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Current uses of GIS for civil engineering in Colombia

Usos actuales de los SIG para la ingeniería civil en Colombia

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This document presents and reviews the GIS (Geographic Information System) in Colombia and its possible current uses in civil engineering. Since a model with georeferenced graphic elements (maps) with additional information associated with a database is a very complete design tool, it facilitates engineering analysis to carry out effective construction projects.

Keywords: Analytics, data, engineering, geography, hardware, information, systems, software

Este documento presenta y reseña los SIG (Sistema de Información Geográfica) en Colombia y sus posibles usos actuales en la ingeniería civil. Ya que un modelo con elementos gráficos geo referenciados (mapas) que cuenta con información adicional asociada a una base de datos conforma una herramienta de diseño muy completa, la misma facilita a la ingeniería la realización de análisis con el fin de realizar proyectos constructivos efectivos.

Palabras clave: Análisis, datos, geografía, hardware, información, ingeniería, sistemas, software

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Introduction

Information systems are designed to improve the quality of the points of analysis and relationships that distinguish the territory. However, much of their success is subject to the degree of assimilation of the tools available, and the development of the necessary frameworks to begin to appreciate the field of application of geographic information derived from territorial systems, which constitute the physical-spatial scenario of the interactions produced when evaluating the characteristics of the territory as an information base (DePrekel, Bouali, & Oommen, 2018; Onden, 2018; Palmer, Koumpli, Cole, Gottschalg, & Betts, 2018; Rowden & Aly, 2018).

This article will focus on GIS for Colombia, showing a frame of reference, theoretical review, methodological design, and use (Cantillo, Garces, & Marquez, 2016; Florez, Rincon, Cardona, & Alzate, 2017).

What is a GIS?

Geographic Information Systems (GIS) are methodologies that help us to perform calculations that help us to integrate modeling results, identification, and different geographic features, giving the possibility to generate forecasts, for the corresponding decision making, also helps us with issues related to spatial distribution, capture storage, manipulation, analysis, modeling and presentation of georeferenced data. In addition, GIS can perform high-speed, high-volume numerical calculations, generating accurate and fast communication within and between organizations. It is easily accessible and increases effectiveness and efficiency among groups in a specified location or across multiple locations.

Historical review

The design of maps dates back to Ancient Egypt, where they began to use maps to delineate the land near the Nile River, all this to get the most out of it, in terms of agriculture, is that fact means the beginning of cartographic works. What propitiated the birth of the GIS, the birth of the computer era in the mid-sixties, with that in mind the GIS has sustained a constant evolution, as the emergence of sources that could be used for geographical analysis, in addition to the development of disciplines have contributed to the development of the GIS itself.

The evolution of GIS, comes from a discipline, technology, data, techniques, and formulation, discipline, GIS has achieved a relationship with other scientific disciplines, in technology through GIS software and computer elements has had remarkable growth; with the benefit of the constant acquisition of information increasingly accurate in storage, gives the opportunity for new solutions for management, thanks to the development of new concepts, approaches, theories or branches of knowledge to enhance technical and formulations that ensure better data management.

GIS in Colombia

Technological advances have led to the development of GIS so that a model with georeferenced graphic elements (maps) has additional information associated with a database, which facilitates analysis to produce new results.

The implementation of the systems obeys the relevance of codifying and monitoring, using technological tools, the information on the geographic structure of each region, a framework that implies the revision of the forms stipulated up to now to evaluate and make territorial management.

Contributions to GIS by public companies. The consolidation of geographic information systems as a spatial and territorial database is designed to organize the collection of geographic references available for the time being in analog format. In this regard, the Colombian State assumed the application of information systems in local and regional geography through the Geographic Information System for Land Use Planning (SIG-OTN), under the responsibility of the Agustín Codazzi Geographic Institute (IGAC, 2006), to establish land use and territorial planning processes through the systems (art. 49 of Law 152 of 1994).

Information systems are designed to improve the quality of the points of analysis and relationships that distinguish the territory. However, much of their success is subject to the degree of assimilation of the tools available, and the development of the necessary frameworks to begin to appreciate the field of application of geographic information derived from territorial systems, which constitute the physical-spatial scenario of the interactions produced when evaluating the characteristics of the territory as an information base.

The information systems have as a reference the territorial conditions among those who execute the development plans, as they assume parameters of state and institutional coordination. Thus, the generation of information that permanently assembles the physical-spatial space, allows clarifying the media composition to which planning and projects have been subjected, blurred from the logical order foreseen by the spatial and geographical conditions, which directly constitute the road map required to evaluate the territorial parameters.

The interest in establishing the correlation criteria between the stipulations of the ordinance with the planning based on the information systems is just beginning. It is still in the stage of transferring cartography and analog maps to the digital system, and some pilot programs and tests are being developed in different areas of the country to articulate the initiative to the territorial conditions, exercises in which

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the perception of the inhabitants regarding the geographic image of the territory has played a fundamental role.

The Geographic Information System for Territorial Planning - GIS-OT is one of the results, to date, of an International Cooperation Agreement, signed between the Colombian Government and the Swedish International Development Agency - SIDA, which seeks to facilitate efficient and timely decision making by the authorities and bodies of the National Planning System (President, ministers, governors, mayors, their government teams, Congress, departmental assemblies, municipal councils, and national and territorial planning councils, among others), in support of better territorial public management, within the framework of the Colombian Spatial Data Infrastructure - ICDE.

The GIS-OT has been developed with the active participation of national and territorial entities such as the Colombian Federation of Municipalities, the Presidential Agency for Social Action and International Cooperation, the National Administrative Department of Statistics - DANE, the National Planning Department - DNP, the Ministries of Environment, Housing and Territorial Development, Agriculture and Rural Development, Education, Transportation, Culture, Social Protection, IDEAM, INGEOMINAS, the Governors of Nariño, Valle del Cauca and Cauca, among others; as well as the Agustín Codazzi Geographic Institute, IGAC, which is in charge of technological development and facilitating inter-institutional participation.

From the beginning, the guiding principles of the methodology for the construction of results were defined, as well as an operational structure to achieve them, composed of a Management Group (directors, deputy directors, and managers of 14 entities), execution, and technical coordination group (led by the IGAC, with the support of delegates from the participating national institutions) and a reference group (national and territorial entities).

Among the guiding principles, the collective construction of knowledge and the generation of useful and timely results in the agenda of the National Planning System stand out. Consistent with the above, the Rational Unified Processes -RUP method was proposed and used, which is an iterative and incremental process based on the evolution of executable prototypes; in each iteration, the system gains in development and facilities; which has favored not only the construction of results but also the appropriation, institutional learning, and feedback from all entities.

With the application of this participatory and incremental methodology, the variables to be contained in the system were prioritized, the conceptual model was designed and the necessary documentation was prepared to support the development of the Geographic Information System.

Contributions to GIS by private companies. Most private companies use the GIS developed by public agencies that have generated large volumes of information for their projects, which represents a reduction in costs by allowing its reuse. This is not a definitive solution, because before being useful for an application other than the one for which it was designed, such information must be reworked by the companies, which has allowed the development of GIS complements.

GIS in private companies has also been extended to distribution, planning, logistics, and marketing activities.

On the one hand, the tools they provide make it possible to locate customers, competitors, points of sale, and, in general, any type of information that can effectively assist in a decision-making process. These operations, as well as defining a sales territory, opening or closing a branch, or placing static advertising are decisions with a clear geographical component.

In addition, vendors have brought to market low-cost, easy-to-use systems designed for less complex needs. The power of desktop platforms and the emergence of systems that overcome the limitations of DOS make it possible to use GIS without barriers.

Colombian companies are already aware that the conditions of user-friendliness, cost reduction, and openness of applications are an option to improve their productivity and competitiveness.

Elements of a GIS

All elements of a GIS are important, geographic information systems depend on five main elements, without which they could not function.

Data. These are the raw material to be able to work with GIS, they are the basis of all the knowledge that can be obtained, these data can be obtained in different ways, through GPS, aerial photographs, files obtained in AutoCAD, Excel, and other types of geographic sources. With all this data you can make the different relevant decisions that are necessary to obtain better results.

Software. Among the most important tools are the following.

- **ArcGIS.** ArcGIS is a set of software products, which allows to analyze, to analyze, to treat, to publish geographic information; using different applications, this software is developed by ESRI.
- **OS Geo.** This is free software developed by the Open Source Geospatial Foundation, this is a non-governmental organization, although it does not focus on software development, its mission is to provide support for geospatial technologies, which can

be used to access GIS, although it is not as powerful as ArcGIS.

• **QGIS.** It is another type of geographic information software, which is developed by OS Geo, it is free software that is available in different types of platforms, such as Linux, Windows, or Mac OS.

Hardware. This is necessary because to use the software we need hardware, of course, depending on the capacity of the hardware, so will be the use of the software.

Persons. To be able to analyze the data obtained, it is necessary to have a staff, although several technological tools help us in these processes, it is always necessary to have a physical staff, for this task several professionals are needed, within this range two different types are needed:

• **GIS Technician/Analyst.** In charge of performing geographic analysis and obtaining results depending on the field of research.

• **GIS Programmer.** In charge of developing web applications and functional desktop GIS parts.

Of course, with the frequent growth of GIS, there is always a need for other types of GIS professionals such as managers, administrators, directors; always taking into account the needs of the projects.

Processes. Processes are developed to optimize the integration of data effectively and appropriately, for these you need software and hardware, you also need staff to use the new technologies. You must always have a good organizational model on which to work.

What is the importance of GIS in Colombia?

Its importance depends on the planning of a specific project in a geographic space, being the GIS an active actor in the decision-making process, which helps to determine the characteristics of the territory.

GIS in the field of civil engineering is quite relevant. In Colombia the GIS is a new tool, for this reason when solving the question we recognize the difficulties that arise in the generation of mechanisms that facilitate its introduction as a tool by the staff that operates, like the one that is responsible for making decisions; in addition, there are problems of availability of reliable data that is obtained from the local authority. Regional and National are those involved in land use planning, as such an influential factor, if we want to make progress in the use of GIS.

On the part of the state the use of the GIS, in this case, the municipalities, have used the application, in the fulfillment of the territorial management plans, the problem lies in that this information is not consulted, it is not updated with the information, knowing that with the application daily information is generated, this turns the GIS application, a product that is obtained by hiring external personnel turning it into an element of work, and its importance is left aside, as an active actor in the diagnosis and at the time of decision making in front of pertinent planning.

The GIS facilitates the review of the gap between desired and current conditions, as they allow us to move from a general vision, to the particular with a degree of detail required by the user, in Colombia it is necessary to use the application from a simple but reliable basis because it is an excellent start of the application, to be available to any municipality, being collected daily information, which is easily organized, analyzed, promoting good planning decisions, to ensure that familiarity and experience with the application are reached.

For the above mentioned, the use of GIS applications in Colombia, as an active tool, thanks to being an application in planning and subsequent decision making, in the territorial organization, it is necessary to know their current uses of geographic information systems in Colombia, to recognize and see how they are being used and how to ensure their greatest potential when using them.

The triumph and development that GIS has had throughout history are mainly due to the development of technology, they are born of a simple problem, the need for geographic information, and the ease of obtaining it.

It all began in the ’60s with the work of John K. Wright, in the American Geographic Society, Elements of Cartography. With works such as John’s, this field is expanding until it reaches a level where a system can be proposed in mature computer science.

Waldo Tobler developed the first computational system or tool in 1959 with MIMO (map-in map-out). It was he who proposed the systems for obtaining databases, coding, analysis, and tools necessary for their organization, it was Waldo Tobler who developed the main elements that make up the GIS databases.

The official birth of GIS occurred in Canada in the early ’60s, with the system called CGIS (Canadian Geographical Information Systems), sponsored by the Federal Department of Energy and Resources and developed by Roger Tomlinson who is called the father of GIS, although there was already some development in geographic information technologies Tomlinson is considered a pioneer in his field.

The development of new technologies is a really important step for GIS, what matters for these systems is the encoding and storage of geographic information. Guy Morton made an important contribution with the development of his Morton Matrix, which overcame the deficiencies of the equipment of that time, the most important deficiency overcome was the lack of storage units with random access capacity.

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SYMAP was an application developed to allow the input of information in the form of points, lines, and areas. This software was developed at Harvard Laboratory, this application drove the development of a new generation of cartography and the evolution of these systems to more advanced ones.

GIS platform

There are currently different platforms, chosen depending on the activity and purpose, and even two or more can be used for the same activity.

With the development of free software in the last years, more and better products have been appearing that rival in power and versatility with the most known products with payment license and of privative character. The use of free software allows one not to depend on a software license to be able to continue expanding and deepening the knowledge and development of these systems.

The following is a list of the most commonly used GIS programs.

ArcGIS. ArcGIS is non-free software developed by Esri. The two main desktop applications for GIS professionals are ArcMap and ArcGIS Pro, both of which are part of ArcGIS for Desktop. Each application has unique features to suit your needs. You can create everything from simple web maps to complex analytical models.

QGIS. QGIS is open-source software licensed under the GNU - General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It is available for Linux, Unix, Mac OSX, Windows, and Android and supports numerous vector, raster, and database data formats and functionalities.

gvSIG. gvSIG is easy to use, interoperable, and used by thousands of users around the world. gvSIG Desktop works with a variety of formats, vector and raster, files, databases, and remote services, having available all kinds of tools to analyze and manage geographic information. gvSIG Desktop is free software, with GNU/GPL license, which allows its free use, distribution, study, and improvement.

GRASS GIS. GRASS GIS, more commonly known as GRASS, is a free and open-source GIS software used for geospatial data management and analysis, image processing, graphics and map production, spatial modeling, and visualization. GRASS GIS is currently used in academic and commercial environments worldwide, as well as by many government agencies and environmental consulting firms.

OpenJUMP. OpenJUMP is free GIS software that allows visualizing layers and spatial queries performed on a PostgreSQL/PostGIS database.

SAGA GIS. SAGA is the abbreviation for System for Automated Geoscientific Analyses, an open-source and Free GIS, with an interesting set of scientific algorithms for working with vector and raster data. A very powerful and robust alternative to the most popular GIS mentioned above.

LAStools. It is a collection of tools for LiDAR data processing.

CARTO. CARTO es una herramienta para la creación y publicación de mapas en la nube. Las funcionalidades son muy amplias, y están diseñadas para distintos perfiles de usuarios. Desde aquellos sin experiencia que únicamente quieran visualizar y analizar un conjunto de datos geográficos, a aquellos que quieran crear aplicaciones y visualizaciones complejas, o realizar análisis profundos de los datos con que trabajen.

Fusion Tables. Google Fusion Tables is a Google web service for managing data stored in tables that can be consulted, shared, and edited by any user over the Internet. Fusion Tables allows definition access permissions to the tables and offer an environment for data visualization through graphs, scatter diagrams, and timelines. Also through maps based on Google Maps.

Mapbox. Mapbox is an online platform that allows the creation of cartographic reference bases, as well as the development of web maps and mobile applications for the consultation of georeferenced information.

ArcGIS Online. ArcGIS Online allows you to use, create and share maps, scenes, applications, layers, analysis, and data. It provides access to a databank and creates interactive web maps. As ArcGIS Online is part of the ArcGIS system, it can be used to extend the capabilities of the different products that make up the system (ArcGIS Desktop, ArcGIS Enterprise, ArcGIS Web APIs).

PostgreSQL. PostgreSQL is a freely distributed relational database management system (DBMS) under the BSD license. Among its potentialities, it is worth mentioning: the high level of accessibility for any type of user; the existence of an extension or module (PostGIS) that provides geographic capabilities to the databases; the high quality of the product, being the most advanced open-source DBMS.

PostGIS. PostGIS is the spatial extension for PostgreSQL that allows the storage of geographic data. It adds functionality to spatial objects that allows SQL queries.

SpatiaLite. SpatiaLite is an SQLite database engine to which spatial functions have been added. SQLite is a simple but robust database management system, easy to use, and lightweight. Each database is simply a file.

OpenLayers. OpenLayers is an open-source API for displaying interactive maps on the web.

Leaflet. It is an open-source API for displaying interactive maps on the web.

GeoServer. GeoServer is an open-source web server that allows serving maps and data of different formats for web applications.

GeoWebCache. GeoWebCache es una aplicación web basada en Java que sirve para mejorar el rendimiento de las teselas de mapas procedentes de distintas fuentes como geoservicios OGC (WMS).

GeoExplorer. GeoExplorer is an application, based on GeoExt and OpenLayers) allows the symbolization and creation of online maps. It allows to easily assemble maps from GeoServer or any OGC geoservice (WMS) and integrate with maps such as Google Maps or OpenStreetMap.

GeoNode. GeoNode is a web application and platform for developing Geographic Information Systems and implementing Spatial Data Infrastructures. It is an open-source project of OSGeo.

GeoNetwork. GeoNetwork is a catalog for managing geospatial data metadata. It is an open-source project of OSGeo.

iD. The iD editor is the de facto browser-based OpenStreetMap editor. iD is easy and fast to use and allows mapping from different data sources such as satellite and aerial imagery, GPS, or Field Papers.

JOSM. It is a free desktop software programmed in Java for editing data in the OpenStreetMap project. It has numerous advanced features. Some of the most notable features of JOSM are GPX file import, working with satellite images or orthophotography through standardized protocols (WMS, TMS, and WMTS), support for multiple cartographic projections, information layer management, relationship editing, error validation, filters, and rendering styles among others.

GIS structure

The success of a GIS depends on the structure of its implementation since these are complex tasks. But to organize and coordinate in an effective and adequate way all the elements of a GIS must be a basic task, in general, each of the elements must be considered individually and its relation with the others, the organization, and formation of a GIS is conformed by the following structure.

Data. The data are the fundamental basis of a GIS, in general, all the data are important, but at the time of using them it is necessary to have a selection of each one of them, that is why to be able to have access to them in an effective way it is necessary to create a database, that not only is modifiable by him, or the designers but also by the users, for them it is necessary to have good communication with the person who is going to make use of these data and to obtain the information that helps to optimize the database.

First, data must be collected, that is to say, information must be obtained from already structured databases such as those of private suppliers, government agencies, or any other entity that has them, especially to optimize the information that is acquired and create new information from it, that is to say, to optimize the database.

If data collection is taken as a percentage of the process, it could be said that it is only 50%, if a new database is created from those already obtained, we will have a large number of similarities in the information obtained and even more if all the information comes from a single database, This does not help the search work of the users, that is to say, not all will be served by the same information, therefore, it is necessary to look for particular characteristics and separate the information, so that when you want to carry out an investigation you do not get too much-unwanted information and that does not offer something to the project you want to carry out.

In general, some data can cover regions with too much extension and only a small sector is sought, in those cases, the information must be delimited, and on the contrary, very little information can be obtained from a site of great extension, for that reason, it is necessary to try to obtain more information in order to obtain a more updated and efficient database.

Persons.

Software.

Hardware.

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GIS functionality

When analyzing the functionality of GIS, it should be taken into account that, being a specialized program, it has a high degree of complexity, for this, it is useful to divide the topic into subtopics, to make a better description of the most representative functions, of these we will talk about: technology, data, methods, organizations, and network. In addition, it is necessary to talk about functions such as Information Entry, Storage, Management, Spatial Analysis, and Output or Graphical and Cartographic Representation of Information.

Network. The network is the main element of a GIS because it generates advantages in the field by allowing the visualization, consultation, and analysis of spatial information without the need to download large amounts of data.

Technology. It is structured by software and hardware. In the case of hardware, the user can perform different actions of input and output of information as in the case of file transfer, output devices such as printers, monitors, etc., regarding the software, it acts as a logical entity that organizes, directs and gives consistency to the whole system.

Data. Data are the part using which reality is represented, with which it is searched in the situations, for the realization of specific application, since data are restatements of facts and represent a necessary pillar for knowledge.

Methods. The methods aim to establish the structure of a GIS, while at the same time seeking to support decision making to achieve project success.

Organization. GIS only makes sense in the context of an organization, as it establishes procedures, reporting lines, control points, and other mechanisms to ensure the budget, these factors being paramount to the work, ensures the need for the organization.

Functions for data entry

They are those that allow the introduction, edition, and visualization of geographic data, its importance resides in issues where spatial information is very scarce. Where the process of obtaining it can be tedious and very expensive. The processes in the information input function usually absorb between 50% and 70% of the budget for the implementation of a GIS and also require large resources in the modification of the geometric characteristics of the orientations, position, shape, and correction of inconsistent data.

Storage functions

Once the geographic information has been captured, and a large amount of data has been collected, the storage function appears in this process, where, in addition to the computer hard disk, it is necessary to transfer the information to other computers or electronic devices, given the importance of having backup copies.

Management functions

This function extracts from the GIS database the proportions of spatial information that are of interest at the time, thus the management function is responsible for allowing the independence of the physical organization (database) from the logical organization of the data (programs that manage the data), to achieve control of storage and retrieval.

Spatial analysis functions

They are those that are attributed the value to the geographic data, to expose us to geographic data because without it we cannot perceive, know and understand the spatial operations, besides being a useful tool to plan better and efficient work. Among its capabilities are the query operation, perimeters, areas, overlapping layers of information, reclassification of data.

Output functions or graphical and cartographic representation of information

They are those that allow the transfer of data, maps, this we perform the representation of stored data that allow visualizing the information according to the required need, for this case depends on how it is done, in this sense should be careful in the way in which it is done, be aware of the result they are looking for.

Application of GIS for civil engineering in Colombia

GIS applied to geology

Currently in Colombia, the national geological information is managed by the state government through the Ministry of Mines with the Colombian Geological Service. The "Geoportal of the Colombian Geological Service" was developed for the visualization of the geological characteristics of the national territory.

The purpose of this Geoportal is to present to users the information generated by Geo Basic Sciences, Mineral Resources, Geo threats, Nuclear Affairs, Laboratories, and Information Management, in compliance with Law 1712 of 2014 "Law of transparency and the right of access to public information" and according to articles 11 literal J and K, article 12, article 13 and article 14.

The information is stored in a corporate geodatabase managed by the Oracle database engine, ESRI Suite tools, and customized web applications using ESRI Geoportal Server (Open Source Software).

Through this platform, the information is dynamically managed and available to the user online. It also complies with open source standards such as WMS (Web Map Service), WFS (Web Feature Service), WCS (Web Coverage Service), and REST (Representational State Transfer) services.

The purpose of this information is to establish initial conditions of the territory for the realization of public and/or private projects. Among the information found in this Geoportal are:

- Basic geosciences
- Mineral Resources
- Geo hazards
- State geological mapping
- Petroleum Information
- Volcanic hazards
- Geophomodynamics
- Geochemical Anomalies and Geochemical Potential
- Geological Atlas Colombia
- GNSS Stations SGC 2014
- Maximum Observed Intensity
- Carboniferous Potential Map Colombia

GIS applied to mobility and transportation

As mentioned repeatedly in this article, GIS allows us to extract the necessary information in a more effective way reducing search times and providing the relevant information for further analysis, in mobility, they are widely used, they allow us to know the state of the roads and also to know the traffic density of a given road.

Several urban transportation companies use these systems to optimize their times and provide a better service, such as Transmilenio, Mio, Medellin subway, etc., in general, these companies filter the information obtained, although this is already filtered in a useful way it is not perfect since these systems are still under development.

For a road system, it is necessary to make a previous analysis with a GIS, at the present time the use of these systems is indispensable, more in cities with a great density of traffic like Cali, Medellín, or Bogotá, since most of the roads of these have been thought for the transit of particular vehicles, and the massive systems of transport have been left to aside, in the last years it has changed something of that thought, but due to the errors committed with the type of design of the roads the consequences have been terrible, with help of the GIS some of these problems can be solved.

The GIS provide us with different types of information such as the location, the condition of the terrain, the trend, the possibility of developing roads from one place to another, and models, the GIS have a lot of advantages, within these are the cartographic manipulations which allow us to handle the information obtained in such a way that we could make an estimate of the work and the amount of material that needs to be moved. We also have the ability to compare the information in a relevant and effective way, in order to make a more accurate decision making.

For the respective analysis of a road network, a Geodatabase must be created, which is a database containing traffic density, geological risks, hydraulic network, cadastre, surface types, slopes, and other information necessary to develop a well-structured road in a way that does not affect the environment and that solves the mobility problems that arise in the sector. GIS is the main solution to the geomorphological problems that arise in mobility and ease of access to the different terrains of our country.

GIS applied to urban planning

In order to talk about GIS applied to urban planning is necessary to know the agency responsible for urban planning in Colombia is the National Planning Department (DNP), of which among its functions is to provide technical support to public entities of national and territorial order, in addition to generating plans for a short, medium and long term, where investment is prioritized. DNP is in charge of monitoring projects with an emphasis on regional convergence, territorial planning, and articulation between levels of government and sources of resources in the territories, also in functions is the programming of the budget of the different sources of investment resources, taking into account government priorities and development objectives of the country, likewise participate directly in the evaluation of private investment projects, national or foreign in which the government is part.

As illustrated, GIS is a fundamental tool for this agency, because it generates opportunities for better information management, accurate location in the region, in the search for investment and better territorial control, in addition from the GIS decisions can be made, facing the design and methodologies of urban socioeconomic stratification and population centers, To achieve this type of decision making, it is necessary to have protocols for the georeferencing of data (which are considered metadata for the immense amount of information that is acquired daily), which at the same time provide us with digital cartographic products that serve as support for the operational processes of data collection in research.

Strengthening the use of geographic information systems provides us with relevant results of public interest in national, regional, and local development, ensuring access, use, and security of national geographic information, within the framework of social, demographic, and economic policies.

The importance of GIS lies in the convenience of having geospatial information available, where processes, procedures, policies, strategies, and norms can be articulated to standardize and geographically complement economic,

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social, and environmental issues, for a closer public evaluation.

Colombia currently manages the SIGOT platform for national-territorial planning and management. The SIG-OT (Geographic Information System for National Planning and Land Management) is a tool whose main objective is to contribute to efficient and timely decision making, supporting the actors -authorities and agencies- in the planning system at national, regional, and local levels, with georeferenced political-administrative, socio-economic and environmental information that supports development management.

The SIG-OT is framed within the principles, objectives, and strategies postulated by the Colombian Spatial Data Infrastructure - ICDE. It is the result of a technical cooperation project with the Swedish International Development Agency (ASDI). The project has the support of Swedesurvey, the Swedish counterpart of IGAC, executor of the cooperation. IGAC is technically responsible for and facilitates the inter-institutional management of the project.

The objective of the SIG-OT is to facilitate mayors, governors, and those responsible for national and sectoral planning, the elaboration of diagnoses, and the follow-up, evaluation, and control of their respective development plans. It contributes to the definition of strategies for the management of their territories and to the targeting of goals in the territorial management plans. It helps to generate a culture in the use of geographic information as a basis for decision-making.

Governors, planners, and society, in general, can make use of the SIG-OT through the IGAC's web page, where a user-friendly and free-access portal has been set up. The only requirement is Internet access. On the portal it is possible to build, display and print national and departmental maps of various topics; prepare executive reports on the status of a topic by department or throughout the country, and consult the technical data sheets of the maps (Metadata).

These maps are used, at the national level, to evaluate territorial imbalances in terms of quality or coverage of education, and to define policies and strategies with a territorial approach. At the departmental level, they are used to evaluate imbalances and compare with the allocation of territorial public spending to establish strategies and additional measures to rationalize investment. And at the municipal level, they are used to compare with the context (departmental or regional) and define priorities and goals; they allow temporal comparisons to analyze change or stagnation to better orient actions.

GIS applied to the environment

Institutionally, environmental information is managed by the Ministry of the Environment through the SIAC platform. The Colombian Environmental Information System (SIAC) is the integrated set of actors, policies, processes, and technologies involved in the management of environmental information in the country, to facilitate the generation of knowledge, decision making, education, and social participation for sustainable development.

SIAC is based on a process of interinstitutional, intersectoral and interdisciplinary coordination, led by the Ministry of Environment and Sustainable Development (MADS) and the Environmental Research Institutes: Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH), Instituto de Investigaciones Marinas y Costeras (INVEMAR), Instituto Amazónico de Investigaciones Científicas (SINCHI) and Instituto de Investigaciones Ambientales del Pacífico (IIAP), as well as the Special Administrative Units, the National Parks System and the Autoridad Nacional de Licencias Ambientales - ANLA. The Ministry of Environment and Sustainable Development, through Resolution 1484 of October 31, 2013 regulates the constitution of the Steering Committee of the Environmental Information System for Colombia SIAC. Advisory body of the ministry in charge of proposing policies and strategic guidelines for the management of the country's official environmental information.

SIAC member institutions are working to develop instruments and tools to promote the use and full and open exchange of data and information for research, environmental education, public policy design, and corporate sustainability strategies.

Among the tools designed is the SIAC Viewer version 1.0. The SIAC viewer is a platform that centralizes the official geographic information of the different institutions involved in the environmental sector for its visualization, management, and analysis. This tool is aimed at groups of professionals, institutions, companies or organizations and, in general, citizens who have the interest and need to consult, process, and analyze environmental data associated with different variables, in such a way that it serves as a support for planning, decision making on the territory, evaluation of environmental impacts, programming of productive activities, identification of trends, generation of forecasts and prediction of environmental alerts.

The SIAC geographic viewer contains the following information on the national territory.

Water. Supply, demand, water quality, and vulnerability.

Soil. Threats, forest reserve area, transformed areas, land cover change, forest degradation, species distribution, the legal status of the territory, strata of anthropic intervention, wetlands, forest map, ecosystem maps, land cover maps, glacier monitors, conservation

portfolio, forest cover change, national system of protected areas, environmental zoning.

Weather. Hazards, precipitation, temperature, vulnerability.

Environmental licensing. Energy, mining, infrastructure, hydrocarbons.

Conclusions

This article is a study and analysis of the importance of Geographic Information Systems (GIS) at the civil engineering level, particularly in the context of Colombia. First, the basic characteristics and functionalities of GIS systems are defined, and then an analysis is made of what they have been in Colombia, their initial intention, and their current operation from the perspective of the existing tools and their uses. The institutions in charge of their use and maintenance are also detailed.

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