HIGH DENSITY DEVELOPMENT; ARE WE SUPPORTING SUSTAINABLE DEVELOPMENT? THE CASE OF BOGOTA – COLOMBIA

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Key Words: population density, urban form, city sprawl, urbanization, social development, geographic information systems (GIS), developing countries.

SUMMERY

Economic growth and faster transport systems have facilitated low-density urbanization. Today cities face confronting pressures to decide on vertical (high-rise) or horizontal (sprawl) urbanization. A micro-level GIS analysis of Bogota urban development was conducted to understand the relationship between social, environmental and economic factors with population density. Results show that even though Bogota is one of the densest cities in the world, densification does not always represent a higher standard of living. It appears that high population density cannot be seen in isolation as an ultimate goal by all cities, particularly in the developing world. Further research is needed to better understand urbanization in the context of sustainable development. The objective of a high number of inhabitants per square kilometre needs to be placed in the context of social, economic and environmental goals.

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1. INTRODUCTION

The growth of cities is a reality around the world. In 2008, urban population exceeded the rural population for the first time, and in 2011, the global population reached seven billion. Medium projection suggests a total world population of around 9.1 billion by year 2050 (UN-PD, 2008). This population growth and migration to cities is even more significant for the developing world. In developing countries, and using as baseline the year 2000, population is expected to double by 2030 (UN-PD, 2008).

Sustainable development as a concept has been gaining popularity across many research sectors, particularly urban planning. This trend was initiated by the publication of the Bruntland Commission Report (WCED, 1995) and supported later by the United Nations 2005 World Summit in New York. With population growth and migration to cities, a focus has been placed in understanding how land-use planning interacts with the "interdependent and mutually reinforcing pillars" of sustainable development: economic development, social development, and environmental protection (UN-PD, 2008).

Across the literature a concern appears to emerge in the use of natural resources for conducting this growth in a sustainable way for current and future generations. While in the 60s and 70s the prime concern of growth was in relation to food supply (Ehrlich, 1968), today the focus is in understanding the impact of cities' growth on our environment (Urdal, 2011). In this changes to land uses is fundamental.

Given the persistent decline in the density of cities during the last century, built-up areas and urban landscape areas can be expected to triple (Nations, 2009). As it has occurred in the past, this growth is likely to occur in the outskirts of the city, causing urban sprawl (Williams, Burton, & Jenks, 2000).

In consequence, urban expansion is likely to have a significant impact on our natural environment. Natural areas that may have environmental protection value and agricultural land are likely to be taken over by urbanization with the pressure of land markets (Urdal, 2011).

Although solving growth challenges is likely to demand a multidimensional approach from governments (perhaps similar to that applied to address food security challenges in the last century), higher population density appears today as a main instrument to achieve sustainable development.

There is relative consensus among researchers that densification helps in obtaining sustainable development (Kasanko, Sagris, & Lavalle, 2007; Newton, 2000). Studies that have compared compact development with sprawl - for example Williams et al. (2000) - has concluded in favour of densification. However, these studies have mostly been conducted on already sprawling cities in the developed world. Opportunities may exist to better understand urban growth forms in developing countries where not only environmental but also social

conditions are substantial.

In this paper we study population density for the city of Bogota, a capital city in the developing world with significant population growth challenges. Today Bogota, as a metropolitan area, has different alternatives for urban form development including growing on the outskirts, increase densities on existing populated areas, or doing a combination of both.

Deciding in the adequate form to grow is complex for all cities and in Bogota this presents additional challenges. Bogota is already the densest city in the Americas region (including South, North, Central and the Caribbean) and the 13th densest city in the world (Demographia, 2011).

There are always implications to density, as higher densities require high-rise developments or people living in smaller places. However, it does not always mean people need to have inadequate housing (Patel, 2011). Long-term urban planning strategies are needed to determine the balance between high-rise buildings and smaller dwellings if a more compact city is desired.

Based on current literature, it appears that there is not clear understanding of what conditions (both social and environmental) Bogota offers as a very high-density city at a micro-level. Moreover, there are opportunities to better understand if increased densification improves the population´s wellbeing in Bogota and at the same time protect its natural environment.

This investigation focuses on answering questions about Bogota´s densification from a social perspective. For this, three main social aspects are explored; income, personal safety and mobility.

The paper is organized as follows. Section 2 briefly reviews the relevant literature, exploring arguments in favour and against densification of cities both in developed and developing cities. Section 3 presents the approach and methodology used to explore density at micro-level using geographic information systems (GIS). Section 4 describes the case study in Bogota and discusses the main results of the research. Section 5 concludes and explores alternatives for future investigations.

2. RESEARCH CONTEXT AND LITERATURE REVIEW

As new people need to be located in cities, either because they are born in them or have emigrated from country areas, cities have a challenge to find space for them. Patel (2011) shows that this debate is about allocating new land for this growth either horizontally (greenfields in the outskirts) or vertically (taller buildings on existing areas). There are always possibilities for cities to do both at the same time in different degrees (which is normally what happens) or encourage inhabitants, using market mechanisms, to use less space for housing, recreation and social activities.

All references to population density in this research are gross density, which is "the

population of the area divided by the total area, which is the sum of the private buildable areas plus the public land area" (Patel, 2011).

The debate around densification is not new (Williams, 2000) and consensus appears to be reaching in favour of compact cities for developed countries. For developing countries, research exists that have presented evidence, primarily on social aspects, in favour of and against densification. These arguments and research findings in favour of and against more dense cities are discussed next.

2.1 The Case for more population density

Those that advocate for compact city development, support their arguments in mainly three areas:

- Economy of scales
- Better used of a scarce resource (land)
- Less impact to the environment as, for example, less travel (both in distance and frequency) would produce less carbon emissions and other environmental impacts

Urban sprawl, the opposite concept of densification or compact city form, is characterised by many aspects. Sprawl has shown to result in consequences such as (Johnson & Lester, 2002):

- Energy misuse, as more energy is needed for the same outcome or wasted during transmission or travel
- Less regional open space for the community
- Land-use changes that affect food production or environmental protection
- Urban development where activity centres do not provide synergies between them or with residential areas
- Increased trips to a central business district (CBD) both in frequency and length
- Domination of the private above the public for urban space.

Planners proposing compact cities have found that it provides (Hillman, 1996):

- Use of less land and resources
- More social interaction as people are closer to each other
- Better civic services and more equality in access to them
- Decrease in trip distances because of mixed land uses
- More use of sustainable transport modes (walking and cycling) and less dependence on cars
- Less heating costs, creating less energy use and less pollution
- Centralization of activities that produces elevation of life quality, more security and more active environment and protection of jobs and services.

Hillman's (1996) investigation found that the most important outcomes of urban planning away from sprawl were a decrease in traffic extent. In addition, a more compact city form appears to reduce the presence of disadvantages such as bad neighbours; creating less social conflict and more quality in the living environment from an urban design perspective. In this, mixed land uses as a tool to increase density appears to be the more beneficial densification

strategy for suburbs (Hillman, 1996).

A compact city could be achieved under multiple urban planning models. Mixed urban form and smart growth are the two main models (Littman, 2004). An investigation on a developing country used multiple models to study urban sprawl. They identified that those cities exhibiting patterns of urban sprawl are likely to end on ecological, social and economical outcomes away from sustainability. For this case study, Smarth Growth (Littman, 2004) was found as a valid alternative for the growth of cities in Iran where urban sprawl has occurred already (Mobaraki, Mohammadi, & Zarabi, 2012).

From an environmental perspective, a compact city has a significant advantage in terms of monitoring and enforcement of legislation. A concentration of activities facilitates strategies for the diffusion of information and mechanisms to have a more vigilant government as administrative costs are reduced (Jones, 1991).

2.2 Implications of a dense urban environment

In contrast to a densification strategy for city development, literature that provides challenges for densification in large cities (particularly in developing countries) was reviewed. In this, three aspects appear as relevant to the case study developed in this research:

- Densification has normally been applied with no changes to administrative structures. The same governance infrastructure has to administer larger populations
- High-density development creates a market with a scare resource (land). The presence of a scare resource facilitates social unrest in poor areas
- Over densification could limit the ability of the environment to absorb environmental impacts

Those advocating for low density, in the form of low-rise buildings, claim various social and economical benefits including easier monitoring of playgrounds, more interactions with neighbours and less maintenance costs, as lifts are not needed (Patel, 2011).

Katz et al. (2012) investigated the provision of health services in urban areas from a governance perspective. In this research, the need for significant coordination between levels of government to ensure effective provision of services was identified. This is of particular interest in situations where disparity exists between rich and poor which exacerbates health inequities (Katz et al., 2012). From this it could be concluded that in developing countries, where disparity is common, the densification of areas without proper adaptation of the governance system would have an impact in the social services. A negative spiral could be created where conditions are created for more poor people to live in areas with the same levels of services (particularly health) and under the same administrative systems.

As compacting a city encourages land available for urbanization to become scarce (Urdal, 2011), governments are likely to require additional funds to purchase the services demanded by the denser population. These include parkland, hospitals and schools or, alternatively, to provide these services in smaller areas. For health services, previous experiences have shown

that this is the case. This situation has been exacerbated by a lack of collaboration and communication among levels of government and between their local and national communities (Katz et al., 2012).

Also for a compact city, a relationship has been found between scarce resources and violence in developing countries. These studies, normally conducted in the geographically disaggregated area, provide some support for the relationship between violence and land scarcity caused by densification (Katz et al., 2012). This appears to be exacerbated by cities where not only low income is present but a young population profile exists (Urdal, 2011).

Homer-Dixon (1999) argues that resource capture occurs in a situation of resource degradation and population growth, providing incentives for powerful groups to emerge. Imperfections in the developing world and scarcity is likely to generate unrest for those with low income (Kahl, 1998). Therefore, if it is assume that policies for a compact density create a market of scarcity of land (Bertaud, 2007), densification has an influence on violence as it modifies social dynamics.

Urla (2011) points outs in its review of literature on violence and resource scarcity that social dynamics inviting conflict occur in a micro-scale and patterns are difficult to understand at a national or state level.

From an environmental perspective, there are trade-offs of densification. Natural processes, including the absorption and processing of carbon emission by vegetation, are a vital part of the system of measures and strategies to achieve sustainable development. When analysing the planning of urban form, consideration should be placed on identifying over-densification that occurs when the urban environment places an excessive burden on absorptive capacities of the local environment (Martínez-Zarzoso & Maruotti, 2011).

From the literature reviewed in this paper, it appears that arguments against densification are built based on evidence drawn from particular experiences and generalization are difficult to do for all cities, particularly when comparing those in developed and developing countries.

In conclusion, densification and sprawl have trade-off to be considered for all cities. There is not an urban form that would achieve gains in all aspects and compromises are always required. In this, limits to densification are important as limitations on high-rise are a reality (Patel, 2011) and cities have limited space to sprawl.

In the next section the approach and methodology used in this research and applied in the Bogota case study is presented.

3. RESEARCH APPROACH AND METHOLOGY

3.1 Principles of the approach proposed

In order to investigate social and economic conditions under which density occurs in Bogota, two main principles where used: micro-level, raster GIS and sustainability factors.

3.1.1 Micro-level analysis

The literature reviewed indicated that environmental and social aspects, such as violence (Urdal, 2011), were to occur at a micro-level. The approach of this investigation focused on identifying population density and other socio-economical characteristics in small urban areas (around 2500 square meters or 50x50 squares).

Multiples studies of density are conducted at a region or sub-regional level. This is primarily a consequence of a strategic planning focus. Although these large-scale analyses are able to divide large spaces into sub-areas (Patel, 2011), they still cover regions in where multiple densities and socio-economical conditions (for example income) appear at the same time.

Additionally, a detailed examination of density facilitates the identification of urban behaviours such as commission housing, where the provision of housing has particular characteristics depending on national and local policies.

However, there are trade-offs that come with a fine grain for the analysis of densification. While some datasets could be interpreted at this level (for example transport or open space) other social aspects do not occur at a small scale or data is not collected at this scale. This is, for example, the case of personal safety (studied in this research) where the occurrence of events is scatted across the entire city. To address this, the use of Raster GIS as an advanced spatial representation of the urban environment is used in this investigation.

3.1.2 Raster GIS

GIS are computer systems and processes capable of storing, analysing and presenting geographic information with the objective to support decision-making GIS has been used extensively in multiple fields, particularly in urban planning where its analytical capabilities have permitted representation and modelling of urbanization (Paez, 2005).

GIS is a representation of our real environment and as a representation it relays on simplification. Currently there are two main models for representing reality in GIS: vector and raster.

Vector GIS represents all elements in the space as three main geometrical elements: points, lines and polygons. It is commonly used to conduct analysis under discrete spatial conditions such as political boundaries, city blocks or roads. Accuracy in the vector model depends on the level of detail and precision of the tools used to acquire the information.

Raster GIS, on the other hand, simplifies the real world by representing it as a grid. Every part of the space under study belongs to a cell and characteristics, such as density, land-use or elevation, are assigned to each cell. The size of the grip determines the accuracy. Although commonly misconceived, raster is neither more nor less precise than vector. Both representations could provide high level of accuracy depending on the design of the data model.

However, vector and raster GIS models have different analytical possibilities (Chang, 2009). Commonly raster GIS have been used to describe continues elements or phenomenon (for example elevation or slope).

Raster model has been identified as the most feasible for the needs of this research as population density could be considered as a continuous spatial phenomenon that is present in every space of the city.

Moreover, the need to develop analysis at a micro-level allowed raster GIS to divide in a more effective way the urban area analysed in comparable areas. In vector GIS, however, the analysis would probably have had to be conducted on existing boundaries such as neighbourhoods or wards, creating difficulties in comparing them as they would have different density characteristics.

Additionally, using rates GIS to integrate socioeconomically indicators sourced differently and with widely representation possibilities, appears as the most feasible model. This was particularly valid for those indicators (such as accessibility to public transport) where distance to the service from every area of the city needs to be considered. For this type of Euclidian distance analysis (Greenberg, Rueda, Hestir, Santos, & Ustin, 2011) raster GIS has proven to be a better option.

In this research the study area was represented as a continuous raster grid with a cell size of 50 x 50 meters (2500 square meters in area for each cell of the grip).

3.1.3 Sustainability factors

Multiple factors could be used to analyse urban characteristics under which density occurs in a city. The sustainability pillars for sustainable development: economic development and social development developed by the United Nations 2005 World Summit in New York were used in this research for selection of key factors to be considered in this research.

Three factors, addressing the pillars, were analysed alongside population density at a micro-level. These factors are:

- Income: Level of economic development by inhabitants
- Mobility: Accessibility of the different areas to public transport and the arterial road network
- Personal Safety: Level of criminal activities based on occurrences of murders

The next table represents how each indicator was transformed into a raster GIS model in order to be considered under the pillars of sustainable development.

Table 1: Factors for Sustainable Development

Indicator	Raster GIS model layer	Sustainability Pillar	Key analytical question for analysis
Income	Continuous surface representing level of income or economic capacity of inhabitants (low, medium or high)	• Economic development • Social development	What is the level of economic development and density? Are the poorest living in densest areas?
Mobility	Line interpolation of the density of transport services available based on the public transport network and arterial road network	• Social development • Economic Development • Environmental protection	Can high-density areas access economic opportunities? Is public transport available to high dense areas?
Personal Safety	Point interpolation of density of murder occurrences across the city	• Social development • Environmental protection	Is low density inviting crime? Is high density facilitating negative social conditions?

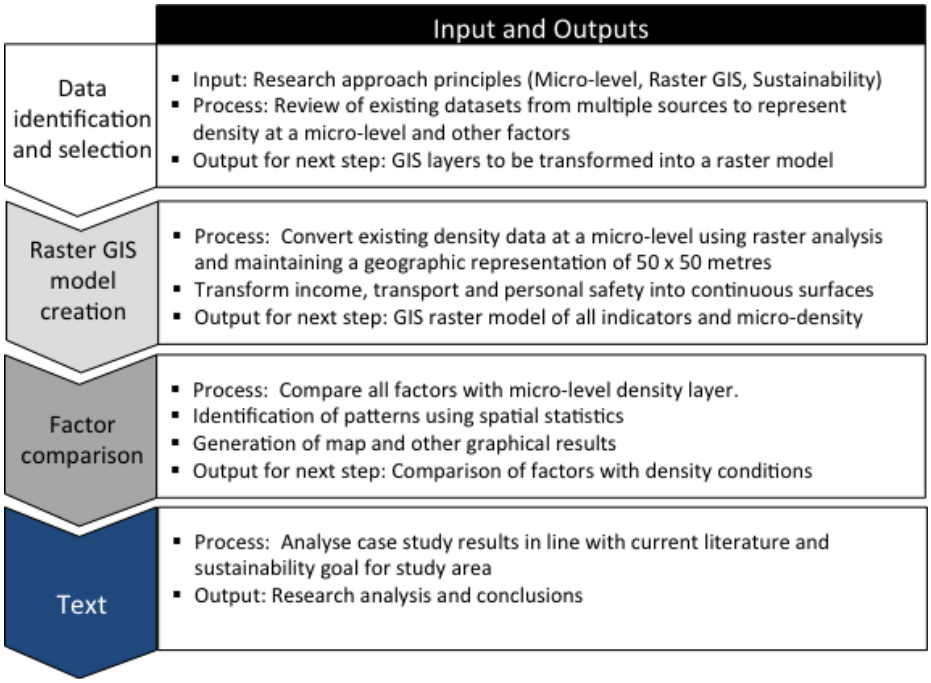
Source: authors' elaboration

3.2 Methodology

The methodology used in research had four steps: Data Identification and Selection, Raster GIS Model Creation, Factor comparison, Analysis and Results. The objective and outcome of each step is explained in

Figure 1.

Figure 1: Research Methodology



Source: authors' elaboration

4 CASE STUDY: BOGOTA

4.1 Background conditions

Bogotá is the capital of Colombia, a developing country classified as low-middle income (Martínez-Zarzoso & Maruotti, 2011). For Colombia, Bogota is the largest city in terms of area and population in Colombia. The city extends across 1637 square kilometres, 355 of which are urbanised (Planeación, 2010). Bogota is the densest city in the region (including South, North and Central America and the Caribbean region) and the 13th densest city in the world (Demographia, 2011). Population in 2010 was 7.3 million inhabitants with a density of about 20,500 inhabitants per square kilometre in the urban area (Planeación, 2010).

From a physical perspective, Bogota is located on a plateau. It is constrained by mountains to the east and part of the south and has significant space for urban sprawl both in the west and north where flat areas are used for agricultural or low intensity industries.

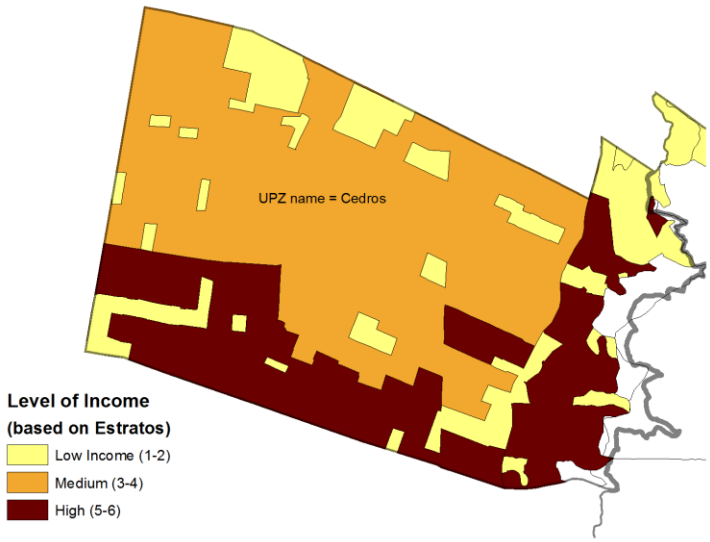
Bogota is an independent administrative entity from its surrounding municipalities. It`s special administrative status gives it significant planning independence from state and national authorities. These administrative conditions are likely to have limited the expansion of the city in the west and north. However, in a southern neighbourhood municipality called Soacha, a significant population growth of low income occurs (Dureau & Gouëset, 2011).

The spatial distribution of population and urban activities shows important differences throughout the city. Low-income households are settled in the southern and western borders. These peripheral zones have the lowest formal employment densities and the highest population densities. These dense areas are developed based on low-rise, creating that the high density is achieved due to small dwellings close together (Planeación, 2011). On the other hand, northern and central locations are characterised by high-rise developments, lower population densities, and a high concentration of formal employment (Bocarejo, 2012).

Bogota municipality is divided into 112 planning zones called Unidades de Planeación Zonal (UPZ) UPZ has in the past been the main geographic unit to analyse densities in Bogota. The size of each UPZ will vary depending on existing land uses and building form. The diversity of UPZs in Bogota make it possible that they cover areas of between 0.2 and 10 square kilometres and population ranges between 300 to 100.000 inhabitants.

Although there are UPZs that have uniform socio-economic characteristics across their entire territory, it is common that these zones provide a range of urban development particularly on the east where illegal and recently legalised low-income settlements are near high-income areas. ***Figure 2*** shows the UPZ of Cedros where multiple levels of income can be identified.

Figure 2: Multiple income levels in Cedros UPZ in Bogota



Source: City of Bogota and research analysis

Next, key findings in relation to population density at a micro-level and its relationship to sustainability factors are presented and discussed.

4.2 Micro-density conditions in Bogota

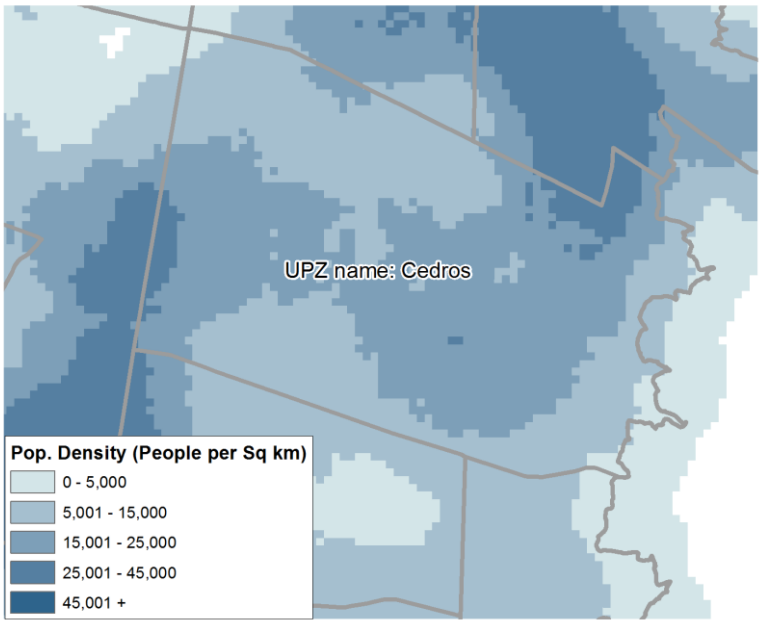
Using a kernel distribution of point data (Wu1, Qiu1, & Wang, 2007), a continuous surface was developed for density in Bogota. This was possible based on an interpolation from point data for population data obtained for each city block (see ***Figure 3***). After multiple data cleanings and taking base population figures for 2010 in each UPZ, a surface was interpolated to determine micro-level density.

*Figure **4*** shows population density information for each UPZ and the calculation conducted at a micro-level on a raster surface (each cell of 50 x 50 metres or 2500 square metres).

Figure 3: Population Data per block in point form

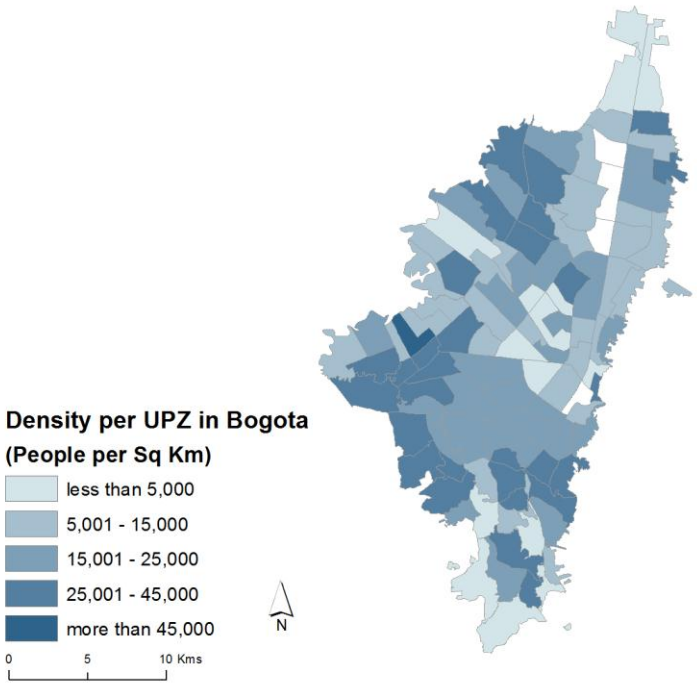
Source: City of Bogota (point data 2005) and research analysis

Figure 4: Micro-density distribution (Cedros UPZ)



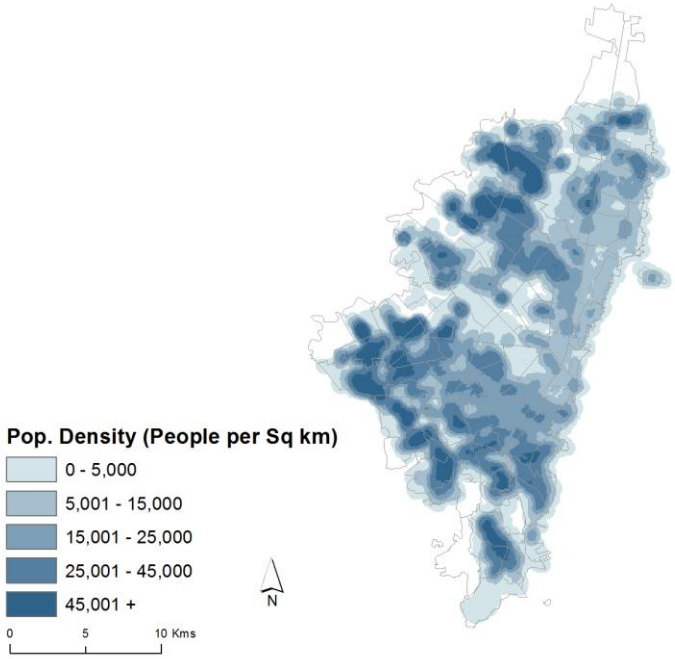
Source: City of Bogota (UPZ data 2010) and research results

Figure 5: Population density in Bogota per UPZ



Source: City of Bogota (UPZ data 2010) and research results

Figure 6: Micro-level population density for Bogota



Source: Research results and data from City of Bogota (2005, 2008,

As can be seen from the previous Figures, density across the city has been classified across 5 groups. These groups are:

- Very Low (less than 5000 inhabitants per square kilometre)
- Low (between 5001 and 15000 inhabitants per square kilometre)
- Medium (between 15001 and 25000 inhabitants per square kilometre)
- High (between 25001 and 45000 inhabitants per square kilometre)
- Very High Density (more than 45000 inhabitants per square kilometre)

This range of population densities is considered to represent conditions in Bogota well. These ranges are the basic classification for conducting comparisons between density and the multiple sustainability factors studied for Bogota. However, this classification is not intended to be used comparing densities in other cities, particularly in the developed world, were even the Very Low group could be considered high density.

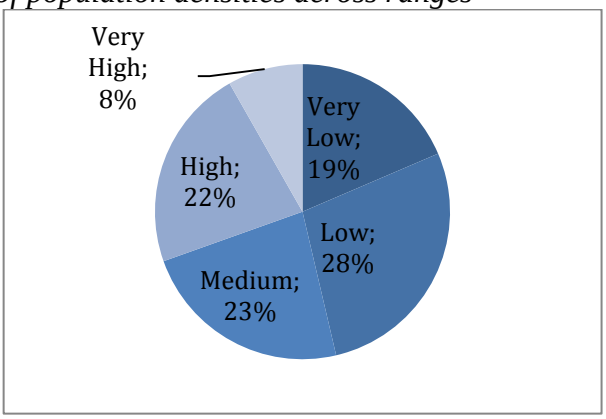
Further analysis of the density dataset allowed calculation of percentage of population living at the different levels of density. ***Table 2***and ***Figure 7*** show the results.

Table 2: Distribution of Densities in Bogota

Density range names	*Density range numbers (People per Sq. kms.)*	*% of total city area in each range*	*Estimated range area (square kms.)*	*Estimated population in each range*	*% of total population in each range*
Very Low	less than 5,000	19%	66,3	174.953	2%
Low	5,001 – 15,000	28%	99,1	992.329	13%
Medium	15,001-25,000	23%	82,9	1.706.040	23%
High	25,001-45,000	22%	79,3	2.671.974	36%
Very High	45,000 or more	8%	29,4	1.841.855	25%
Total		**100%**	**357,0**	**7.387.150**	**100%**

Source: Research results and interpolated data for 2010 UPZs (Planeación, 2011)

Figure 7: Distribution of population densities across ranges



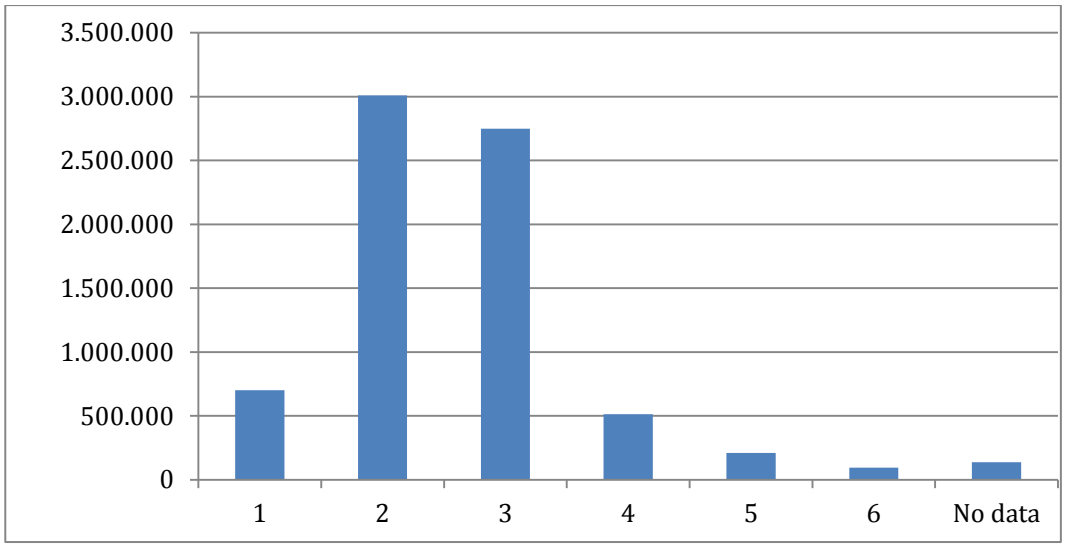
Source: Research results

It is important to note that all numbers in the previous table are from estimations made from the raster interpolation and adjustments were required. Average density calculated using the methodology developed in this research was 19,700 people per square kilometre. Official density data for 2010 was 20,500 inhabitants per square kilometre (Bocarejo, 2012), providing a reasonable error factor.

4.3 Density and low-income residents

In Bogota, a system of classification of households based in their income and economic condition has been developed (Birchenall, 2001). This system allows allocating an "estrato" or strata to each dwelling of the city, which represents general income levels. Estratos range from 1 to 6 where 1 is where the poorest live (often bellow the poverty line) and 6 for the richest areas.

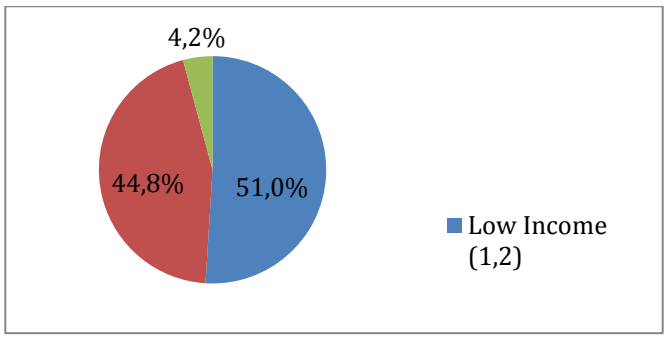
Figure 8 shows the distribution of population per estrato in Bogota calculated using the micro-level density distribution and data provided by the City of Bogota for 2010.
Figure 8: Inhabitants per Estrato in Bogota



Source: Research results and estratos data from City of Bogota (2010)

Based on the estratos data, three population groups where built: Low-income, (estratos 1 and 2) Medium-income (estratos 3 and 4) and High-income (estratos 5 and 6). These groups were made to facilitate comparison between density factors and economic factors. ***Figure 9*** shows the distribution of population in these groups.

Figure 9: Ranges of income in Bogota



Source: Research results and estratos data from City of Bogota

Research results found that significant higher densities occur in both Low and Medium-Income levels (

Table 3). In high-income areas population is almost three times lower than poor areas. This results in a significantly larger area occupied by High-Income inhabitants compared to the other two income levels. While for Low and Medium-income levels, land occupation and % of population are comparable, this figure is significantly large for the High-Income group.

Table 3: Summary analysis population density and income

Analysis Indicators	Low-Income (1,2)	Medium-Income (3,4)	High-Income (5,6)
% population per income level	51%	45%	4%
% area per income level	43%	46%	11%
Gap between % population and % area	8%	-1%	-7%
Average Population Density per income	30.193	24.995	10.539

Source: Research results

Table 4: Population density for Low-Income in Bogota

Density range levels	Density range numbers (People per Sq. kms.)	Percentage of Low-income across population density ranges
Very Low	less than 5000	1%
Low	5001 - 15000	1%
Medium	15001-25000	2%
High	25001-45000	54%
Very High	45000 or more	41%

Source: Research results

Table 4 shows the results after analysing simultaneously income and population density data for Low-income persons in Bogota. Low-income population appears primarily on the highest density ranges. It is particularly significant that at the first three ranges of population there is nominal presence of Low-income inhabitants. All Low-income in Bogota concentrates in High and Very High density areas.

4.4 Population density and mobility

Mobility is a crucial aspect for achieving sustainable development as all three pillars could be significantly impacted by changes in how people move. Therefore, mode use, accessibility to them (both physically and economical), and distance travelled become fundamental.

In this investigation we analysed physical accessibility to transport as a measure of mobility for Bogota. Three datasets were used for this purpose:

- 2010 bus routes line GIS from Bogota´s road authority
- 2011 arterial road network from Cadastre office

- 2010 BRT network (both stations and feeder routes) from Transmilenio S.A.

Using point and line density interpolations (see Raster GIS section on the Research Approach chapter of this paper), density of transport for all areas was calculated. ***Table 5*** shows a summary of results relating to population density.

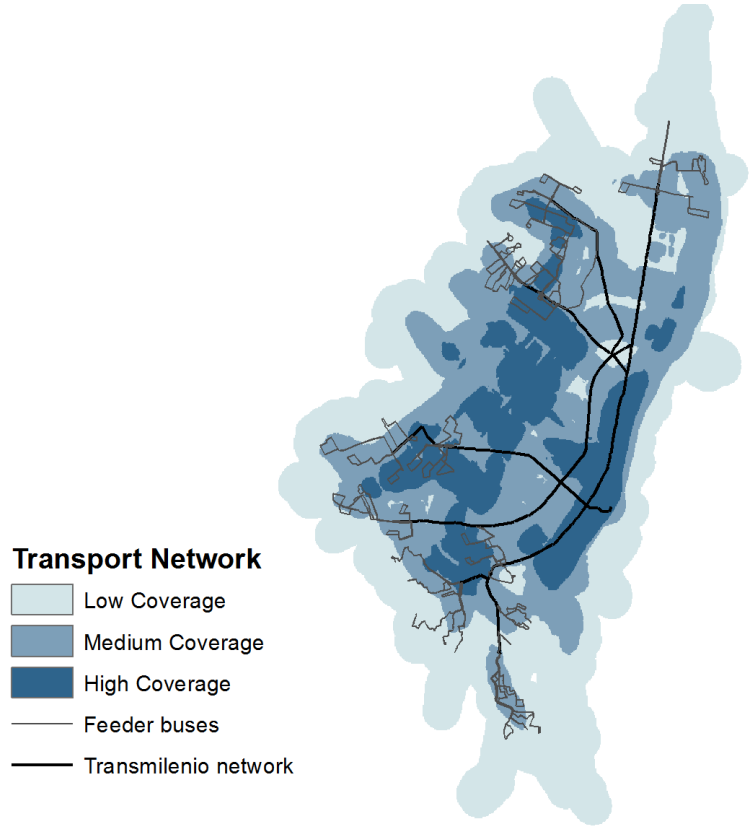
Table 5: Mobility and population density analysis for Bogota

Level of Coverage in area of the Transport Network	Very High Density	High Density	Medium Density	Low Density	Very Low Density	% total city area
Low coverage	12%	18%	3%	30%	52%	**25,3%**
Medium Coverage	71%	52%	62%	47%	35%	**49,9%**
High Coverage	17%	30%	35%	23%	13%	**24,8%**

Source: Research results

The next figure represents in a map form the different levels of mobility coverage for the city with the BRT Transmilenio network.

Figure 10: Transport coverage in Bogota (this research)

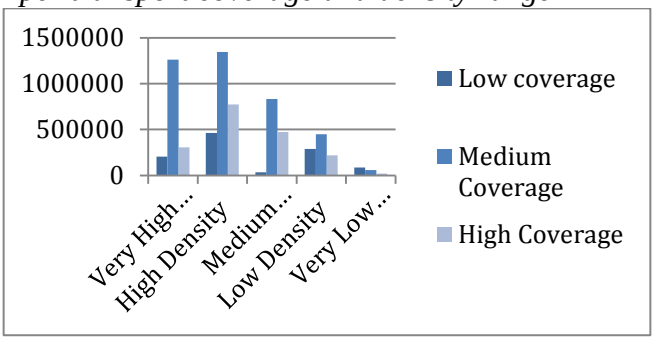


Source: Author's elaboration

Most ranges of population density would have their levels of coverage as Medium. This is also valid for Very High and High density ranges. Medium density has the highest percentage of area in high coverage. The transport network covers poorly Very Low density areas.

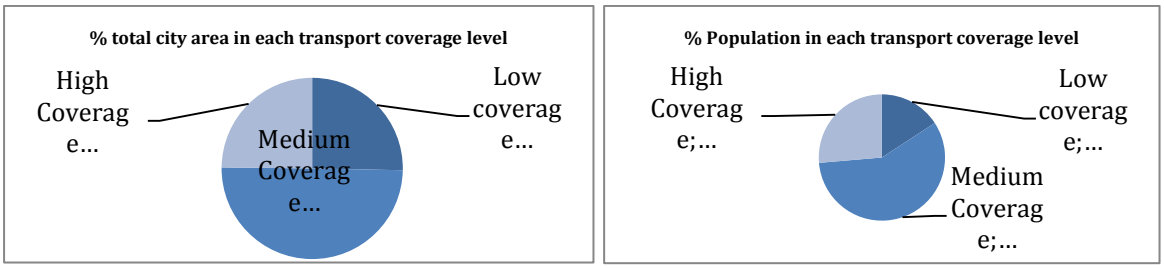
The following Figures (***Figure 11*** and ***Figure 12***) present mobility and density relationships.

Figure 11: Population per transport coverage and density range



Source: Research results

Figure 12: Population and area coverage level of the transport network



Source: Research results

4.5 Population density and personal safety

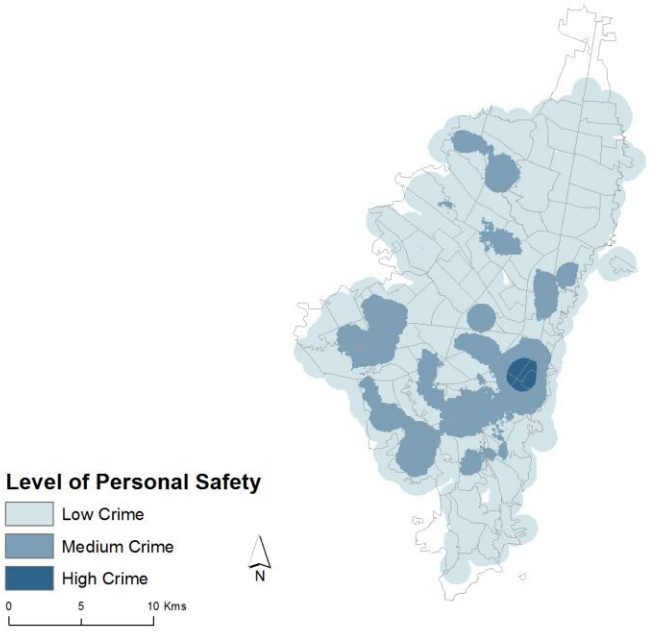
Personal safety was identified in this research as a key element to support sustainable development of cities in developing countries.

Personal safety conditions were processed using a kernel GIS (Brunsdon, Corcoran, & Higgs, 2007) interpolation as a means to convert individual events (represented as points) into a continuous surface. For this, data of homicides for the years between 2000 and 2003 was used. This data was sourced from the National Coronel office of Colombia (Departamento de Medicina Legal). Data was classified into three level of personal safety using a natural breaks classification:

- Low Crime
- Medium Crime
- High Crime

Map representation of the results (***Figure 13***) shows a significant concentration of high crime in the central area of Bogota (old town). These levels of crime were between 3 and 5 times larger than the rest of the city.

Figure 13: Analysis of personal safety for Bogota



Source: Research results and homicide data from Departamento de Medicina Legal

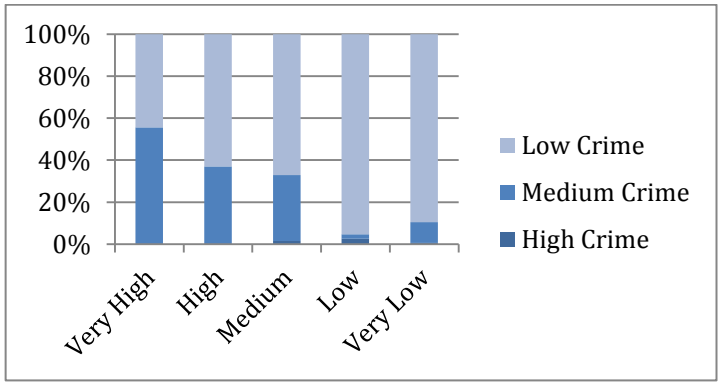
Analysis of level of density and crime does not appear to show significant trends between these two variables. ***Table 6*** shows results of this research for these variables.

Table 6: Analysis Population density and personal safety factors for Bogota

Personal safety levels	**Percentage of area for each population density range**					
	Very High	High	Medium	Low	Very Low	All city
High Crime	0%	0%	2%	3%	1%	1%
Medium Crime	56%	54%	29%	2%	10%	36%
Low Crime	44%	91%	62%	98%	90%	64%

Source: Research results

Figure 14: Crime levels per density range



Source: Research results

Medium density range appears to occur in areas where most of the crime occurs in Bogota. Additionally, for the data used in this analysis, crime in Bogota has a significantly low presence in Low and Very Low density areas (***Figure 14***).

5 SUMMARY AND DICUSSION

The application of the research approach to better understand density conditions in Bogota provided insight into the application of micro-level density analysis and factors for urban sustainable development.

Based on comparing results from this research with official population data and density for Bogota, the methodology used appears to provide a consistent way to conduct population density at a fine grain. Raster GIS modelling - in the form or kernel, liner and point surface interpolation – was confirmed to be a feasible method to analyse population density and other factors.

For the city of Bogota and after analysing sustainable development factors with population density, it was found that:

- As expected Low-Income areas of Bogota have larger population density. However, it was surprising that the difference between Low/Medium and High Income densities are very significant. In Bogota, wealthy areas are 3 times less dense than the poorest areas and 2.4 less than Medium-Income areas.
- Transport network coverage in Bogota has an uneven distribution. Most density ranges have a medium level of coverage. Good transport coverage does not appears to cover the most dense areas of the city.
- Personal safety in Bogota is also uneven. High incidents are concentrated in and around downtown (old town) where population densities are not high. Low crime also occurs in low density areas. Medium density areas (between 15,000 and 25,000 inhabitants per square kilometre) have the largest incidents of crime.

In summary, high densities in Bogota are characterised for Low-Income, average to poor transport coverage and medium crime levels.

While densification is justified under economies of scale theory for the provision of services, it could be concluded that high density cannot be seen in isolation as an ultimate goal to be achieved by all cities in the developing world. Further research appears to be needed in the area of urban policy with the objective to better understand holistic dense urbanization, where not only a high number of inhabitants per square kilometre is the objective, but also social, economic and environmental goals.

This research could not provide conclusions for consequences between higher density, social unrest and land scarcity in poor areas. These relationships are also an alternative for further investigation.

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