The Compact City - Measuring Urban Sprawl using GIS

FERIM GASHI, IBRAHIM RAMADANI
Department of Geography,
University of Prishtina "Hasan Prishtina",
Mother Teresa Street, no: n/a, 10 000 Prishtina,
KOSOVO

Abstract: - It is thought that the compact city is the best goal to prevent or reduce the negative effects of urbanization on the environment. Therefore, this work focuses on the use of controlled urban planning parameters and zoning parameters, during the drafting of the urban development plan in Kosovo, which in most cases are ignored. The aim of this paper is to find a way to develop compact and sustainable cities in Kosovo, and is based on quantitative research. The paper evaluates the built area within "urban zones" in order to identify the expansion tendencies of settlements, with the aim of contributing to preventing future uncontrolled developments. Additionally, land use should be in full compliance with spatial plans, both national and local. In this case, the treatment of the city of Kaçanik was taken as an example for Kosovo's conditions, based on the demographic potential, intensity of land use, style of construction, with the implementation of the zoning parameters, showing the way of land use, which should be in harmony with the concepts of sustainable development.

Key-Words: - Compact city, urban growth, Density, Land use, Development, Sustainability

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1 Introduction

Demographic growth always needs more construction so, it is important to provide a spatial analysis of land use. This paper focuses on the expansion dynamics of built areas within urban zones due to rapid social and economic changes. The lack of quantitative and qualitative research for the Kaçanik region has affected land use, which has been unplanned and not-to-standard, and has not preserved agricultural land. In the last two decades – since 2000 – there has been considerable growth in the construction sector across Kosovo. Although, according to the spatial plan, property owners have the right to develop and use their own property in their own best interests, these regulations do not give them the right to work outside the legal framework of the local plan itself. This study will contribute to the sustainable urbanization of settlements and preservation of agricultural land. The results of the study will also help to make important decisions for built areas, by providing necessary recommendations for steps to be taken to have a land use based on common interests.

Compact cities are generally characterized by high-density urban development. They have increased socio-economic diversity and improved public realm that provide many opportunities for social interactions and exchanges; they are pedestrian friendly and equitable access to goods, services and facilities, thereby minimizing environmental degradation. On the other hand, land resources in Kosovo are limited, hence it is necessary to accommodate the population on the same land and make sure that sufficient land is also available for agriculture and other purposes.

Globally, more people live in urban areas than in rural ones, with 54% of the world's population residing in urban areas in 2014 [1]. With all global population change and trend, one can notice that Kosovo has been impacted by urban population growth. According to the Kosovo Agency of Statistics (2011) in Kosovo's urban settlements, the number of flats increased from 21,000 in 1951 to 88,000 in 1981, and has doubled today (Kosovo Agency of Statistics, 2011).

This paper focuses mainly on the importance of using spatial data to analyze and track social and economic development in the city of Kaçanik. Its aim is to get results that will help in making important decisions about the future spatial development and expansion of the city. Administrative and legal spatial planning is based on land use patterns by defining clearly the areas for the development of socio-economic activities, in order to conserve the best agricultural land and increase citizens' quality of life. To achieve this, planning is settled by laws ranging from national spatial planning at the first level, municipal

development plans at the second, and detailed urban plans at the third and lower levels. If the legal framework of Kosovo is analyzed, one would notice that it is still in need of improvement, including planning regulations set out by the European Spatial Planning Directives. Land use should be in full compliance with spatial plans, both at the national and local level, therefore the city of Kaçanik approved the Urban Development Plan for the period 2010–2020.

In the case of Kaçanik, the implementation of numerous projects in infrastructure, education, culture, sport, and other economic and residential buildings, have rapidly transformed space. However, the lack of political power and will to implement the rules set up in the development plans continue to be destructive to the land. Over the last two decades, there has been a significant increase in the construction sector. Due to the lack of administrative and legal rules and not following urban plans, the settlements in Kosovo have continued to spread in a chaotic and unplanned manner, causing distressing effects to the environment.

2 Literature Review

Cities are considered as complex organizing systems that require the interconnection of theories and planning laws with different planning parameters leading to the sustainable development of urban centers and the efficient use of urban areas. Planning theory, laws, and systems are focused on the process of planning and decision-making. Alfasi and Portugal (2007) noted the role of many factors that shape the built environment rather than the resultant properties of the built environment itself. Orderly urban planning and efficient land management, and adequate infrastructure, site protection and services are the fundamental starting points for appropriate and sustainable housing within both urban expansion and urban densification [2].

The density of construction is one of the most important measures not only to preserve land resources, but also to make the urban environment functional, as well as easier access for citizens to services. The compact city is an expression of sustainability in its entirety (figure 1).

In the process of drafting urban or municipal development plans, urban planning parameters such as population density calculations, population size calculation at the end of the projected period, land use mode, building coefficient etc. are of particular importance. All these problems have been addressed by many authors, especially from [3], [4], [5], [6], etc. Development control mechanisms and application of urban parameters help the realization of sustainable urban centers.

Population density is one of the indicators that can be calculated through the techniques of population projection [7]. An innovative approach developed by demographer Donald Newling is the population density model. It assumes that past growth rates and population density, measured in inhab/ ha, affect population changes.

The density of construction is one of the most important factors and parameters of urban development planning and urban regulatory planning. Many studies point to a strong correlation between urban density and sustainability, especially in relation to transport [8], with a number of benefits [9], [10], [11], [12], [13], [14].

Based on various publications [15] it has been proven that the compact city is one of the leading paradigms of sustainable urbanism.

Compact city planning is strongly promoted by global and local policies due to its positive outcomes in terms of contributing to the economic, environmental, and social goals of sustainability. Compactness, density, diversity, mixed land use, sustainable transportation, and green space are the core design strategies of compact city planning and development. The compact city model is justified by its ability to contribute to the economic, environmental, and social goals of sustainability, towards balancing the three components of sustainability.

- The concept of urban sustainability has been addressed by many authors [16], [17], [18], [19], [20], [21], [22], [23] who argue this process as an interaction between social and technical solutions for sustainable cities. As such, the compact city can potentially address more of the wider issues of sustainability than simply saving land from development. However, this also means that these wider claims of sustainability, such as improvements in quality of life, can be questioned on many different levels. Sustainable cities are developed on the basis of some important criteria, such as:

•High density and integrated land use,
•The diversity of activities,
•Mixed land use or heterogeneous zoning,
•Compactness of built environment [24],
•Sustainable transportation [25], and
•Passive solar design through the orientation of construction and the density of construction and "Greening" of the city [26].

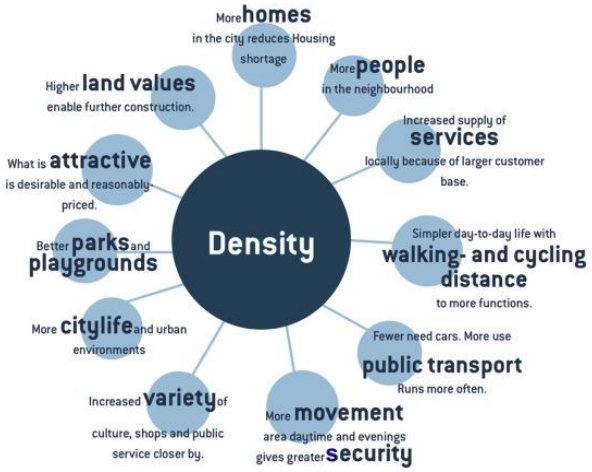

Fig. 1: Compact city planning and development: Emerging practices and strategies for achieving the goals of sustainability. Source: [27].

One of the contemporary researchers [28] addresses these advances by investigating how and to what extent the strategies of compact cities and eco-cities and their integration have been improved and strengthened. According to [29] the strategies of compact cities through new planning and development practices are being supported and utilized by applied solutions dealing with directed data smart cities. Sustainable urban development is seen today as one of the keys to unlocking the search for a sustainable world.

3 Data and Methods

During the drafting of urban development plan, it is necessary to calculate the number of inhabitants at the end of the planned period. The projection time can be up to 20 years. In addition, urban plans can be drafted for even shorter periods, but for safer urban planning are required solutions, which enable the city's long-term development. The population number is verified by calculating the data for the planned period, according to the mathematical calculations [30]. Such a calculation of the number of population for the planned period can also be done for the territory of the municipality and the state. An example in this case was the city of Kaçanik, where the number of population was calculated for the period 2011-2020.

The methods that have been used in connection with the realization of this work are statistical and mathematical methods, Comparison method, Graphic methods, GIS method, and Cartographic method. The object of research in this case is the city of Kacanik (Kosovo), while this material can be used as a methodology for the implementation of control parameters of zoning in spatial plans, in order to minimize errors in land use for the specified period in the plan. The Municipal Sector assisted data collection for this study for Urbanism, Fieldwork and other supporting literature. With the help of orthophotos and GIS, the analysis of the existing situation has been made, such as the density of residential buildings, social buildings, calculation of population density, calculation of population at the end of the projected period, unbuilt areas, the way of land use, construction coefficient, etc. All these were made concrete with maps and tables, which helped to draw conclusions for further action.

4 Study Area

Kosovo is situated in the central part of Balkan Peninsula. It has a surface of 10.905 square km. It is bordered with Macedonia in the southeast, with Albania in southwest, Serbia in the north and northeast and with Montenegro in the west. Surrounded by the mountains such as: Sharr Mountains in the east and south east, Albanian Alps in the west and Kopaonik in the north. Kosovo stretches on two plateaus: of Kosovo on 600 m over sea height and of Dukagjin on 300-500 m above sea level. It has a population of around 2 million inhabitants [31].

As a study area for this purpose, the city of Kaçanik (Kosovo) was taken. It is located in the south part of Kosovo Plateau, respectively in the Nerodime River valley, at the beginning of the Gorge of Kaçanik and Lepenc River, between the mountain and shore complexes of Sharri and Karadak, at an altitude of 447 m. Across its territory passes the highway Skopje- Prishtina and wider. This enabled this city to develop communication, administrative, craftsman ship and trade function. The urban territory covers an area of about 200 ha, with gravity zone of 211 km2, while according to demographic criteria it belongs to the group of small towns of around 13 thousand inhabitants (Municipality of Kaçanik 2011). The convenient position of this city between the mountainous systems of Sharri and Karadak had to be attractive for housing since prehistoric times [32]. Because of the relief topography, the settlement was developed in a longitudinal way along the banks of the Nerodime River, but also along the Pristina - Skopje axis, while this conditioned the linear shape of this urban center. Kaçanik has a good urban tradition, thanks to its strategic position as an important communication link connecting Kosovo with North Macedonia.

Figure 2. The geographical position of Kaçanik in the Republic of Kosovo. Source: authors, 2020

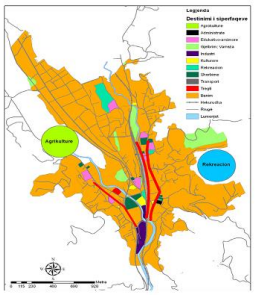

Figure 3. The Urban Development Structure of Kaçanik. Source: authors, 2020

5 Results and Discussion

In the spatial planning process, it is of great importance to discuss the gross and net density of the population of the city. The value of gross density is expressed by the number of inhabitants per 1 hectare of the territory of the city. This density depends on the size and the character of the city, the inherited structure which will be preserved according to the plan, the natural conditions affecting the construction mode, the number of social and commercial buildings that are foreseen by the plan. Gross density grows along the size of the city. Thus, it is known that for small towns the gross residential density reaches 100-120 inhabitants per hectare, for medium cities 120-140 inhabitants/ ha, while for big cities 140-150 inhabitants/ ha (Table 1) [33].

Table 1. Summary of the two case studies Population and households in the City of Kaçanik in the period 1948-2011.

Year	Population and households		Period	Index Population	Index Households
1948	Population	2.094	*1953/48*	108,6	96,7
	Households	428			
1953	Population	2.275	*1961/53*	128,5	130,0
	Households	414			
1961	Population	2.923	*1971/61*	154,4	135,5
	Households	538			
1971	Population	4.513	*1981/71*	146,9	139,0
	Households	729			
1981	Population	6.629	*1991/81*	147,8	132,5
	Households	1.013			
1991	Population	9.800	*2011/91*	137,2	135,3
	Households	1.342			
2011	Population	13.450	*2011/48*	*642,3*	*424,3*
	Households	1.816			

Source: KAS-Kosovo Agency of Statistics. 2011. Kosovo Census Atlas, Prishtina. Remark: The population in emigration was not registered at the last census in 2011.

The precise projection of population growth for the planned period, the needs for new housing, social facilities, infrastructure, green areas etc., can only be realized correctly through the implementation of urban parameters (standardized parameters). In this case the terms are used: Floor Space Ratio (FSR), Floor Space Index (FSI) and Floor Area Ratio (FAR). In the case of the city of Kaçanik: It is allowed to build up to 5 floors, respecting the coefficients of defined ISDmax= 2.8, IUP (construction coefficient) = 40%, max= 50% (based on the allowed surface for construction within the construction line), for the purpose of mixed housing (high construction, and business), with accompanying spaces per inhabitant, as well as a part of the area for greenery and recreation, parking spaces, internal roads, pedestrian paths, playgrounds for children etc., and low construction up to two floors, with the specified coefficients ISDmax= 1.3, IUP= 40%, max= 50% (Master Plan 2018).

If the natural conditions or the character of the settlement require larger areas of greenery, lower residential buildings, large health complexes such as in the case of baths, then the lowest density of housing is proposed, that is around 50-60 inhabitants per hectare. These measures can only serve as approximate orientation when calculating the required area for population. The real measures of residential density are obtained only based on the final projections, with the approval of a certain type of residential buildings, the rate of residential space per inhabitant, but in this case also should be taken into account the size of families that differ in the number of members. For the calculation of net density (residential areas or neighborhood), the residential complexes are taken together with the surfaces of the social character and the internal traffic network within the residential area.

The estimation of net density primarily depends on the height or number of building floors and the way of construction. As the number of floors increases, the distance between the buildings increases due to light, hence, the net density increases as well. The net density does not depend solely on the aforementioned factors, but also on the way the buildings are grouped, the network of educational facilities such as kindergartens, schools and social facilities, the size of green areas and the road network. According to Omar [34] as a rough orientation for the first phase of projection, these functional parts of urban territory can be obtained in percentages: residential complex (40-50%), social buildings (15-20%); green spaces (15-25%); road network, stations, squares (15-20%).

In spatial plans, space utilization is represented by numbers for population density and density of construction: Dn (net density) represents the ratio of the number of inhabitants and the number of built-up area; Db (gross density) represents the ratio between the number of inhabitants and the areas built with flats and broad functions such as: all roads, parking lots, parks, primary schools, playgrounds and recreational areas. The population density indicator determines the number of floors and through this becomes possible characterization of residential construction [35] 100-200 inhabit/ha is a parameter for ground floor and low-rise buildings 2-3 floors and 300-350 inhabit/ha is a construction parameter for up to 5 floors. The method of use and regulation of the space are represented by numeric indicators as: construction coefficient, land use coefficient and population density [36], [37]. Through this case will be analyzed implementation of zoning control parameters in spatial plans, in order to minimize land use errors for the foreseen period of time in the spatial plans. The data collection for this study was assisted by the municipal sector for urban planning, fieldwork and other supporting literature.

One of the most important issues in the process of drafting spatial plans is the preparation of the development program for the city, or the respective area. The program represents the basis for the drafting of the urban plan of the city of Kaçanik, which is considered an integrated part of the urban development plan. This plan contains the following elements: analysis of natural conditions, including geographic position; analysis of the existing state of the city; economic development of the city; the volume of residential and social buildings; calculation of the number of population forecasted at the end of the planned period; facilities and premises for municipal services such as warehouses, refrigerators, silos, slaughterhouses, bakeries, carwashes, firefighters, large garages and parking lots for public transport; complexes with special functions such as health facilities, school entities, etc., reconstruction of roads, expansion and opening of new roads; spaces for recreation, sports and entertainment inside and outside the city.

The scope and content of state planning legislation varies widely from state to state with respect to its treatment of the comprehensive plan. The American Planning Association has developed model state planning legislation in its Growing Smart SM Legislative Guidebook (2002). The guidebook suggests a series of required elements and optional elements. Required elements include: land use, transportation, community facilities (includes utilities and parks and open space), housing economic development, critical and sensitive areas, natural hazards and agricultural lands.

However, in most urban plans in Kosovo, planning parameters are not used properly. These parameters ensure an accurate population growth and the density of constructions for which the Law on Urban Planning in Kosovo gives priority (Law on Spatial Planning 2009). This approach would enable the protection of agricultural land and easy access to important social institutions. Based on the basic elements of demographic development, the results of population forecasting in the Kaçanik are also provided. The average annual rate of population growth was estimated for the period 2011–2020. It shows the per capita contribution to the population change over a unit time period. This rate, also known as the intrinsic rate of increase, expresses the change in population size as a fraction of the initial population size. It was expressed as a percentage. Population change results from both vegetative growth and migratory balance in a population and can be positive or negative, meaning population increase or population decline, respectively [38]. Population growth rate was computed as:

$$PGR = \left(\frac{1}{t}\right) \text{x } ln \left(\frac{P}{Po}\right) \text{x } 100$$

where PGR is the average annual population growth rate, ln represents the natural logarithm, P is population size in 2020, Po is population size in 2011, and t is the number of years in the study period.

According to these calculations it turned out that in 2020 the number of population of the city of Kaçanik would be 16.812 inhabitants. From the existing situation analysis, the density of dwellings is calculated on the basis of which

the net density is 92 inhabit/ha, while the gross density is 67 inhabit/ha. The city of Kaçanik had a continuous increase in the number of population during forementioned period, but not high intensity as in most urban centers in Kosovo. This is due to the influence of the two main urban centers in the vicinity: Skopje in the south (34 km) and Ferizaj in the north (19 km). The population of the city grew from 2.094, as it was in 1948, to 13.450 in 2011, or in the period of 6 decades (1948-2011) increased by 6.4 times. Out of a total population of 13.450, it is seen that the average population density in the city ranges to about 70 inhabitants/ hectare. This parameter <100 inhabitants/ hectare is not economically reasonable from the point of view of the establishment and maintenance of municipal

infrastructure. These results point to the need to change the building structure, from low-individual buildings to high buildings (IV-VI floors). The starting point for the upcoming population forecast of the city is the number of 16.800 inhabitants or 3.360 more people by 2020, with the increase of the 68.000 m2 residential area fund, which will express the increase of city density (in the center about 115 inhabitants per hectare) and the increase of intensity of total urban land use with a coefficient of 0.24, which is for some degrees higher than in the previous period.

But, as it is mention before, high density of construction doesn't always represent better life quality. This can be confirmed by the following example: Figures 3 and 4 show two compact forms from two different cities of Kosovo with the same surface (3.5 ha) but with different forms and contents. In Figure 3 (the central part of Kaçanik/ Kaçanik town) there are about 70 individual residential buildings and live 300 inhabitants, or 85 inhab/ ha, while in Figure 4 (Kodra e Diellit - Prishtina) there are six residential complexes with 240 apartments, and live over 1,100 residents, or 314 inhab/ha. Figure 3 refers to compactness, but an unplanned development; with narrow and dysfunctional roads, lack of greenery, lack of free spaces, pollution, or in a word urban chaos. Whereas, in the residential complex in Figure 4, there are about 3.5 times more inhabitants, but with much better living conditions; greenery, lighting, clean and quiet environment, easy access to services, but also protection of land from construction etc.

Figure 4. Compact urban form – Unsustainable development, Kaçanik 2020. Source: google, Imagery Date, 2020

Figure 5. Compact urban form – Sustainable development, Prishtina 2020. Source: google, Imagery Date, 2020

The construction coefficient is the ratio of the total built gross surface of all buildings (residential and public) and the total area of the city complex. In addition, the building coefficient can be calculated only for residential buildings or public buildings, gross area (total area of residence), or net area (residential or work area). From the digitization of all constructions in the town of Kaçanik, it is noted that the total surface covered with constructions is 42 ha, while the total surface of the city is 200 ha. According to the results the gross construction coefficient is 0.21, which means that 21% of the urban territory is covered with buildings, which is not in harmony with the contemporary parameters of the urban structure for small towns [39].

While land use coefficient is the reciprocal value of the construction coefficient and shows how much net land surface is needed for 1m2 of gross constructed surface area. From this calculation, the result is 4.8, which shows that in this area the load of construction land is significantly lower than in other urban areas. Obtained results show the low building density, due to horizontal development of the city, mainly consisting of private houses with gardens, which decrease agricultural land. This way of development is inconsistent with modern planning processes [40]. Individual residences in the settlement of Kaçanik have small land plots, mainly in the central zone of settlement. The characteristics of individual constructions are:

- ✓ Construction without plan,
- ✓ Low construction index = 0.21,
- ✓ Low land plot use index = 21%,
- ✓ Low density in the residential zone = 70 inhab/ha.

According to the data extracted and analyses of population and land, the main feature of urban development in this case is the unplanned territorial expansion of the city, as well as the uncontrolled and spontaneous development of residential and business areas. At the conclusion of this research, the authors emphasize that, the city of Kaçanik is subject to dynamic and chaotic socio-economic activities and therefore it is important to change the situation by taking the following measures:

1. Drafting a regulatory plan for the central zone and zoning the city as a whole; the definition of expansion of the construction area through the design and implementation of a construction line, with particular emphasis on the protection of agricultural lands;
2. Legalizing residential and business buildings in accordance with standards established by law; implementing a project for a feasibility study on the height (floors) of buildings/facilities at the urban zone level.

6 Conclusions

As a conclusion, the general urban characteristics of the city of Kaçanik are as follows: Urban

development plans in generally in Kosovo, including partially the city of Kaçanik, have not implemented urban development criteria and parameters, such as population prediction at the end of the projected period, housing density, construction parameters and the land use coefficient. In the city of Kaçanik predominates mainly low constructions (individual housing) 2-3 floors, while about 20% of urban territory is covered by facilities. Residential function covers about 70% of the built area, a parameter that indicates an insufficient development of urban functions, while the average parcel size is around 600 m2. The residential area per member is 15.2 m2/inhabitants, which is lower than the contemporary standards. Attendance of low quality material facilities is considerable, mainly in the center area. The city is characterized by a low density of housing, the density of housing in the center area is 93 inhabit/ha, in peripheral areas of the city is 50 inhabit/ha, while the average density is about 70 inhabit/ha. The population of the city grew from 2.094, as it was in 1948, to 13.450 in 2011, or in the period of 6 decades (1948-2011) increased by 6.4 times.

So, based on all these calculations, it can be concluded that the city of Kaçanik, due to its low investments and some uncontrolled professional activities, had a slow development and irrational land use. However, future developments promise to change the functional urban structure and increase the intensity of these processes, such as increasing housing density, living standards, appropriate use of parcels in accordance with urban standards, advancing urban infrastructure, building socially-owned objects, etc. All these measures will reflect on the change of structural relations within this urban system, which for the moment is not in harmony with contemporary developments. From the literature review and the short analysis of the urban planning process of Kaçanik town, it can be seen that the objective of harmonization of some standard parameters and the implementation of urban control parameters for the urban planning needs in the territory of Kosovo has been achieved, from the fact that spatial plans represent the basic framework of the overall socio-economic development orientations, as well as the assessment of impacts on the environment. In this case, the main analysis focused on the demographic potential, the manner and intensity of land use, the mode and style of construction etc. The municipal authority should focus on strategies and implementation of urban control parameters when drafting spatial plans. This is a necessary act and a key element, since all activity and organization of urban life will be linked to them, for only one purpose, to be useful as rationally as possible, while it is in full harmony with the concepts of sustainable development. It is also important that the planning code and the building regulations are replaced with more realistic regulations. Accurate forecasting of population growth for the planned period, needs for new housing, social facilities, infrastructure, green areas etc. can only be realized correctly through the implementation of urban control mechanisms (standardized parameters), with the assistance of which can be avoided eventual mistakes. This will also reflect on the protection of agricultural land, the protection of the environment, the management and use of land properly within urban territory and the functional organization of the urban system. Good management would give concrete results for resource conservation for the next generations as well.

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