

# Urban Geoplanning: Computational Methods and Models from an Urban Perspective

Ricardo Gómez Maturano, Marielena Medina Ruiz\*, Ma. de los Ángeles Martínez Ortega

Instituto Politécnico Nacional,  
Escuela Superior de Ingeniería y Arquitectura, Unidad Tecamachalco,  
Mexico

**Abstract.** In the new digital age, with the emergence of new information and communication technologies (ICT), Big Data (BD), the Internet of Things (IoT), and Artificial Intelligence (AI), it is essential to propose new perspectives to take advantage of these innovations that address growing urbanization processes and global environmental challenges, using advanced approaches and innovative technologies to plan and develop cities in a sustainable manner. This chapter provides a systematic review of tools, methods, and studies in the field of urban geoplanning. This new tool can be defined as a systematic approach that uses geospatial technologies, ICT, AI, BD, and IoT to design, evaluate, and manage territorial development. Its approach integrates and articulates spatial data and socio-environmental analysis to support territorial planning and management.

**Keywords.** Urban geoplanning, spatial technologies, territorial development.

## 1 Introduction

In recent years, our understanding of cities has been enhanced by the implementation and exploration of new technological tools that optimize the interpretation and prediction of complex urban processes in their geographical environments. In this context, territorial geoplanning, also referred to in the English-speaking world by Topchiyev et al. (2010) as geoplanning, has emerged. This is a methodological approach applied to geography and urban planning, focused on the integration of other disciplines such as physical geography, human geography, economics, and ecology, to

plan the use of a geographical space in an efficient and sustainable manner (Lisetskii et al., 2014). In fact, it forms a framework of strategies and actions that are operational and lead to land management through comprehensive resource and infrastructure planning (Topchiyev et al., 2010) in both urban and rural areas.

One of its main characteristics is what is known as geographical holism (Topchiyiv et al., 2022), whereby reality can be observed from the Earth's surface layer to the geosphere. This transformation is contextualized at the global level, with the latest scientific revolution (Andrade et al., 2009) pushing the scientific community, as Topchiyiv et al. (2022) call it, towards an "information revolution" based on technological foundations. Likewise, contemporary research for Grigoreva and Buryak (2016) has been linked to the intersection of landscape ecology, environmental modeling, and geoinformatics, which require technological resources for their study and understanding.

Territorial geoplanning in the digital age uses information and communication technology (ICT), combining geoinformation and geotechnology to perform geospatial data analysis, visualize it, and subsequently make strategic decisions in areas such as urban planning, environmental management, and even the redesign and evaluation of public policies, among others (Geertman and Stillwell, 2000). So, in the end it is a comprehensive process involving participation by various actors.

It is considered disruptive and capable of driving the digital transformation of societies

through integration with advanced technologies such as big data [BD], understood as “a new generation of architectures designed to extract value from large volumes of data from different sources [...] recognized by three characteristics: volume, variety, and velocity” (León, 2019, p.55); on the other hand, the Internet of Things [IoT], which “enables the connection between remote sensors via the internet, making the data produced by each one complementary, which facilitates a response in almost real time” (León, 2019, p.60); and finally, artificial intelligence [AI], which stands out for having the “ability of machines to use algorithms, learn from data, and use what they have learned in decision-making just as a human being would” (Rouhiainen, 2018, p.17). It is understood that a digital machine can perform tasks that require human intelligence (Ricardo et al., 2021).

Therefore, these technologies play a very active role in urban planning, generating new results in terms of their application, in addition to their ability to holistically study contemporary challenges in territorial development. Thus, their disruptive nature and transformative potential can be observed, in principle, through the development of computational models that simulate development scenarios and anticipate problems, enabling proactive and adaptive planning that reduces risks and optimizes resources.

On the other hand, geoplanning benefits from geographic information systems (GIS) as a technology that allows space to be studied at a geographic and quantitative level. This is a system that has a set of theoretical and methodological tools (Buzai et al., 2019) that collect, store, retrieve at will, and visualize real-world data at the spatial level for different purposes (Burrough et al., 2015) and that are geographically referenced, in other words, it allows data to be managed according to its location (Heywood et al., 2011). For others, it refers to the study of issues arising from the management of spatial information and is conceptualized based on three key elements: the

first is computer hardware, the second is software application programs and modules, and the third is interconnected users (Burrough et al., 2015); thus, through databases and how the network infrastructure is designed.

However, they are not only applied to technological issues in terms of modeling and forecasting, but also as an informative support resource for their implementation in management decision-making (Buryak et al., 2014). Additionally, the use of GIS facilitates the creation of computational models through aspects such as:

First, spatial analysis (Buzai et al., 2019), the application of different mathematical and statistical techniques to data that are distributed in a particular way in a geographical space were, based on GIS, specific procedures can be used according to the type of study. Miraglia (2018) adds that this process studies space and its analysis model can describe its configuration, which can be static, evolving, or even dynamic.

Second, terrain modeling or digital elevation modeling (Mena et al., 2011) is a geomatics process that allows us to see the specific characteristics of a place, such as its surface area, slope, curvature level, and terrain classification, including basins, river junctions, hills, ravines, and geomorphological features, among others.

Thirdly, network analysis (Buzai et al., 2019), which is used to analyze structures and connection dynamics between various elements such as infrastructure, population flows, economic relations, or goods and services, resilience, and risk management within a territory to facilitate the visualization and analysis of the patterns of relationship or impact between them. These are represented by nodes (points of interest in space), links (connections between nodes), or networks (sets of nodes and links). This can be done using GIS, mathematical models, and data analysis [Big Data] (Maté, 2014).

The fourth consists of remote sensing, also known as teledetection (Sánchez, 2018), which is

a rather specific technique used mainly in ecological landscape studies, vegetation indices, environmental and climatic issues, as it allows information to be acquired at the earth's surface level by detecting and measuring the electromagnetic radiation reflected or emitted by objects on that surface. It uses sensors that are in airplanes or drones or at the spatial level from satellites (Romero, 2016). This information is acquired through perception images which, when processed using GIS, allow for the analysis of spatial heterogeneities or homogeneities at the digital level, according to Moizo (2004), since each image is composed of pixels from which information is abstracted, calculated, or tabulated, making it possible to perform analyses at different territorial scales.

On the other hand, in fifth place are multivariate analyses (García and Humacata, 2019) that capture spatial asymmetries and derive from the combination of three or more variables, allowing for the definition of clusters based on high internal homogeneity and, depending on the case, heterogeneity in relation to other spatial units. This means that, through this process, it is possible to obtain homogeneous socioeconomic areas, for example, that reveal the internal heterogeneity of a study territory. Thus, the use of these technologies in geoplanning plays an important role in different urban and regional scenarios and scales, as it is often a dynamic technology with significant potential for the future (Scholten and Stillwell, 2013) by providing tools and data that enable planners to take informed action for the development of efficient and livable territories.

This raises the question: how do information and communication technologies, big data, the Internet of Things, artificial intelligence, and geographic information system methodologies generate geoplanning processes?

In this regard, this chapter systematically presents a review of global studies that have used geoplanning and, on the other hand, examples of methods and tools that have been applied at the Instituto Politécnico Nacional. Particularly in the

geomatics and urban processes workshop offered as part of the graduate studies program at ESIA Tecamachalco.

## 2 What is Urban Geoplanning?

Geospatial planning has undergone significant evolution since the 1990s thanks to technological advances and models or practices that guide urban planning (Geertman and Stillwell, 2000). In this process, aspects such as the greater availability of geospatial data for GIS and remote sensing have stood out. On the other hand, the integration of geo-information on land characteristics that has an explicit reference to geographic locations (Goodchild, 1992) in planning allows data to influence public policy.

Also, since the development of spatial data infrastructures [SDI] (Nebert, 2004), which are connected in such a way that they can be used and analyzed comprehensively, as they include metadata catalogs, data services, tools, and applications. In fact, according to Maguire and Longley (2005), SDI specifically refers to platforms that provide policy frameworks and technologies that enable different organizations to share, access, and use such data, as each country has interactive databases or platforms designed to contain layers of information, generating accessibility and interoperability.

As a concept, it has been understood since the application of planning techniques based on a geospatial context (Lisetskii et al., 2014). In the English-speaking world, it is known as geoplanning (Topchiyev et al., 2010) because it is a systematic approach that leads to the development and management of a territory, using spatial data to evaluate possible alternatives and decisions on the use of natural soil resources (Shen, 2012). In fact, it involves geographic modeling in urban and regional planning (Wilson and Fotheringham, 2008).

It is also understood as the process of using geospatial technologies to design and evaluate development scenarios, leading to more effective and adaptive planning (Steinitz, 2012).

Furthermore, it is based on an approach that integrates GIS and spatial analysis into urban and regional processes, leading to a deep understanding of the temporal and spatial dynamics of a city (Batty, 2013).

Geoplanning is therefore an interdisciplinary field that combines analytical tools for planning, management, and spatial analysis for territorial development (Goodchild and Janelle, 2010). It focuses on the use of technologies in planning, but from a more technical and data-based approach.

However, in Anglo-Saxon countries, there tends to be a slightly more formalized interaction of geospatial modeling techniques in urban management processes together with GIS, but with a marked emphasis on accuracy, sustainability, and efficiency. Therefore, according to Steinitz (2012), it is more oriented towards advanced technology that includes the use of geodesign, a concept that originated in the 2000s and 2010s that evaluates and designs development scenarios, as well as the use of predictive analytics and big data (Kitchin, 2021), which were incorporated into urban and regional planning in the 2010s, marking a new stage in precise geoplanning.

On the other hand, the concept of geoplanning stems from the need to integrate geospatial information banks into management processes (Sili, 2022). However, it is an approach that has been developed in response to the challenges of rapid urbanization, vulnerability to natural disasters, urban informality, and the imperative need to achieve sustainable and inclusive development, particularly in Latin America (Su, 1998). It stands out for its holistic nature, linking GIS with the social, economic, urban, and environmental processes of a given region (Tomlinson, 1998) in urban and rural contexts (Rodríguez and Glasson, 2004). These are, in effect, tools that analyze and plan land use and territorial development (Pietsch, 2012), and in turn support regional planning decisions (Hopkins, 2001) and natural resource management (Yeh, 1999).

From an urban planning perspective, it plays an important role as it links environmental, social, and economic factors and urban infrastructure planning with data applied to issues such as zoning and land use, identifying suitable areas for each; finding flaws or imbalances and even disconnects in terms of distribution, carrying capacity, and supply.

On the other hand, it leads to risk assessment based on the identification of areas prone to flooding, earthquakes, hurricanes, and extreme temperatures, which influences the location of projects or emergency planning policies based on the data captured and analyzed. Lisetskii et al. (2014) argue that geoplanning of a territory at the urban level is a specific environmental training activity in territories of a certain size and aims to support the spatial diversity of the land and the protection of the environment, based on the possibility of planning rural territories. In fact, they add that the key components are nature, population, and economy.

We can conclude that urban geoplanning can be defined as a systematic approach that uses geospatial technologies, such as Geographic Information Systems (GIS), information and communication technologies, big data, the Internet of Things, and artificial intelligence to design, evaluate, and manage the territorial development of a given region. This approach integrates spatial data with social, economic, urban, and environmental processes, enabling more effective and adaptive planning. It focuses on the use of analytical tools and technologies to understand the temporal and spatial dynamics of a territory, facilitating informed decision-making in land use management, urban planning, and natural resource management.

### **3 Urban Geoplanning in Latin America**

To understand how this concept is applied, various studies have been published that implement geoplanning based on urban

processes. For example, from a social and economic perspective, García and Humacata (2019) classify data spatially using exploratory data analysis and multivariate analysis. Specifically, they use a standardized average approach based on urban cost and benefit variables, with their cartographic results showing an analysis of the social and housing status of the population through spatial distribution under different levels of favorability.

Another example is provided by Rasse et al. (2019), who examine urban expansion, economic factors, and housing policies in Mexico City and Santiago, Chile. Although these are Latin American cases, this study develops a methodology for analyzing and comparing processes resulting from the expansion and social and spatial transformation of these cities, using demographic, territorial, and socioeconomic data. Therefore, geoplanning is applied through the construction of cartography using computational models that visualize and analyze gentrification with and without displacement.

In environmental matters, authors such as Humacata and Buzai (2018) conduct a spatial analysis of land cover change using GIS, which leads to the construction of statistical models and linear and multiple regression models (Chowdhur, 2006) as they allow for the study of variation relationships in a specific space at the social and economic level, as well as issues of deforestation in forest areas (Jaimes et al., 2010). Lücke et al. (2014), meanwhile, consider that access to renewable energy sources is becoming increasingly important in different industrialized countries. They therefore propose an optimization approach for the geographical planning of power plants, which seeks to find suitable locations for different types of plants based on environmental constraints from evolutionary strategies in Germany.

Therefore, the performance and efficiency of this type of energy system depend on its location and the application of geoplanning strategies to enhance its value. Melentyev (2022) highlights the geoplanning of the Prokhorovsky district in the

Belgorod region, which is one of Russia's leading entities in terms of agricultural production and occupation. He approaches it from the perspective of optimization in the form of systematic and rational conservation of both water and soil in landscapes, based on the optimization of conservation in areas exposed to erosion. In fact, he states that in geoplanning, it is important to choose approaches and criteria that isolate divisions of the territory in space from operational units, design, and monitoring based on the insertion of watersheds.

In the city of Zagreb, Croatia, Mihalić et al. (2012) use different existing data to understand the geological, seismic, and hydrogeological conditions of the area, mainly due to the presence of the Pannonian Basin. Here, geological maps of soil composition, seismic activity, and landslide inventories were used, which are essential for urban planning and mitigation. Finally, geological risk zoning maps were also used. Therefore, accessing and processing this type of information allows for a comprehensive assessment to take safe and sustainable planning actions.

Now, from an environmental and risk perspective, the study by Utami et al. (2022) uses spatial analysis to correlate two variables: urban growth and changes in surface temperature in the city of Palembang in Indonesia.

From an architectural and urban planning perspective, Gambo et al. (2018) apply geoplanning from a systematic approach that includes selecting a study area, collecting data through satellite images from different years, and analyzing this data to assess changes in land use between 1989, 1994, and 2016. They opted to use advanced image analysis techniques and object-based analysis, pixels, and support vector machines.

Geoplanning in this study is manifested through the application of advanced geospatial technologies, the detailed evaluation of changes in land use over time, and the proposal of conservation and monitoring measures to ensure the protection of protected areas and surrounding biodiversity.

Benavente et al. (2011) provide a clear example of the implementation of ICT through future scenarios and models in planning on a metropolitan scale in Spain, since this country does not commonly use future scenarios (Schwartz, 1997), spatial simulation models (Benenson and Torrens, 2004), or instruments that support planning decisions (Geertman and Stillwell, 2004).

On the other hand, Chermack and Van der Merwe (2003) define geoplanning as a set of methods used to increase options and awareness of different possible futures in a decision-making process; these are effectively included in planning where they are designed with planning tools using GIS. This results in images of future evolution, as it is known in the English-speaking world according to Stillwell et al. (1999) as “spatial scenario planning.”

Benavente et al. (2011) propose three types of scenarios: one is predictive of the near future, exploratory prediction; and finally, normative prediction, which imagines scenarios involving better design that approximates what is desirable in terms of urban criteria.

Therefore, based on these studies, it can be seen that geoplanning and geoplannification have slightly different origins and approaches due to the specific regional context; however, both share a common basis in the use of ICT at the geospatial level to improve territorial planning and management.

In fact, de Vries (2018) adds that the practices involved in this process involve the regulation of instruments by spatial planning agencies through governmental and non-governmental organizations, which ultimately aim to intervene in socio-spatial relationships, biophysical characteristics, artifacts, and constructions that benefit from the land in general and the habitat, as observed in the previous cases presented.

However, urban planning interventions have functions and, in fact, relationships that depend on changes at the governmental level, socio-spatial relationships, the economy, and the law (de Vries, 2021); thus, these functions are options

that can be observed from the way they are executed within the functions of management, territorial, and spatial planning.

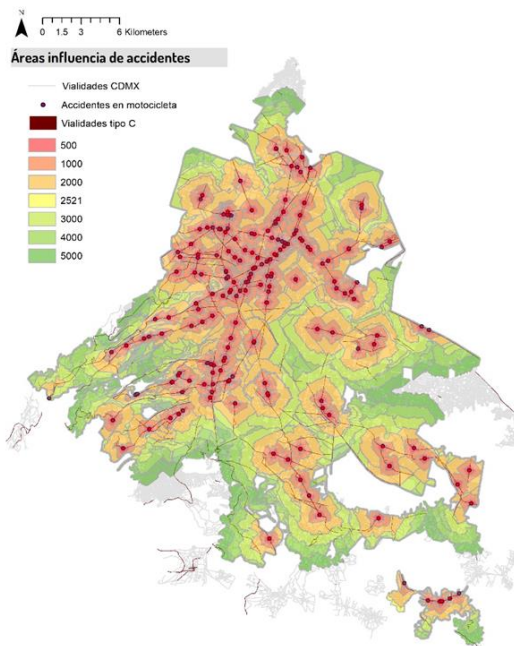
These examples show how geoplanning is implemented through model building, spatial analysis, and the use of advanced geospatial technologies for the analysis of environmental, social, and economic factors in territorial and urban planning.

#### **4 Methodological Applications of Urban Geoplanning at The Instituto Politécnico Nacional**

When considering examples of geoplanning applications for land use and regional urban planning decisions, it is essential to consider methodological and scientific principles supported by a database of real information (Buryak et al., 2014). In the case of Mexico, recent studies have been carried out at the Geomatics and Urban Processes Workshop, in the Postgraduate Studies and Research Section of the Higher School of Engineering and Architecture, Tecamachalco Unit of the National Polytechnic Institute, on territorial geoplanning using geotechnologies and geodesign, in the identification of urban processes that arise as a consequence of territorial decisions, based on issues of infrastructure, residential segregation, urban mobility, transportation, urban morphology, and environmental variables.

These analyses generated computational models based on a quantitative geography methodology, which relies on generalization to make diagnoses that seek to explain a spatial dimension deductively. Although this method is characterized by the collection of statistical data, where spatial analyses are performed using GIS, information and communication technologies, big data, the Internet of Things, and artificial intelligence to create models, the processes are presented in cartographic results.

First, there is a study of areas of influence in motorcycle accidents that occur in Mexico City

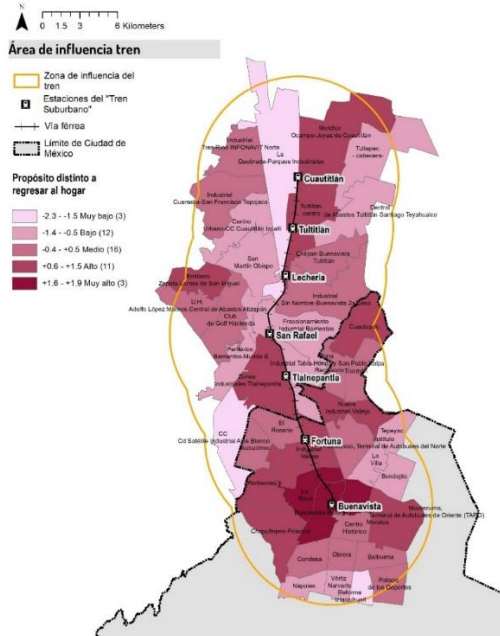


**Fig. 1.** Computational model of road safety in motorcycle mobility in Mexico City in 2022. Source: Raquel Andrea Delgadillo Díaz (master's thesis 2024)

[CDMX] specifically in the year 2022. It was carried out using geoprocessing techniques that identify the areas with the highest level of exposure to accidents near main avenues with speed limits above 50 km/h. This makes it possible to identify the roads that are least safe for people traveling by motorcycle (Fig 1).

Within the context of mobility, a study of the suburban railway in the Mexico City Metropolitan Area (ZMVM) was also conducted in 2017. To this end, data was taken from origin and destination surveys [EOD] for that year in order to compare both the number and duration of trips made, particularly in the area of influence of the suburban train. This was done by means of a proximity analysis, drawing an eight-kilometer perimeter using buffers at each station on the train line.

Then, each ODS was analyzed, and trips made for purposes other than returning home were identified. In the end, it was found that only some of the districts surrounding the new suburban train stations have increased their urban mobility since this transportation system was inaugurated. This type of analysis can be applied to evaluate public policies on urban mobility (Fig. 2).

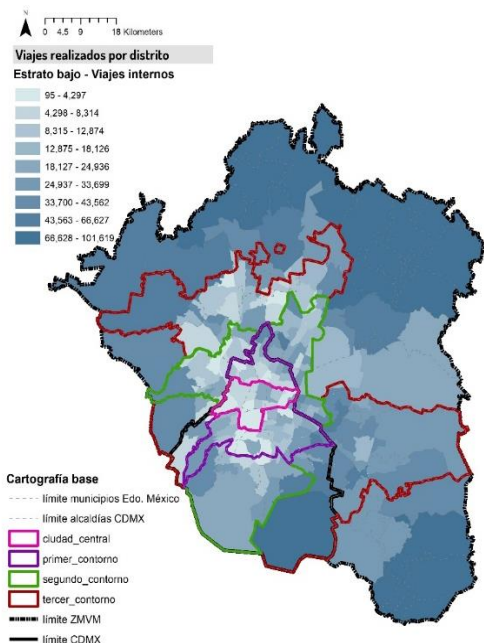


**Fig. 2.** Individual travel costs in daily mobility within the area of influence of the suburban train in 2017. Laura Vázquez Nájera (master's thesis, 2021)

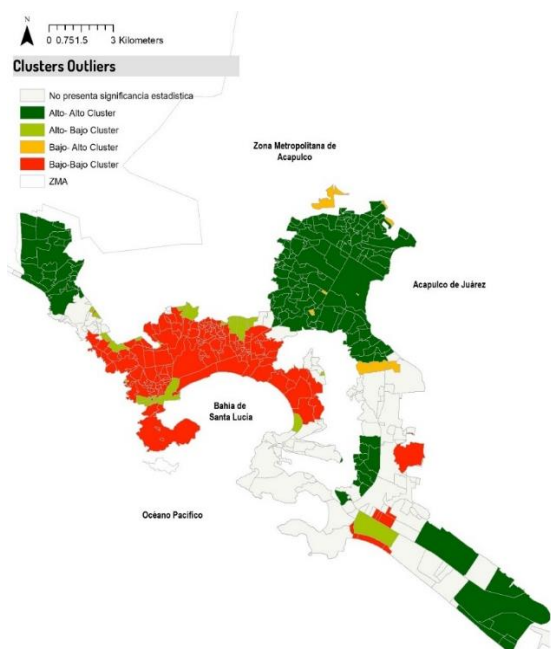
On the other hand, there is a study analyzing daily mobility patterns in the ZMVM from a spatial justice perspective. Here, geoplanning is viewed from the construction of a computational model that correlates the analysis of daily mobility using indicators such as number of trips and analyzed by each socioeconomic stratum.

The study concluded that the largest number of interdistrict trips made by the lower stratum occurs in the periphery. In fact, it was observed that a significant percentage of the low socioeconomic stratum chooses to travel mainly within the same district where they live.

This model shows signs of spatial segregation due to two characteristics: first, the poor only move around the periphery, and second, their mobility is conditioned by their immediate environment, meaning they cannot exercise their right to the city, as shown in Fig 3.



**Fig. 3.** Trips made by district, internal trips by the lower socioeconomic stratum. Margarita Ruiz Camacho (doctoral thesis, 2024)



**Fig. 4.** Urban segregation in the Acapulco Metropolitan Area. Maripaz Carbajal Herrera (doctoral thesis, 2023)

The following study analyzes urban segregation in the Acapulco Metropolitan Area using cluster analysis. The results indicate that the population with the lowest level of education is segregated from the most touristy parts of Acapulco, namely the amphitheater facing Santa Lucía Bay, where it generates a low-low cluster, meaning that there is no population from this group in this area.

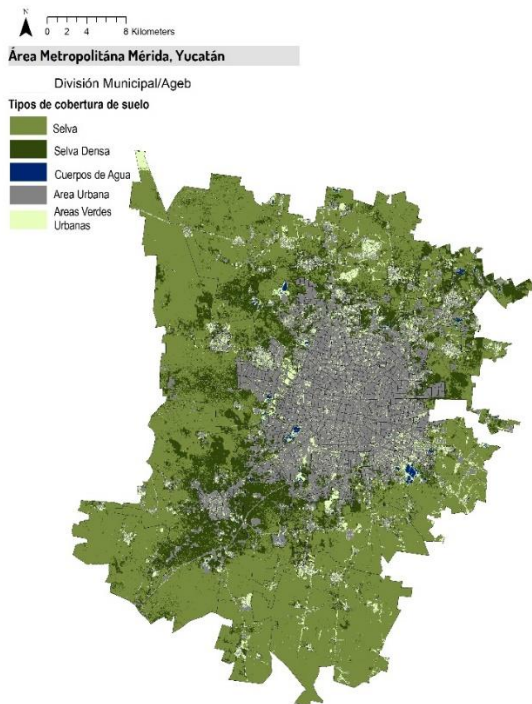
On the other hand, people with no education do generate five high-high clusters on the outskirts of the ZMA, evidencing residential segregation on a macro urban scale (Fig 4).

In the case of the Mérida Metropolitan Area, Yucatán, Mexico, an exploratory analysis was conducted to identify urban sprawl from an urban morphology perspective. This involved the use of remote sensing with vector format satellite images from the United States Geological Survey (USGS), followed by the use of GIS to obtain two-dimensional images of points and pixels, which facilitated the analysis of a geostatistical framework. Finally, the different land uses are visualized. In this case, the aim was to identify urban sprawl, one of the processes that is most affecting urban sustainability due to the dispersed growth of cities (Fig 5).

## 5 Discussion and Conclusions

Urban geoplanning, highlighting the opportunities it can offer for the challenges facing contemporary cities today, which require significant elements of planning and land use management. To this end, there are key concepts that, when integrated with advanced technologies, can contribute to the construction of sustainable, resilient territories, as explained by Lisetskii et al., (2014); Topchiyev et al. (2010) and Steinitz (2012), as it drives digital transformation by linking geospatial technology to more inclusive and transparent governance processes in urban planning.

The use of ICT and GIS, through these Mexican case studies, facilitated the identification of urban phenomena and processes that are so diverse and common in Latin America. The role of



**Fig. 5.** Morphology of urban sprawl in the Yucatán Metropolitan Area, Mexico. Brandon Yaval Montalvo Olguin (master's thesis, 2024)

geoplanning in these processes provides the tools and methodologies necessary to improve land use planning and the construction of computational models that provide accurate data and analysis to inform these planning decisions.

These models lead to the identification of patterns that require the implementation of zoning regulations, regional urban planning strategies, and, why not, the use of geodesign to improve future decision-making in the face of possible short-, medium-, and long-term impacts.

For example, the morphology of urban sprawl in the Yucatán metropolitan area, urban segregation in the Acapulco Metropolitan Area, urban mobility in the Mexico City Metropolitan Area, daily mobility within the suburban train's area of influence, and road safety for motorcyclists in Mexico City, which allows us to understand the level of exposure to accidents on main avenues. Thus, it can be inferred that there

is a relationship between urban planning and territorial geoplanning that tends to be a little more synergistic and collaborative.

Urban geoplanning can address the challenges of sustainable development, especially in a world that is being affected by climate change and has exceeded the limits of urbanization, the carrying capacity of the world, and its resources. Therefore, effective urban planning is required, which can be achieved through the integration of geospatial tools and computational simulation models. However, it is imperative to increase the level of benefits in terms of overcoming challenges involving data access, inter-institutional coordination, and technical capacity from academic training.

Therefore, based on the results of the case studies, which are postgraduate research projects at the National Polytechnic Institute, it is considered that innovation in the knowledge of cities for urban planning is possible. It is therefore imperative to include geospatial technologies in educational programs to teach students about planning issues and new technological advances. In fact, educational programs based on GIS, information and communication technologies, big data, the Internet of Things, and artificial intelligence will be key tools for research, leading to a deeper understanding of geoplanning.

Digital transformation through territorial geoplanning has gained relevance in Mexico's National Strategic Programs (PRONACES). One example of this is environmental sustainability through the integration of geospatial data for resource management and environmental conservation. In fact, the use of ICT creates real-time monitoring platforms and future scenario modeling. From rural and urban development, land planning is carried out in these two contexts and digital solutions are implemented, such as geodesign for infrastructure management. In terms of health, areas of critical need can be identified for planning health infrastructure.

From the perspective of social inclusion and reducing inequalities, it is possible to analyze the distribution of resources to identify levels of

inequality in terms of water, pollution, energy and climate change, education, health, safety, and housing. Thus, through the current digital transformation with the disruptive nature of geoplanning, PRONACES in Mexico can be strengthened, as advanced technology tools are used to collect, analyze, and visualize data at the geospatial level. In fact, this synergy leads to more sustainable, equitable, and efficient planning and management, which can go hand in hand with global and national objectives.

Therefore, by integrating digital technologies into the geoplanning process, Mexico as a country can move toward resilient and inclusive development. In fact, this process offers several opportunities spanning multiple sectors powered by ICT, AI, big data [BD], and the Internet of Things [IoT]. One of these is sustainable urban growth to address uncontrolled urban expansion, as these tools facilitate the creation of predictive models that project smart densification. Another is ecosystem conservation (changes in vegetation cover), water management (early detection of droughts), agriculture, and food security (production and yield).

The status of geoplanning in Mexico is generally a field that is evolving, but with revealing advances in sectors and areas that continue to need further development. For example, at the political level and within the regulatory framework, institutions such as the Secretariat of Agrarian, Territorial, and Urban Development (SEDATU) together with the National Institute of Statistics and Geography (INEGI) are fundamental for the management and collection of geospatial data for planning. In fact, the Mexican government has also incorporated geoplanning into the National Development Plan as part of policies that seek sustainability and land use planning aligned with sustainable development goals.

So, Mexico, as a great example in Latin America, is making progress in implementing policies that include geoplanning, but it is still consolidating strategies for coordination, training, and implementation. It is therefore essential to continue training professionals in the use of

geospatial tools and digital technologies to transform our territories.

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*\*Corresponding author is Marielena Medina Ruiz.*