urban change detection historical GIS data, SPOT 5 and Quickbird images of 2002 have been used. The analysis was carried out using the Erdas Imagine 8.6 installed in a PC environment.

## 1. INTRODUCTION

In general, the previous development plan of Ulaanbaatar during the time of the centrally planned economy represented not only urban construction and physical architectural plan, but it was based on the capital city's investment planning and had a legal power to plan and control the urban internal land utilization. The reason for this is that the prevailing majority of industrial plants, economic and infrastructure sites, residential and dwelling apartments of the country were mainly concentrated in the capital city. On the other hand, everything was based on such a system, where the entire land of the country belonged to the government and was distributed under the tenure of factories and economic establishments of socialist features and the utilization rules and orders were established by the state power and the tenure had been controlled and inspected by the society via state organs. However, when the country entered the market economy, it was not possible to control all of the rapidly changing activities and many things had happened without any control (Chinbat, 2005).

Since the transition to a market economy the Ulaanbaatar city has experienced much more developments, which resulted in changes of the spatial and functional structures of the city and the most significant changes have been the increase of commercial functions in the city centre and inner city area; the expansion of the urbanized areas along with the growth of formal and informal ger-settlements; the formation of satellite nodes with clusters of commercial functions, and the residential suburbanization in the outer city by single family houses (Chinbat, 2005).

Although there have been many changes over the past decade, very few studies have been carried out on the internal structure of the Ulaanbaatar city. Amarsaikhan *et al.* (2001) and Amarsaikhan *et al.* (2005) conducted the urban growth study of Ulaanbaatar, using historical GIS data sets and multitemporal RS images. However, they explored the general changes occurred in urban land cover classes and did not pay attention to the changes occurred in the spatial and functional structures of the city. Hofstee *et al.* (2004) analyzed the urban land use classes of the capital city and defined 7 classes of the built-up areas.

At present, in the country there are missing urban-oriented research and surveys as well as thoroughly conducted and creative activities, based on the modern urban geographical theory and methodologies, because the research on functional and spatial differentiation of urban areas is a relatively new research direction in urban geography of Mongolia. In the present study, we wanted to detect the changes occurred in the central part of Ulaanbaatar city using RS and GIS techniques. For this purpose, the urban land use has been selected within the CBD area of the capital city and for the urban change detection historical GIS data, SPOT 5 and Quickbird images of 2002 have been used. The analysis was carried out using the Erdas Imagine 8.6 installed in a PC environment.

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## 2. THE FORMATION OF URBAN STRUCTURE OF THE FORMER SOCIALIST ULAANBAATAR

Ulaanbaatar was founded in 1639 as a small town named Urga and settled at the present location in 1778. However, it has been only since 1954 that Ulaanbaatar has developed in accordance with scientifically based city planning. During the past 'communist regime,' the capital city's master plan was revised four times according to the city's development needs and phases. The plan guided and resulted in the internal structure of the present day city. Tselmeg (2003) highlighted five phases (Figure 1) of urban planning development in Ulaanbaatar in between 1950s and 1990s as follows:

1. In 1954-1965, the first general plan of Ulaanbaatar was developed and the location and construction layouts were initiated, but land mapping and comprehensive surveys were not completed.

2. In 1965-1975, the general plan was formulated with the economic efficiency estimations based on the land maps and comprehensive engineering and geological surveys.

3. In 1975-1985, urbanization development was carried out based on the national policy, methodological directions and norm-documents; the works were well adjusted to the nation's topographic and climatic conditions and to the traditional nomadic ways of life of the people.

4. In 1985-1990, a number of experts on urban projects were trained, thus enabling the national manpower to carry out the projects independently well fitting to the Mongolian local conditions.

From 1990s a radical new trend emerged in the urbanization plan of the capital city in conjunction with the socio-political transformations and transition to a new market economy, and is now in force legally serving as the basic norm documents.

### 1) The first phase

The first master plan of the Mongolian capital was developed in 1954. The plan covered a 20-year period from 1954 to 1974 and expected that the population of the city would reach 120,000 by 1974, but the population already reached 180,000 in 1960. Most of the current central area was built during this phase and the area was surrounded by "Baga toirog", the inner ring, and so called "I-40,000 and II-40,000" residential districts equipped with the basic infrastructure such as streets, water supply, sewage, electricity and heating. At this time, all of the central functions including central government and ministries, banks, universities, diplomatic and international organizations, and so on were concentrated within this central area, thus named "Baga toirog" referring to the relatively compact urban area. Since then the inner ring, Baga toirog, begun to perform the role of the CBD of Ulaanbaatar.

Meanwhile, industry began to develop substantially when the USSR increased its assistance and Soviet-style central planning was introduced. In this period the industrialization occurred most rapidly in Ulaanbaatar. Major projects were completed with the Soviet assistance including the modernization of the Ulaanbaatar industrial complex, which is located in separate from the city centre. The newly built central area and industrial zone were surrounded by traditional ger (Mongolian national dwelling)-settlements.

### 2) The second phase

The time scope of this phase considered 20-25 years starting from 1964 and it expected the city's population to reach 250,000 by 1984. However, the population already reached 349,000 in 1975, exceeding by 100,000 people thus reaching its goal 10 years earlier than the planned year. The master plan also designed about 80,000 ha of built-up area, 20 km long and 7 km wide along the Tuul River valley and with some satellite towns. During this phase, most of residential blocks or districts were built in the traditional inner city area, such as XII, XY, XIX districts and 120,000 district which included schools, kindergartens, hospitals, shopping centers and public service centers (Bumerdene and Chinbat, 2002). The former ger-districts places were converted to urban edges.

In the mean time, three industrial and warehousing zones were built in the city edges, such as the central zone located in the traditional industrial area, the west zone located in the area of Tolgoit with some residential apartments for industrial workers, and the east zone located in Amgalan. These zones were separated from residential areas by the green belts.

### 3) The other phases

The time span of this phase considered 25 years starting from 1976. The city's population was expected to reach 440,000 by 1990. However, the population increased very rapidly and reached 493,000 in 1986, so that the plan had to be renewed again.
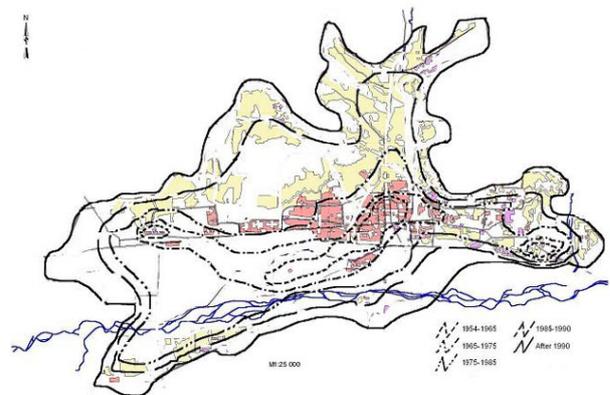


Figure1. The phases of urban development in Ulaanbaatar.

In 1987 the city government prepared the fourth plan with Soviet technical assistance, setting the end year to be 2010. The major features of the plan were as follows: 1. In order to achieve a unified settlement system, Ulaanbaatar's growth was coordinated with the urban development of nearby zones, and several small satellite towns such as Nalaikh, Bio-Songino, Shuvuu, Gachuurt were established. 2. Limits were set to check the ever-increasing population of the capital city. 3. Some industrial, warehousing, and military activities were relocated from the central city to satellites towns. 4. Unprofitable activities concentrated in the inner area of the city were removed to the industrial zone and other areas.

Many residential blocks were built during 1976-1989, mostly consisting of prefabricated high-rise apartment buildings in the

current residential zones and some in the inner city, such as I, III, IY, Y, YI, X, XI, XIII districts and 220,000 district. These residential complexes were accompanied with all necessary infrastructure and local public facilities.

The mayor of the city implemented the fourth plan with central planning budget until 1990. After 1990 the city government decided to implement short term planning scheme because of the large-scale migration and of the market conditions. However, there were not enough financial resources to prepare for a new plan during the 1990-2000 period, and as a result the city government has given approvals and permissions building by building without having general planning criteria.

In this way the city has grown through concentric additions of five zones or areas (Figure 2) such as:

1. The central area in the city core, surrounded by the inner ring where the most of central functions are concentrated.

2. The traditional inner city area of mixed land use, surrounded by the outer ring;

3. The residential zones consisting of apartment blocks, consisted mostly of prefabricated high rise buildings;

4. Ger district zones which are quarters consisting of compounds surrounded by wooden fences.

5. The industrial and warehousing zones, separated from other functional zones.
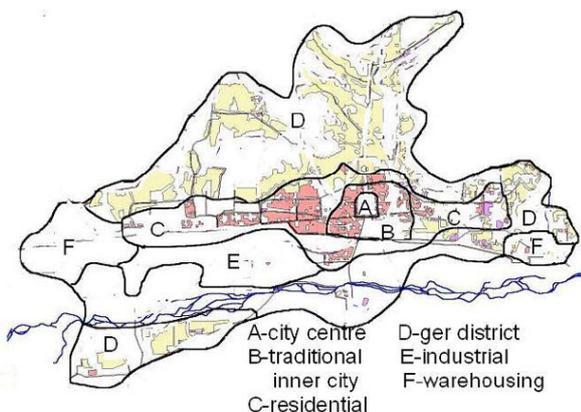


Figure 2. The spatial structure and dominant land use of Ulaanbaatar.

## 3. THE CHANGES IN SPATIAL AND FUNCTIONAL STRUCTURE OF THE CITY

The physical expansion of the city and increasing functional complexity of urban life that is the changes of urban internal structure of Ulaanbaatar, occurred during the transition period. Such changes were conditioned by basically transforming politico-economic and social environments in the entire country. The main transformations of the political, economical and social environments were as follows:

1. Since the transition period the government implemented different policies step by step to privatize state and collective properties and liberalize the prices. As results of that market principles were established irrevocably, and the private sector became dominant in Mongolian economy. To date, the private economic entities produce 56% of the total industrial products; carry out 42% of construction and erection works, and occupy 76% of total retail turnover (Tselmeg, 2003). In the case of Ulaanbaatar, there were 13,559 registered businesses and 13,853 licensed businesses operating in 2002 (Herro *et al.* 2003).

2. Economic restructuring involves another set of processes, which have determined the contemporary urban changes. Most of the state industrial plants have been closed and privatized due to declining employments in the industry as well as the structural changes of traditional industries. Instead, commercial and service industries have grown rapidly. New private companies operate mostly in trade and advanced services, such as finance, audit, consultancy, real estate, public relations, media, tourism, and compete for profitable locations within the city.

3. The central government and the municipality of the capital city implemented policies to limit a mechanical growth of population (until the early 1980s, rural-to-urban migration was under the strict control of the Government). The population growth of the capital city, however, was continuing during the communist time, and this growth was accelerated even further since the transition period, especially after the new constitution. The new constitution has been in force since 1992 and people had the rights of free circulation and settlement. The new situation caused a sudden and great migration flow to Ulaanbaatar where more jobs available for new comers. Ulaanbaatar's official population reached over 812,000 in 2002 and the city population had increased by 48% since 1989.

4. Privatization processes have created a new class of owners some of whom became wealthy, and since the beginning of the economic reforms there has been a rapid increase of wealth differentiation among people. Furthermore, relating to privatization and liberalization of prices, the price differentiation has occurred also in the real estate sector and the housing prices became different depending upon the attractiveness and locations of the residences. In the other words, differentiated household incomes and the prices and rent of housing have contributed to the increase of socio-spatial differentiation.

## 4. THE ANALYSIS ON URBAN LAND USE CHANGES OCCURRED IN THE CENTRAL PART OF ULAANBAATAR CITY USING RS AND GIS

### 4.1 The CBD or Baga Toirog Area

At present, the Baga toirog area (see Figure 2) performs the role of CBD, with concentration of commercial and government functions. Besides the Central Government, Parliament and headquarters of major political parties, the Baga toirog contains approximately two third of ministries, one third of 40 major government organizations, half of diplomatic and international organizations, half of bank headquarters, one fifth of 10 state universities, one third of research institutes and theatres, museums, and one third of headquarters of trade and service companies. Within Baga toirog, the Central Business Height Index is approximately 0.6 and the Central Business Intensity Index is 60%.

Since the beginning of the transition period, the Baga toirog area has attracted the attention of developers and many other business people who were seeking valuable locations for establishing their businesses and commercial services in this area, and so commercialization became the most important process and conditioned the changes in spatial and functional structure of the traditional central business district. The CBD was characterized as the functional core of the city towards which an accessible location for the economic viability or functional efficiency tended to gravitate (Herbert and Thomas, 1990).

## 4.2 Radiometric and Geometric Corrections of the SPOT 5 and Quickbird Images

In the present study, for urban land use change detection a topographic map of 1990 (ie, historical GIS data) scale 1:10,000 and multispectral SPOT 5 image of 2002 resampled to a pixel resolution of 4m and Quickbird image of 2002 with a spatial resolution of 70cm have been used.

At the beginning, the two images were analyzed in terms of radiometric quality and geometric distortion. The Quickbird data had some radiometric noise and in order to correct it, a 3x3 size average filtering (Gonzales and Woods, 2002) was applied. In order to georeference the two images to a Gauss-Kruger map projection, a topographic map of 2000, scale 1:5,000 has been used. The ground control points have been selected on well defined sites and for the transformation, a second order transformation and nearest neighbour resampling approach (ERDAS, 1999) have been applied. In each case of the georeferencing, an image was resampled to a pixel resolution of 70cm.

## 4.3 Image fusion

After applying radiometric and geometric corrections, data with different spatial resolutions can easily be integrated. The image fusion is the integration of different digital images in order to create a new image and obtain more information than can be separately derived from any of them (Pohl and Van Genderen 1998, Amarsaikhan *et al.* (2005)). In the case of the present study, the panchromatic image provides more spatial information due to its higher spatial resolution, while the multispectral image provides the information about the spectral variations of the urban classes. Image fusion can be performed at pixel, feature and decision levels (Pohl and Van Genderen 1998, Amarsaikhan and Douglas, 2004). In this study, the fusion has been performed at a pixel level and for the efficient fusion a Brovey transform has been used.

In this method, multispectral images with a lower spatial resolution are integrated with an image with a higher spatial resolution, thus creating spectrally and spatially enhanced color images (Vrabel, 1996). To create spectrally and spatially enhanced color (RGB) images, the sum normalized multispectral bands are multiplied by the image with a higher spatial resolution as shown below:

$$R=(B1/B1+B2+B3)*B4$$
$$G=(B2/B1+B2+B3)*B4$$
$$B=(B3/B1+B2+B3)*B4$$

where  B1,B2 and B3 - multispectral bands, and B4 - band with a higher spatial resolution.



Figure 3. a) The SPOT 5 image in an original scale, b) The Quickbird image in a reduced scale, c) The fused image of SPOT 5 and Quickbird. The Government building of Mongolia is in the centre of the images.

In the present study, for the Brovey transform, the bands of SPOT 5 were considered as multispectral bands, whereas Quickbird image was considered as higher spatial resolution band. The original SPOT 5 and Quickbird as well as the fused images are shown in Figure 3.

## 4.4 Urban land use change analysis

In this study, we wanted to detect the changes occurred in between 1990 and 2002 in the land use of CBD of Ulaanbaatar city using historical GIS data as well as RS images. Initially, to create the primary historical GIS data, the available land use classes were digitized in a Gauss-Kruger map projection from a topographic map of 1990, scale 1:10,000. Similarly, from the Brovey transformed image of SPOT 5 and Quickbird, the same land use classes have been digitized in a Gauss-Kruger map projection (Figure 4).

The total areas related to each class defined from the digitized map as well as the RS image are shown in table 1. As seen from table 1, in between 1990 and 2002 in this region, the land for hotel, restaurant and bars; cultural places; central government organizations; banks; university, school, kindergarten and academic organizations; hospital and chemists; industry, and residential apartments had been increased by 0.22ha or 22%, 0.4ha or 66.7%, 0.6ha or 31.6%, 0.6ha or 400%, 0.4ha or 19%, 0.2ha or 66.7%, 0.7ha or 333% and 0.3ha or 9.1%, respectively. Meanwhile, the land for green area and reserve land had been reduced by 3.9ha or 63.9% and 4.45ha or 11.2%, respectively. Also it is seen that there had been emerged new types of land

use such as trade and private companies. In addition, it should be mentioned that in many places the ground floors of the residential apartments were changed to small shops, cafeteria and other commercial entities. The land and building structure density in this region reaches 77% and it shows that there is almost no free space to further develop or use. The average population density here constitutes 84 persons per ha. This means that in order to intensify the land use in this region it is necessary to increase the floors of buildings or construct new buildings instead of very old ones.
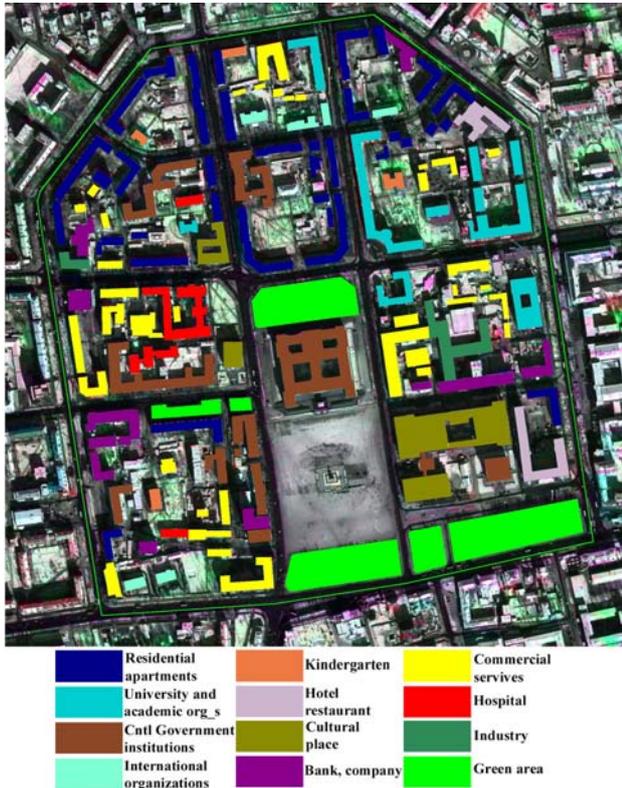


Figure 4. The land use classes interpreted from the fused image of SPOT 5 and Quickbird.

## 5. CONCLUSIONS

The overall idea of the research was to detect the changes occurred in between 1990 and 2002 in the central part of Ulaanbaatar city using RS and GIS techniques. For this purpose, the related urban land use classes have been selected within the CBD area of the capital city and for the urban change detection historical GIS data, SPOT 5 and Quickbird images were used.

As seen from the analysis, during the analyzed period the land use for all classes had been increased except for the green area and reserve land and there were emerged new types of land use such as trade and private companies. Also it is seen that in many places the ground floors of the residential apartments were changed to small shops, cafeteria and other commercial entities.

Furthermore, it is seen that as the land and building structure density had almost reached its maximum, in order to intensify the land use in this region it is necessary to increase the floors of buildings or construct new buildings on the basis of very old buildings.

| | Land use types | Before 1990 | | 2002 | |
|---|---|---|---|---|---|
| | | ha | (%) | ha | (%) |
| | Overall area | 79.5 ha | | 79.5 ha | |
| 1 | Green area | 10 | 12.6 | 6.1 | 7.7 |
| 2 | Hotel, restaurant and bars | 1 | 1.3 | 1.22 | 1.5 |
| 3 | Cultural places | 0.6 | 0.7 | 1.0 | 1.3 |
| 4 | Central Government institutions | 1.9 | 2.4 | 2.5 | 3.1 |
| 5 | Bank | 0.2 | 0.2 | 0.8 | 1.0 |
| 6 | Private companies | - | - | 0.8 | 1.0 |
| 7 | Trade | - | - | 0.1 | 0.1 |
| 8 | International organizations | 0.6 | 0.7 | 0.6 | 0.7 |
| 9 | University, school, kindergarten and academic organizations | 2.1 | 2.6 | 2.4 | 3.0 |
| 10 | Hospital and chemist | 0.3 | 0.4 | 0.5 | 0.6 |
| 11 | Industry | 0.3 | 0.4 | 1 | 1.3 |
| 12 | Reidential apartments | 3.3 | 4.1 | 3.6 | 4.5 |
| 13 | Reserve land | 44 | 55.3 | 39.55 | 49.7 |
| 14 | The other land use types | 15.2 | 19.3 | 19.33 | 24.5 |

Table 1. The total areas for each class, evaluated from GIS and RS data sets.

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