Application of Geographic Information Systems (GIS) and the Practice of Public Administration

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Abstract
Geographic Information System (GIS) applications are tools that allow users to create interactive queries (user-created searches), analyse spatial information, edit data in maps and present the results of all these operations. This paper was particularly focused on the application of GIS in the practice of Public Administration. Public Administration is a branch of management sciences that studies how government organizations operate and how they make decisions. The complexity in achieving equitable distribution of government actions as well as implementation of such actions to the public requires a thorough analysis of costs and benefits. Many GIS tools could be useful to public administrators, such as measurement tools, mapping tools, spatial analysis tools, data capturing and management tools. Data management tools allow administrators to organize and manage large amounts of data. Therefore, GIS technology offers a framework for gathering and managing information and improving planning efforts in the public domain for effective service delivery. They are quite available at the disposal of Public Administration experts if they are to successfully meet the challenges surrounding the procedure of planning development.

Keywords: Application, geographic, information, system, public administration

Introduction
Many university courses and disciplines overlap with others and Geography is one of them, especially with its unique contemporary research tool – the Geographic Information System (GIS). GIS is a system designed to capture, store, manipulate, analyze, manage and present spatial or geographic data. GIS applications are tools that allow users to create interactive queries (user-created searches), analyse spatial information, edit data in maps and present the results of all these operations. While the professional expertise in GIS is domiciled in the discipline of Geography, its application can be used by an array of disciplines, including Town Planning, Building, Environmental Management, Engineering, Agriculture, Geology and Public Administration in their diverse practices (Daniel, 2020). Frans (2000) asserts that the unique approach of GIS to spatial data has been embraced by numerous disciplines that benefit from a standard instrument to analyze information streams.

This paper is particularly focused on the application of GIS in the practice of Public Administration. Public Administration is a branch of management sciences that studies how government organizations operate and how they make decisions. It combines elements of political science, sociology and management theories to help government agencies work more effectively through the cooperation of group effort on the implementation of government action to achieve its goals. The complexity in achieving equitable distribution of government actions as well as implementation of such actions to the public requires a thorough analysis of costs and benefits. Suffice it to admit that public administration engages in methods of policy assessment and value of all consequences of a policy which Boardman et al., (2018) see as a tool that helps in social value or more technically, to improve allocative efficiency. Public administration experts can therefore make well-informed decisions such as where to allocate resources and how to best serve the public with the use of GIS tools in analyzing data about populations, resources, and services.

Many GIS tools can be useful to public administrators, such as measurement tools, mapping tools, spatial analysis tools, data capturing and management tools. Spatial analysis tools, for example, can allow administrators to identify patterns and relationships in the data. Data management tools allow administrators to organize and manage large amounts of data. As an example, Daniel (2023) has highlighted that censuses of population and housing are important sources of data for land information systems and therefore suggests that as the National Population Commission (NPC, 2021) prepares for a fresh round of censuses in Nigeria, the Commission should make provision for housing questionnaire section that include questions related to land and property information. The researcher further stresses that location is a common link between population data and land data which is in growing demand stimulated by technological advances. The use of Geographic Information System (GIS) allows for the integration of all types of relevant data in a common reference system (Daniel, 2023). With GIS, geo-information continuously advances the capacity of data spread such that the idea of the information revolution cannot be distorted (Noleney et al., 1993). This is because all GIS software, according to Campbell & Shin (2012) contains a database management system capable of administering and accommodating both spatial and attribute data, and permits linking the two types of data together to create information and facilitate analysis. It was indeed good news when the Akwa Ibom State Government located the technology and contracted aerial mapping consultants crew with survey aircraft for the Akwa GIS project. As the Commissioner for Lands and Water Resources was quoted as saying "The idea of the aerial mapping is to ensure that international best practices are brought into play in the areas of lands acquisition and general land management. When completed, and implemented, the land transaction processes will be better, as it will help in making work faster in terms of searches, approvals, and other related matters" (TEAM, 2021).

More examples of the use of GIS in sustainable development and case studies from around the world abound in the literature that public administration experts can find very useful as areas of collaboration with spatial scientists to further their practice. However, the aim of this paper is to particularly highlight the data capturing tools and mapping tools that the public administration experts can themselves handle to perfect their role for the smooth functioning of the public system.

Global Positioning System (GPS) for Data Capturing

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions (see Fig. 1). It is made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. The technology orbits the earth and transit signals GPS that was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. It works in any weather conditions, anywhere in the world, 24 hours a day. It is freely accessible to anyone with a GPS receiver. There are no subscription fees or setup charges to use GPS (Daniel, 2020).

Fig. 1: The Global Positioning System (GPS)

Data capturing and mapping were the first commercial adaptations of the Global Positioning System (GPS), as it provides a latitude and longitude position directly without the need to measure angles and distances between points. Mapping involves gathering information about the positions of certain points as well as the angles and distance between them. GPS makes it possible to obtain location, distance, and height measurements almost instantaneously – the only requirement is that the instrument must have a clear view of the sky to receive signals from GPS satellites. When used properly, GPS offers the highest level of accuracy and is much faster than conventional spatial data-gathering tools. The accuracy of spatial data sets is dependent on the quality of the instruments used to gather the data. With the use of GPS technology, complex calculations can be made more quickly and accurately than ever before. Generally speaking, GPS has five key uses, namely: determining a position (location), moving from one place to another (navigation), monitoring the movement of a person or object (tracking), creating a map of an area (mapping) and making precise time measurements (timing) [Daniel, 2020]. The process is dynamic but represents surveying areas for existing needs and considerable growth in the future in public policy making (Campbell & Shin, 2012).

GIS and Public Administration

Geographic Information (GI) particularly relates to information on cultural, and natural phenomena, human resources, periods and development in which all these elements found their location on the earth. However, Public Administration is seen as a generic discipline practice in all spheres of life. Therefore, public administrators apply specific data which covers all kinds of (GI) such as socio-economic, development planning, natural resources, natural disasters and all sorts of work that pertains to public affairs and GIS serves as an important instrument used for extracting such Information.

From a larger perspective, GIS technology offers a framework for gathering and managing information and improving planning efforts in the public domain for effective service delivery. It can serve as a new way to organize revenue mobilization, waste collection and management, health service delivery, tracking of the tourism sub-sector and even evaluation of the environmental impact of natural resources. In a bureaucratic system, GIS in as a component for easy access to workers' statistics to analyse work performance in Miniseries, Departments and Agencies and their local offices. As opined by Kirfi et al., (2013), it is possible to treat every service misfortune if the Nigeria public service sub-sector by sub-sector is critically analysed. Therefore, suffice it to say that GIS provides a platform for the implementation of tasks and expanding the scope of public policies for national development the contemporary society.

The Process of Obtaining Field Data with GPS

The steps outlined in this section are followed to obtain accurate data sets for analysis that can lead to rational decisions for optimum public interest which are primarily concerned with administrative-technical support:

Step 1: Setup the GPS: ensure that the GPS device is in good order. Ensure that you have installed the appropriate batteries as specified by the manufacturer. Ensure that you select the appropriate Coordinate System in the 'setup' menu.

***Step 2*:** Set out the GPS: The GPS can be handheld or mounted on a tripod. To install and mount on the tripod, see the GPS owner's manual.

***Step 3*:** Acquiring GPS Satellite Signals: You are now outdoors in an open area away from tall buildings and trees ready to acquire data. Ensure you position the GPS exactly at your desired station. Turn on the device. Acquiring satellite signals can take a few minutes. The bars on the GPS information page indicate satellite strength. When the bars are filled and the accuracy level number drops to the lowest possible figure, the GPS has acquired sufficient satellite signals.

Step 4: Enter/Mark: On the GPS device, press and hold to save your current location. You also need as a backup/supplementary data record a field data sheet. On the sheet, create a waypoint column and description column where you record the station's GPS-generated number called 'waypoint number' and also provide a brief description of the station/object or feature. The GPS information page displays

elevation (height above sea level), the estimated accuracy level, the receiver's status, satellite locations, satellite signal strength, the date, the time and the coordinates of the current location of the GPS receiver. To mark your current location, you must press and hold 'Enter/Mark' until the marked waypoint page appears. Then a default three-digit name and symbol are assigned to the new waypoint. To accept the waypoint default information, select 'ok'. To change the waypoint information, select the appropriate field, after making changes, select 'ok'. Once you are done with the current location, you move to the next location and repeat the process accordingly until you finish the current project.
Step 5**:** Connect Your Device to a Computer. Plug the small end of the USB cable into the mini-USB port on the back of the device or as otherwise instructed in the GPS operation manual. Connect the larger end of the USB cable to an available USB port in your computer. Check your connection, then press 'menu' twice and select 'setup' > interface > connected. The waypoints can now be transferred between the GPS device and a computer using appropriate computer programme/software such as 'GPS Utility', 'Map Source', etcetera. Next, open the programme on the computer, and select 'waypoints' to transfer. Click 'Received from Device' on the 'transfer' menu. Save the file as a 'database' file so that it can be accessible in the GIS programme where the process of mapping can be done (Daniel, 2020).

Geographic Information System (GIS)
The main focus of Geographic Information System (GIS) is to address all physical, social, economic, cultural/spiritual problems of the world by searching for answers to what? Where? Why? How? And when? Almost everything that happens happens somewhere. Knowing where something happens can be critically important (Longley *et al*., 2005). Therefore, geographic location is an important attribute of activities, policies, strategies and plans. The need arose for a system to manage the multi-complex human system data with the capability of guiding analytical and logical answers to the aforementioned questions. The geographic information system (GIS) fills this need. It offers special classes of information systems that keep track not only events, activities, phenomenon and things, but also of where these events, activities, phenomena and things happen or exist.

GIS provides an effective way of monitoring land use change. With the increasing proportion of world's population resident in cities and towns, and so understanding of the environmental impacts of urban settlements is an increasingly important focus of attention in science and policy. Public Administrators can find GIS to be a useful tool for investigating and understanding array of public administration related problems and their consequences and thus able to predict the future consequences. Such predictions can be based on historic patterns of growth, together with information on the location, and other factors. Each of these factors may be represented in map form, as a layer.

This paradigm was what was followed by scientists who examined the cause of Spanish Flu pandemic of 1918/19 in 1997. They started by examining an exhumed body of a young woman who was the victim of the flu in 1918 and was laid in a permafrost in Alaska frozen ever since. The analysis helped to know that the influenza was caused by virus and that it can be spread from person to person in respiratory secretions expelled by coughing, sneezing and talking. Scientists predicted a comeback of such pandemic after identifying present prevailing conditions similar to the 1918 to include; high volume of international travel due to development of transport; a number of war zones with inherent problems of malnutrition and poor hygiene; growth of world population and increased proportion of urban population; many urban areas with decaying infrastructure in terms of waste disposal. The conclusion was 'put simple, each year brings us closer to the next pandemic. This eventually came true as "COVID 19". During the period beginning December 2019 through almost the whole of 2020, the virus, called 'corona virus' spread rapidly throughout the world. Morbidity was extensive in all age groups, and there was widespread disruption of social and economic activities in all countries. Health care systems in even the most economically developed countries could not adequately cope with the demand for health care services. This was similar to what took place in 1918/19. Victims of the Spanish flu died en masse, for there was no effective cure. Millions of healthy young people were suddenly cut down during their most productive time of life, corpses piled up faster than they could be buried. In some places entire towns and villages were wiped out (Daniel, 2020).

In following section of this article, the practical methodologies of the use Geographic Information System for map making is discussed with simplicity to equip the public administrator with the skills of using the GPS obtained field data discussed in the previous section to produce simple maps and plans needed for his various professional practices without being engrossed in the complexities that concern the professional Geographers and Cartographers.

The Process of Geographic Information Systems (GIS) Mapping

Maps represent the pinnacle of most GIS projects. Maps are a very effective way of summarizing and communicating the results of GIS operations to a wide audience. The importance of map output is further highlighted by the fact that many consumers of geographic information only interact with GIS through their use of map products. This section of the paper discusses the processes involved in the use of GIS to create formal maps according to well-established cartographic conventions that can be used as reference or communication products. These processes may seem to be complex especially because more than one software package is needed. However, the simple step-by-step processes presented can successfully lead to a complete mapping exercise.

The process of mapping using the GIS technology includes the following:

Step i*:* Acquire the current satellite imagery of the ground area to be represented on a map online from any chosen satellite-producing company.

Step ii: Use the acquired imagery to carry out ground truthing. This involves field exercises to match the true ground features with imagery features using GPS as discussed in the previous section. In other words, at this stage, you try to identify all the relevant features in the imagery on the real ground and label them accordingly.

Step iii: *Raster Data Capture Using Scanners:* A scanner is a device that converts hard-copy (analogue) data layer into digital images by scanning successive lines across the hard-copy image and recording the amount of light reflected from it. The differences in reflected light are normally scaled into bi-level black and white (1 bit per pixel), or multiple gray levels (8,16 or 32 bits). Depending on the scanner and the resolution required, it can take from 30 seconds to 30 minutes or more to scan a map image. This step applies when the base map is available only in analogue form.

Step iv: *Geo-referencing:* At this stage, you ensure that the verified labelled imagery or scanned map image is registered with the global coordinate system to give the proposed map area its true position on the earth's map space. The coordinates of at least three positions in the proposed map area can be obtained online, using the Earth Google Application or tracked using the Global Positioning System (GPS) at any three strategic locations respectively. The obtained coordinate figures are then used to tie the image to the global azimuth. Image processing GIS software such as ERDAS Imagine; ILWIS, ArcMap etc., provide versatile templates to handle this task successfully.

Step v: *Digitizing:* This is the process of converting raster data into vector data. The satellite imagery or scanned map image in the computer is known as a raster data layer. Therefore, the simplest way to create the vector objects from the raster larger is to digitize vector objects manually straight off a computer screen using a mouse or digitizing cursor. This method is called heads-up digitizing because the map is vertical and can be viewed without bending the head down. Through this method, all the map features are digitally captured into the computer. The features may include roads, buildings, boundaries, agricultural fields, streams/rivers etcetera. In GIS, objects or features are classified according to their topological dimension, which provides a measure of the way they fill space. Accordingly, the traditional GIS map feature representation can be classified into three main types namely:

- Point feature – 0 dimension
- Line feature – 1 dimension
- Area feature – 2 dimension

***Point Feature*:** A point has neither length nor breadth nor depth, and hence is said to be of dimension 0. Points may be used to indicate buildings, telecommunication masts and the like depending on the map scale.
***Line Feature*:** Lines have length, but not breadth or depth, and hence are of dimension 1. They are used to represent linear entities such as roads, pipelines and cables.
Area Feature: Area features have the two dimensions of length and breadth. They may be used to represent features such as a region, local government area, senatorial district, federal constituencies and so forth.*
*Insert: *The highly specialised GIS programmes have provisions for three-dimensional features. These allow the use of more complex information for visualisation and analysis and provide more intuitive ways of interacting with the data* (Daniel, 2020).

The GIS mapping software also allows for different sizes, shapes and colours of feature symbols. For instance, there may be line symbols which are blue, brown or black. Some line features could be shown in double lines while others are shown as single lines. Yet others could be shown in interrupted lines. The same is true of points and area symbols. These are known as variations in cartographic symbols. They vary in (i) form (ii) dimension (iii) colour.

Form refers to all possible variations in shape and structure. Dimension refers to all variations in size and includes the width of line symbols and the diameters of point symbols. The color of cartographic symbols consists of three variables, hue, lightness and saturation. Hue refers to the dominant wavelength of electromagnetic radiation contained in or reflected by the colour. Hue gives rise to descriptive names like red, blue, green, yellow etcetera. In ordinary usage, colour is synonymous with hue, but this is not technically correct. Lightness refers to the amount of light reflected by the colour, that is, the brightness of the colour. Lightness is therefore related to the amount of black in a particular colour. Saturation refers to the "pureness" of the colour. A spectrally pure colour is fully saturated. As an example, a fully saturated red will reflect wavelengths in the red part of the spectrum (0.6 – 0.7 micrometres) and very few others. However, the presence of many other wavelengths will render the colour less definitely red. Pink, for example, is de-saturated red.
Step vi: *Creation of Feature Themes:* This stage involves an organised collection of data on different themes or object classes (e.g. boundaries, roads, buildings, etc). Object classes are stored in standard database tables. A table is a two-dimensional array of rows and columns. Each object class is stored as a single database table in the Database Management System (DBMS). Table rows contain objects that are instances of object classes. Examples are data for a single building. Columns contain objects properties or attributes.
Step vii*: Map Design:* This is the last stage in the process of mapping in the GIS environment. Map design is a creative process during which the map maker tries to convey the message of the map's objective. The primary goals in map design are to share information, highlight patterns and processes, and illustrate results. The secondary objective is to create a pleasing and interesting picture while preserving the primary goals.

Map design is a seemingly complex procedure requiring the simultaneous optimization of many variables and harmonization of multiple methods. One may find it challenging to define exactly what constitutes a good design. Generally acceptable is that a good design looks good, is simple, elegant and most importantly, leads to a map that is fit for the intended purpose.

According to Robinson et al. (1995) cited in Longley et al. (2005), map design process is controlled by seven component subjects. These are:

vi. Purpose
vii. Reality
viii. Available data
ix. Map scale
x. Audience
xi. Conditions of use

xii. Technical limits

Map composition: A well designed map usually comprises several closely interrelated elements listed but not limited to the following:

7 Map body
8 Inset/overview map
9 Map title
10 Legend
11 Scale
12 Direction indication
13 Map metadata

A key requirement for a good map within the scope of consideration is that all the map elements are composed into a layout that has good visual balance (Daniel, 2020). See example in Fig. 2.

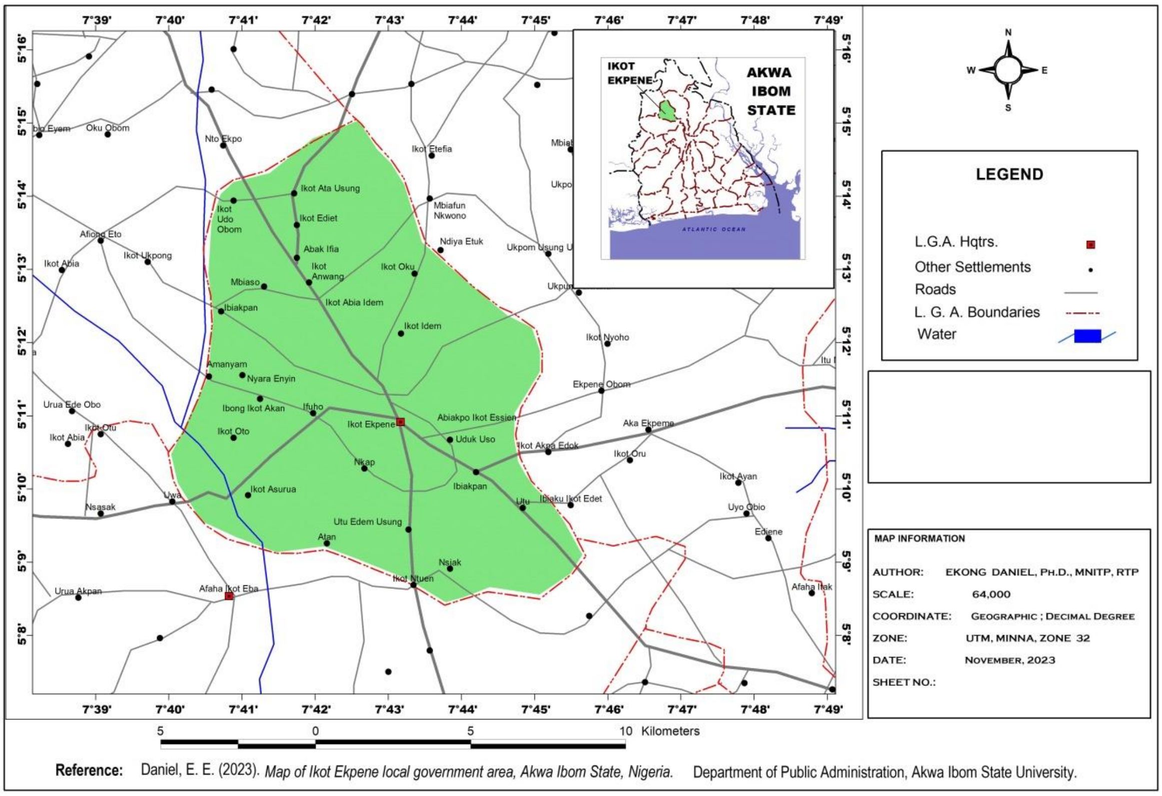

Fig. 2: An example of map composition with all the interrelated elements
Source: Daniel (2023) DOI: 10.13140/RG.2.2.33139.50723

Examples of GIS Applicable Studies in Public Administration

The GIS mapping tools can allow public administration experts to visualize data and help make decisions based on geographic context in the following areas:

i) Using GIS mapping tools to identify areas with high crime rates; by mapping out crime data, public administrators can target specific areas for increased policing or other crime prevention measures.

ii) Using GIS mapping tools to identify areas that are underserved by public services such as healthcare, telecommunication or education. By identifying these areas, public administrators can work to provide more equitable access to services.

iii) Using GIS mapping tools to identify areas that are at risk of natural disaster. By mapping out flood zones, erosion risk areas, and other areas at risk of natural disasters, public administrators can prepare for potential disasters and take steps to protect the public.

iv) Using GIS mapping tools, public administrators can track the progress of disaster relief efforts and ensure that all affected areas receive the help they need (Battersby, 2015; Hensley, 2013; Li & Kenneth, 2016).

v) Using GIS mapping tools, public administrators can identify potential areas for industrial development in rural areas. This can avail opportunities for harnessing the abundant natural resources deposits in our rural settlements thus creating job opportunities and fast-tracking development in these areas (Mbon and Ewium, 2021).

Conclusion

Global Positioning System (GPS) and Geographic Information System (GIS) are contemporary technologies that have the capabilities of providing necessary physical input and intelligence for the preparation of base maps, formulation of administrative planning proposals and acting as monitoring tools during the implementation phase. Other useful tools include remote sensing tools and Satellite imageries that can help public administration experts maintain truthful records of terrain during such period. These tools are emerging as powerful land-related technologies for analysis, decision-making, monitoring and management of public concerns. They are quite available at the disposal of Public Administration experts if they are to successfully meet the challenges surrounding the procedure of planning development. A Public Administration expert is a leader who directs the course of development, therefore he is expected to understand basic space-related concepts and principles such as the concept of coordination, the longitude and latitude, the concepts of scale and measurement technologies highlighted in this paper to generate forms of data sets and analysis needed to guide rational decisions for the general public good.

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