Creation of Geographic Information Systems for Minna, Niger State, Nigeria

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Abstract
Wherever it exists, the Minna Geographic Information Systems (MGIS) has not been accessed in a user-friendly, sharable format: such a format would be a veritable portal by which a lot of operations could be implemented. Thus, this study was undertaken such that this protocol could be created with an attendant dedicated building-layer. An analogue map of Minna was acquired, georerenced and digitized using ArcMap and ArcCatalog routes in the ArcGIS9.3 suite. Subsequent analyses (especially for road network), query, and the layer features were built into this GIS platform. About 235 distinct stations of interest were captured for the building-layer substratum.

Keywords: GIS, GIS layer, georeference, portal, spatial analysis

INTRODUCTION

Overview: Improvements in information technology have provided unimaginable opportunities to support data analyses and communication in the last two decades. Now, the Geographic Information Systems (GIS) has provided new and exciting ways of acquiring natural resource data and also providing efficient means of processing, managing, and integrating these data. Also, geospatial technology is fast becoming a vital tool in environmental physics and management systems covering database management, planning, risk assessment, service area mapping, identification of locations, status of healthcare personnel, etc. Wherever it exists, the Minna Geographic Information System (MGIS) has not been accessed in a user-friendly, sharable format: such a format would be a veritable portal by which a lot of operations could be implemented.

Though the Minna Geographic Information Systems (MGIS) has existed in one form or another (Jonah et al 2011A; 2011B; 2011C; 2011D), an MGIS with a dedicated building-layer (residential, educational, government or administrative, commercial, financial institutions, including key buildings at the Bosso Campus of the Federal University of Technology, Minna) has never been implemented before. For the first time, this new MGIS is user-friendly, sharable, and is now a vehicle by which many different GIS layers are readily brought to the fore and displayed.

The objective of this study is principally the development of a new Minna Geographic Information Systems (MGIS) user-friendly and sharable scheme with a dedicated building-layer. (In addition, this MGIS can perform some spatial analyses such as query, road network analysis, and accessibility of the locations of the various buildings.)
The creation of a user-friendly and sharable MGIS with the aforementioned spatial

analyses would be a boon to environmental scientists, town planners, revenue officials, government planning agencies, and all other stakeholders devoted to studies designed to be components of any audit mechanism tool for Minna town.

The Minna built-up town centre (from the Maryam Babangida Girls Science Secondary School in the north to the Abdulkareem Lafene State Secretariat in the south, and the southwest-northeast Kpakungu-Maitumbi axis), was covered for this study, see Fig. 1.

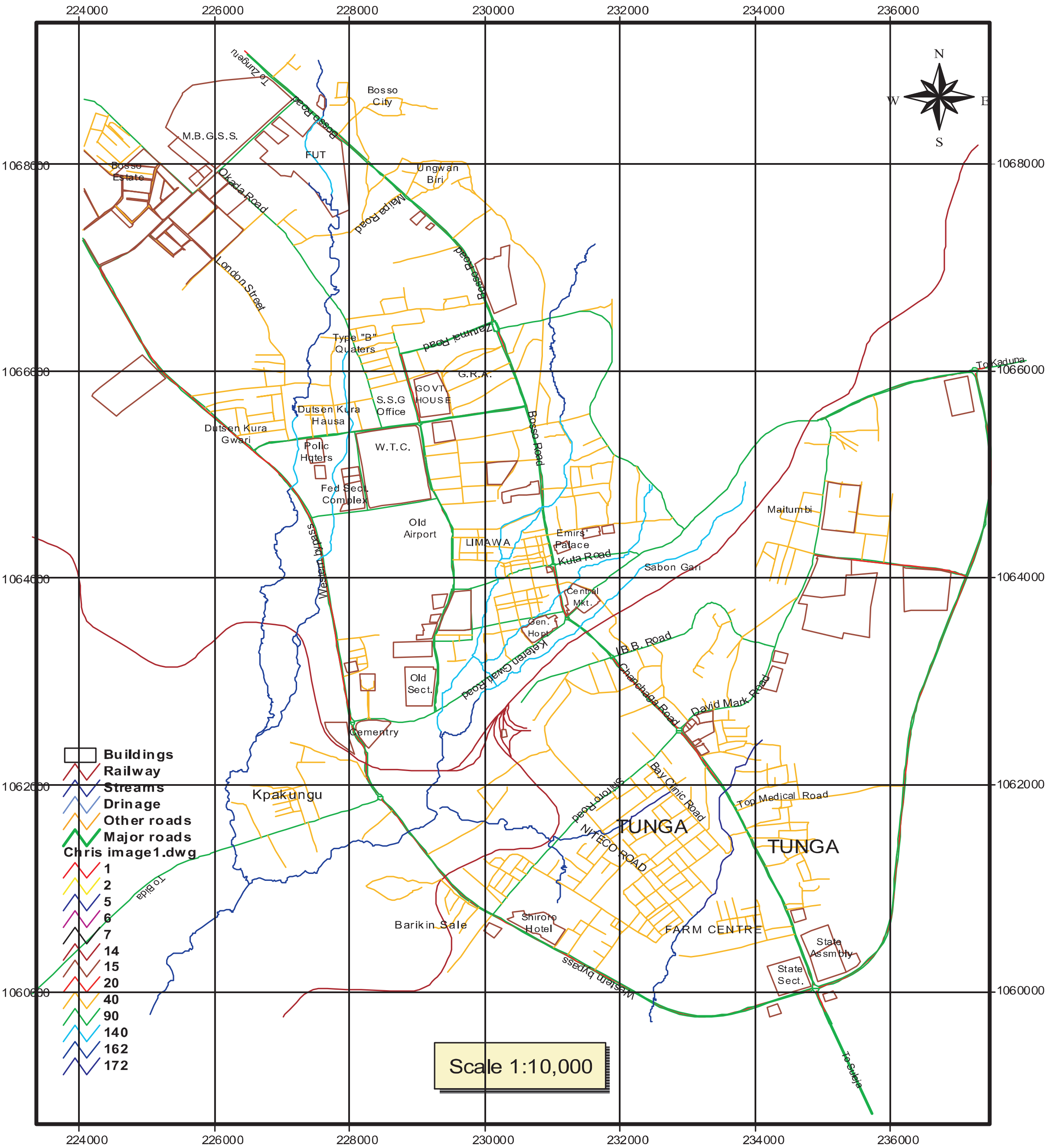

Fig.1. Map of Minna. (The study covered the Maryam Babangida Girls Science Secondary School in the north to the Abdulkareem Lafene State Secretariat in the south, and the southwest-northeast Kpakungu-Maitumbi axis.)

Concept of Georeferencing: There is a great deal of geographic data available in formats that cannot be immediately integrated with other GIS data. In order to use these types of data in GIS it is necessary to align it with existing geographically referenced data; this means that coordinates from a known system are assigned to an aerial photo or scanned paper map (both are raster data). Thus, the photo pixels get a geographic location. Geo-referencing is also a necessary step in the digitizing process. Digitizing in GIS is the process of "tracing", in a geographically correct way, information from images/maps. The process of geo-referencing relies on the coordination of points on the scanned image (data to be georeferenced) with points on a geographically referenced data (data to which the image will be geo-referenced). By "linking" points on the image with those same locations in the geographically referenced data you will create a polynomial transformation that converts the location of the entire image to the correct geographic location. We can call the linked points on each data layer control points.

Concept of Latitude and Longitude: According to Jian and Philippa (2009), latitude can be defined as the angle between the equator and a line perpendicular to the ellipsoid, which ranges from 90^o north or south of the equator. Latitude is commonly given the Greek symbol phi (ϕ) and longitude lambda (λ) . A line of constant latitude is known as a parallel. Parallels never meet since they are parallel to one another, whereas meridians (lines of longitude) converge at the poles. The authors also pointed out that longitude is more complex and only east-west measurements made at the equator are true. Away from the equator, where the lines of latitude decrease in length, measures are increasingly shortened, by approximately the cosine of the latitude. This means that at 30^0 north (or south), shortening is about 0.866, 0.707 at 45^0 and 0.5 at 60^0 . At 60^0north or south, 1^0 of longitude will represent 55km ground distance.

Concept of the Universal Traverse Mercator (UTM): The Universal Transverse Mercator (UTM) is a geographic coordinate system that uses a two (2)-dimensional Cartesian coordinate system to give locations on the surface of the earth. It is a horizontal position representation, i.e. it is used to identify locations on the earth independently of vertical position, but differs from the traditional method of latitude and longitude in several respects. The UTM system is not a single map projection. The system instead divides the earth into sixty zones, each a six-degree band of longitude, and uses a secant transverse Mercator projection in each zone (www. en.wikipedia.org.) Jian and Philippa (2009) stated that a further modification of the Mercator allows the production of the Universal Transverse Mercator (UTM) projection system. It is again projected on a cylinder tangent to a meridian [as in the Transverse Mercator (TM)] and by repeatedly turning the cylinder, about its polar axis, the world can be divided into 60 east-west zones, each 6^0 longitude in width. The projection is conformal so that shapes and angles within any small area will be preserved. This system was originally adopted for large-scale military maps for the world, but it is now a global standard and again is useful for mapping large areas that are oriented in a north-south direction. Projected UTM grid coordinates are then established which are identical between zones. Separate grids are also established for both northern and southern halves of each UTM zone to ensure there are no negative northings in the southern hemisphere. Hence, when quoting a UTM grid reference, it is essential to state eastings, northings, zone number and the hemisphere (north or south) to ensure clarity.

The Universal Transverse Mercator is a global coordinate system that is defined in meters rather than degrees-minutes-seconds. UTM is a very precise method of defining geographic locations; therefore, it is commonly used in GPS and GIS mapping. When using the UTM coordinate system, a location can be identified within a meter (www.brocku.ca2012).

The Geographic Information Systems (GIS): According to Bruce (2008), Geographic Information System (GIS) can be defined as a computer system that stores, manages, displays, analyses and reports on information which has a 'where' component, i.e. a location, because a number of decisions undertaken by staff in land-related organisations often refer to 'what', 'where', 'how much', 'what does this relate to' and 'how does this relate to my other data.' The inclusion of the 'where' component into the decision-making process can be a powerful tool for providing a better understanding of the issues at hand and the implications of specific decision paths. Nicholas (2002) mentions that there are dozens of definitions for the term Geographic Information System (GIS), each developed from a different perspective or disciplinary origin. Some focus on the map connection; some stress the database or the software tool kit; and others emphasize applications such as decision support. One of the most general definitions was developed by consensus among 30 specialists: Geographic Information System – A system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth. While this definition may seem bland, it encompasses all the characteristics, as long as the terms are expanded to their intended meaning. For example, the word system implies a group of connected entities and activities. An automated information system organizes a collection of data, computer procedures, and human organizations to serve some particular purpose. For a GIS, the purpose could involve a complex decision, such as the policy for timber harvest or a routine decision, such as granting a permit or maintaining an inventory. Notice that the definition carefully distinguishes between the data in the system and the information that results from the system. Data provide the raw material for information, much as map symbols convey a map message. For both maps and information systems, the raw data are not enough; additional relationships must be constructed from the context. The most common understanding of a GIS emphasizes that a GIS is a tool. However, no tool is totally neutral; a GIS can be designed to be effective and efficient for a certain purpose. Tools are developed within a social and historical context to serve changing needs, but tools are also intended to change their environment.

According to Encyclopædia Britannica (2012), computer algorithms enable the GIS operator to manipulate data within a single thematic map. The GIS user may also compare and overlay data from multiple thematic maps, just as planners used to do by hand in the mid-1900s. A GIS can also find optimal routes, locate the best sites for businesses, establish service areas, create line-of-sight maps called viewsheds, and perform a wide range of other statistical and cartographic manipulations. GIS operators often combine analytical operations into map-based models through a process called cartographic modeling. Experienced GIS users devise highly sophisticated models to simulate a wide range of geographic problem-solving tasks. Some of the most complex models represent flows, such as rush-hour traffic or moving water, that include a temporal element. Paul (1991) mentions that Geographic Information Systems are computer systems for the integrated handling of geographical or spatial data. The most commonly-used device used by geographers to integrate data relating to the physical, social, economic and political characteristics of an area is the map. A map is both a repository of facts and a tool for drawing inferences. The first of these properties is readily appreciated by looking at an atlas. Questions such as "what is the name of the river on which New Orleans stands?" or "what is the height of Ben Nevis?" can be answered by referring to the appropriate page of the atlas. The second property, that of allowing inferences to be made, requires a map showing two or more features of an area, such as the distribution of tree species and height above sea-level. The human eye and brain can produce generalizations such as "in this particular area, pine trees grow only at heights greater than 90 meters above sea-level." This type of generalization requires the comparism of maps showing the two spatial patterns of elevation of the terrain above sae-level and the distribution of pine trees over that same terrain.

Literature Review: In 1999, Paul et al worked on Geographic Information System characterization of metal loading in the bi-national Tijuana River watershed. According to the authors, the paper describes a GIS- based, land use runoff model that estimates the annual mass emission of copper (Cu), lead (Pb) and zinc (Zn). Their findings indicated that the urbanized portion of the city of Tijuana, Mexico, accounted for 37 to 47 percent of the actual downstream loading of these metals to the Tijuana Estuary and coastal ocean. The fraction of loading contributed by open space was about the same (31-44%), although this land use comprised about 90 percent of the total watershed area. According to the authors, modelled estimates of the annual mass emission of heavy metals are in reasonable agreement with actual measurements, particularly for zinc (within about 10%), thereby suggesting that GIS-based modelling may be useful for predicting nonpoint source pollutant loading in a variety of border development scenarios.

Twigg (1990) reported that spatial analysis of GIS has ability to create buffer zones around the lines or points which represent location of illness, population and other hazardous sites which is of a benefit to investigation in which if the user can specify the buffer zones and sizes and then merge this information with diseases incidence to determine how many counts of the illness fall within the buffer zone.

Mona et al (2006) published a study based on the need to develop tools for healthcare professionals and communities to assess environmental exposures and the need to evaluate the utility of integrating patient-reported environmental health information with Geographic Information Systems (GIS) mapping of environmental data in a pilot study. A survey was used to collect self-reported environmental exposure and health data from a convenience sample of people at an urban community health centre: environmental exposure and census information were also obtained from federal agencies. Analysis was performed using descriptive statistics and GIS. The authors reported frequent environmental health risk factors such as older housing (93%) and household smoking (78%). Health problems, including asthma (54%) and lead poisoning, (14%) were reported. Odds ratios indicated a statistically significant relationship between mold/mildew and reporting asthma. GIS was found to be a useful tool in displaying environmental risk factors and potentially associated health effects. Given the important role that environmental health risks can play in public health, it is critical that community/public health nurses begin to integrate environmental health assessment skills into their professional practices. Simple community surveys can be an effective means to raise awareness about environmental health risk factors and utilizing GIS can further enhance the accessibility of the combined exposure and health information.

According to Ismail and Patrick (2008), geospatial information systems provide avenues to fulfill users' quest for both absolute and relative locations of features/objects. To achieve this, the users need to have access to different geospatial data sets from various sources. This calls for integration of data from different geospatial sources. But, there are shortcomings as different data sets may not map exactly onto one another, one of reasons being the difference in features' geometry. The authors reported on a conceptual model for geospatial data integration that can identify and measure differences and adjust spatial geometries of geospatial features to form meaningful objects which can be used for geo-spatial analysis, modeling, and easy geo-information management.

According to Ehsan and Ahmad (2001), reducing road accidents in Malaysia was a concern to the citizens and government. By making use of IRAS (Intelligent Road Accident System), the police would be control and manage accident events as in real-time. This system exploits WiMAX and GPRS communications to connect to the server for transfer the specific data to the data center. This system can be used for a comprehensive intelligent GIS-based solution for accident analysis and management. The system is developed based on object and aspect oriented software design such as .NET technology.

Holley (2002) reported that, although archaeologists traditionally have viewed Geographic Information Systems (GIS) as a tool for the investigation of large regions, its flexibility allows it to be used in non-traditional settings such as caves. Using the example of Actun Tunichil Muknal, a Terminal Classic Maya ceremonial cave in western Belize, this study demonstrates the utility of GIS as a tool for data display, visualization, exploration, and generation. Clustering of artefacts was accomplished by combining GIS technology with a K-means clustering analysis, and basic GIS functions were used to evaluate distances of artefact clusters to morphological features of the cave. Results of these analyses provided new insights into ancient Maya ritual cave use that would have been difficult to achieve by standard methods of map preparation and examination.

Survey Procedures

Site Selection: The areal extent of Minna town was earmarked for this survey, initially understood to cover all of Maikunkele province to Chanchaga and all of the outlying neighbourhoods of Kpakungu to the outlying neighbourhoods of Maitumbi. However, because of the need to create a Geographic Information System (GIS) of Minna (and its concomitant building-layer) based on the acquired analogue map of Fig.1, the areal extent selected for this project work covered the Maryam Babangida Girls Science Secondary School in the north to the Abdulkareem Lafene State Secretariat in the south, and the southwest-northeast Kpakungu-Maitumbi axis. Within the areal extent identified for this survey, georeferencing the locations of dedicated buildings (i.e. residential, educational, government or administrative, commercial, financial institutions, including key buildings at the Bosso Campus of the Federal University of Technology, Minna) that are necessary to create a building GIS-layer was basically a house-to-house "on-the-spot-assessment" scheme, sort of. In order to maintain some sense of pattern and order in the georeferencing scheme, an east-west traverse was chosen with a gradual southerly progression. Any building of interest was appropriately georeferenced whilst other conventional identifiers (like typical street locations and elevations above mean sea level) at that particular location were recorded. About 235 distinct stations of interest were identified for this project exercise; all of the neighbourhoods within the defined areal extent of this project exercise (i.e. Bosso Estate, Bosso Province, Angwan Biri, Type "B" Quarters, Dutsen Kura Gwari, Dutsen Kura Hausa, Government Reservation Area, Limawa, Old Airport Quarters, Anguan Daji, Sabon Gari, Kpakungu, Tunga, Barkin Sale, and Farm Centre) were visited in the course of this survey.

Survey Tools

Field Compass: The compass was used extensively during the course of this survey as a key direction-finder. Since the map of Fig. 1 has a directional icon indicating the four cardinal points, the compass enabled the survey party to confirm that the vicinity of Maryam Babangida Girls Science Secondary School (the most northern of the stations of interest) is truly northward of the staging or muster point for this survey, i.e. the Federal University of Technology, Minna's Bosso Campus. The compass was also used in tandem with the hand-held Global Positioning System (GPS) unit to eliminate any doubt whatsoever as to whether the study group members were on an exact straight course, when this information was desired.

Hand-held Global Positioning System (GPS) Unit: The Garmin etrex hand-held Global Positioning System (GPS) unit was employed chiefly for georeferencing of stations of interest during the course of this survey; it was also used in tandem with the field compass, for a minor role sort of, to confirm a defined "rectilinear" direction.

The Minna Geographic Information System (MGIS): Upon georeferencing and digitizing Fig.1 in the ArcGIS9.3 environment, the operational form of the MGIS was obtained.

Operational Form of the Building-Layer of the Minna Geographic Information Systems (MGIS): To create a dedicated-building (i.e. those buildings corresponding to residential, educational, government or administrative, commercial, financial institutions, including key buildings at the Bosso Campus of the Federal University of Technology, Minna, even encompassing the new Physics Laboratory 1 and Physics Laboratory 2) layer for the MGIS, the dataset for these buildings (i.e. the principal x and y attributes) were copied into "Notepad" whence "Tools" was accessed, then the "Building" dataset was browsed for from the directory, then "Edit to Set Projection" was clicked on to select predefined coordinate system; all these processes were okayed to inaugurate the building-layer to the ArcMap content. A composite map of the MGIS with the building-layer is shown as shown as Fig. 2.

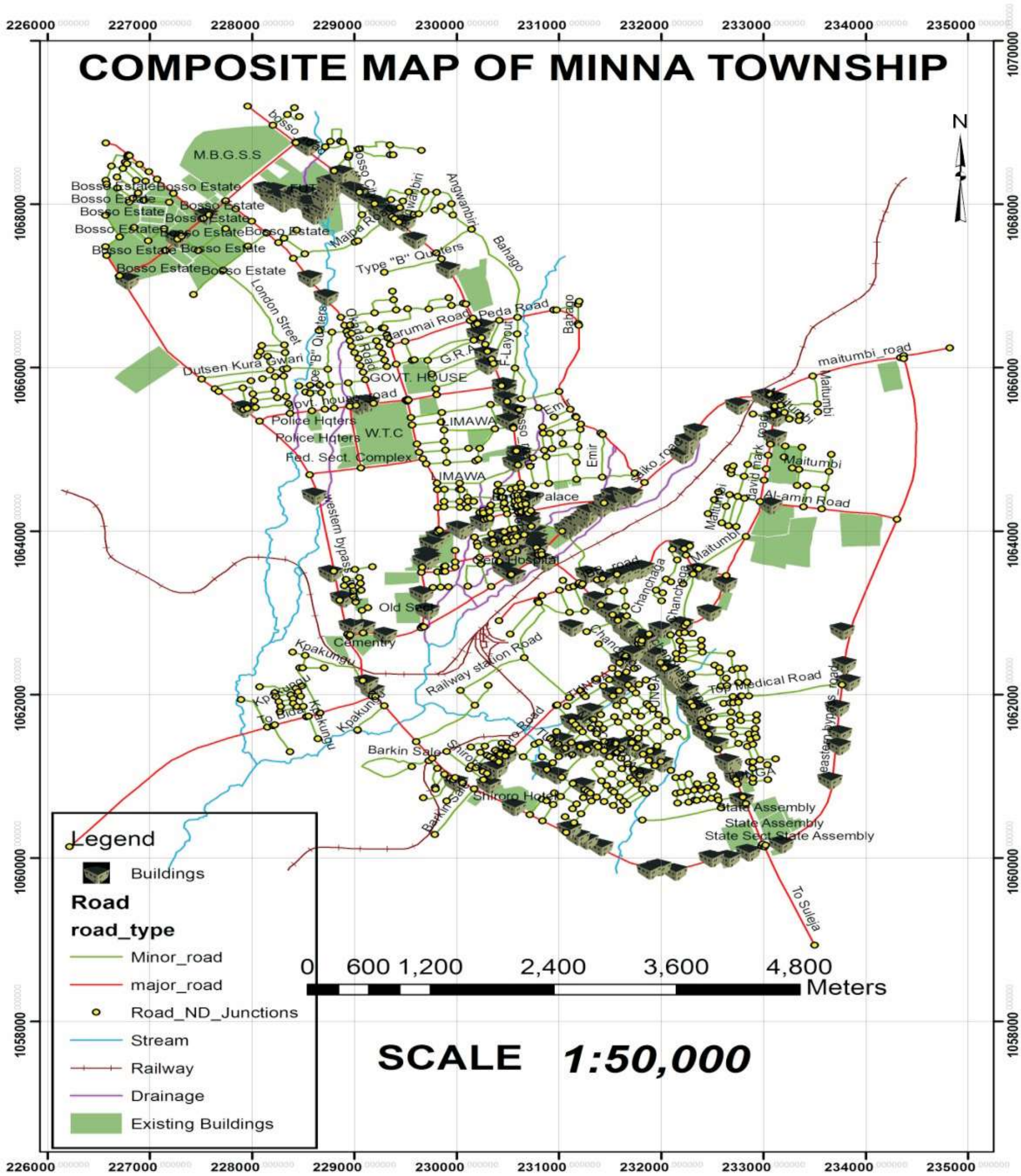

Fig.2. Composite map of the MGIS with the building-layer. (All categories of buildings are shown here.)

The map of Fig. 2 lends itself to query whence such attributes as the commercial buildings, residential buildings, administrative buildings, educational buildings, financial institutions buildings, and dual commercial/residential buildings sub-layers are displayed: see Figs 3-8.

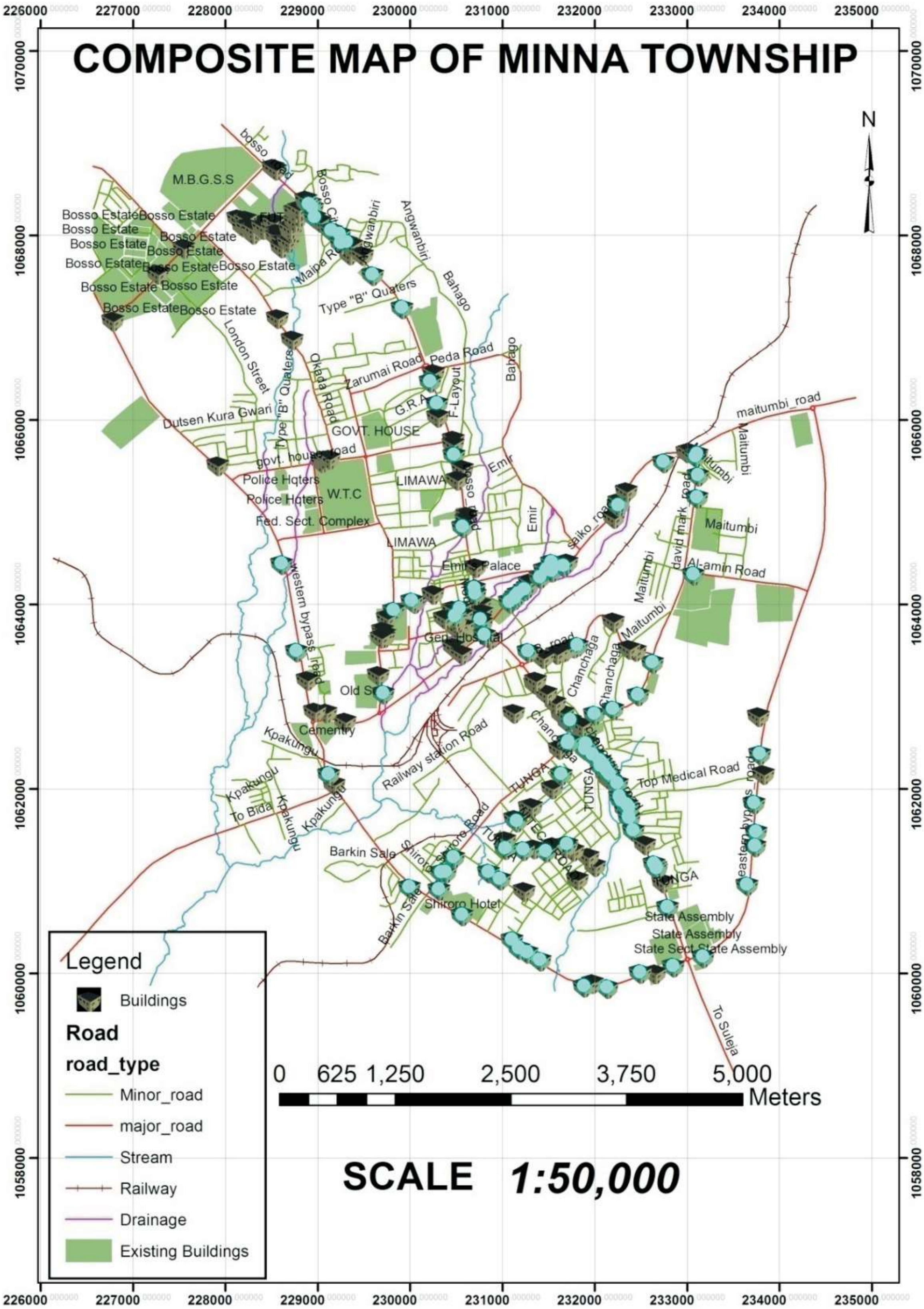

Fig.3. MGIS map with commercial-buildings sub-layer. (Only the commercial buildings mapped are highlighted in blue.)

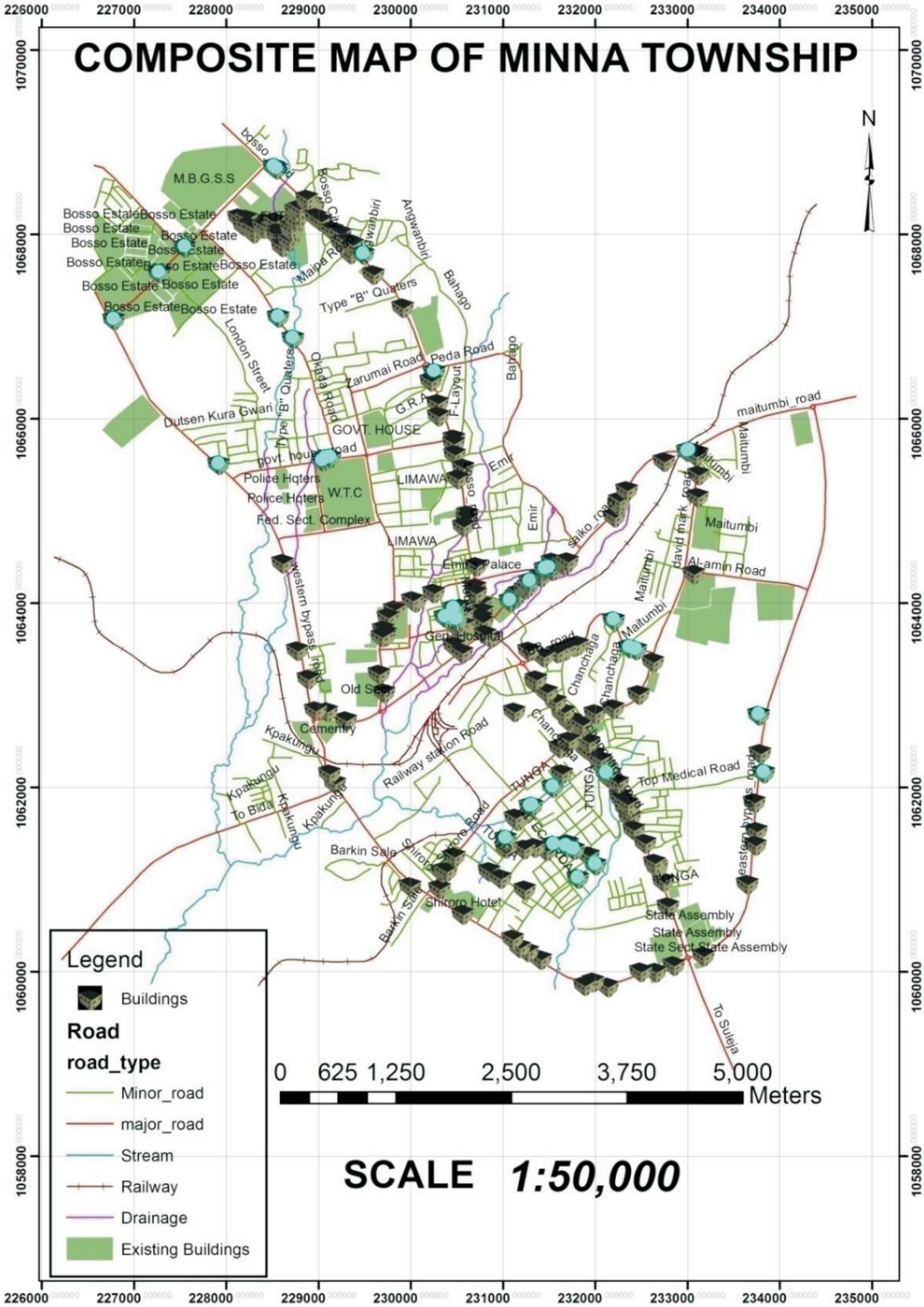

Fig.4. MGIS map with residential-buildings sub-layer. (Only the residential buildings mapped are highlighted in blue.)

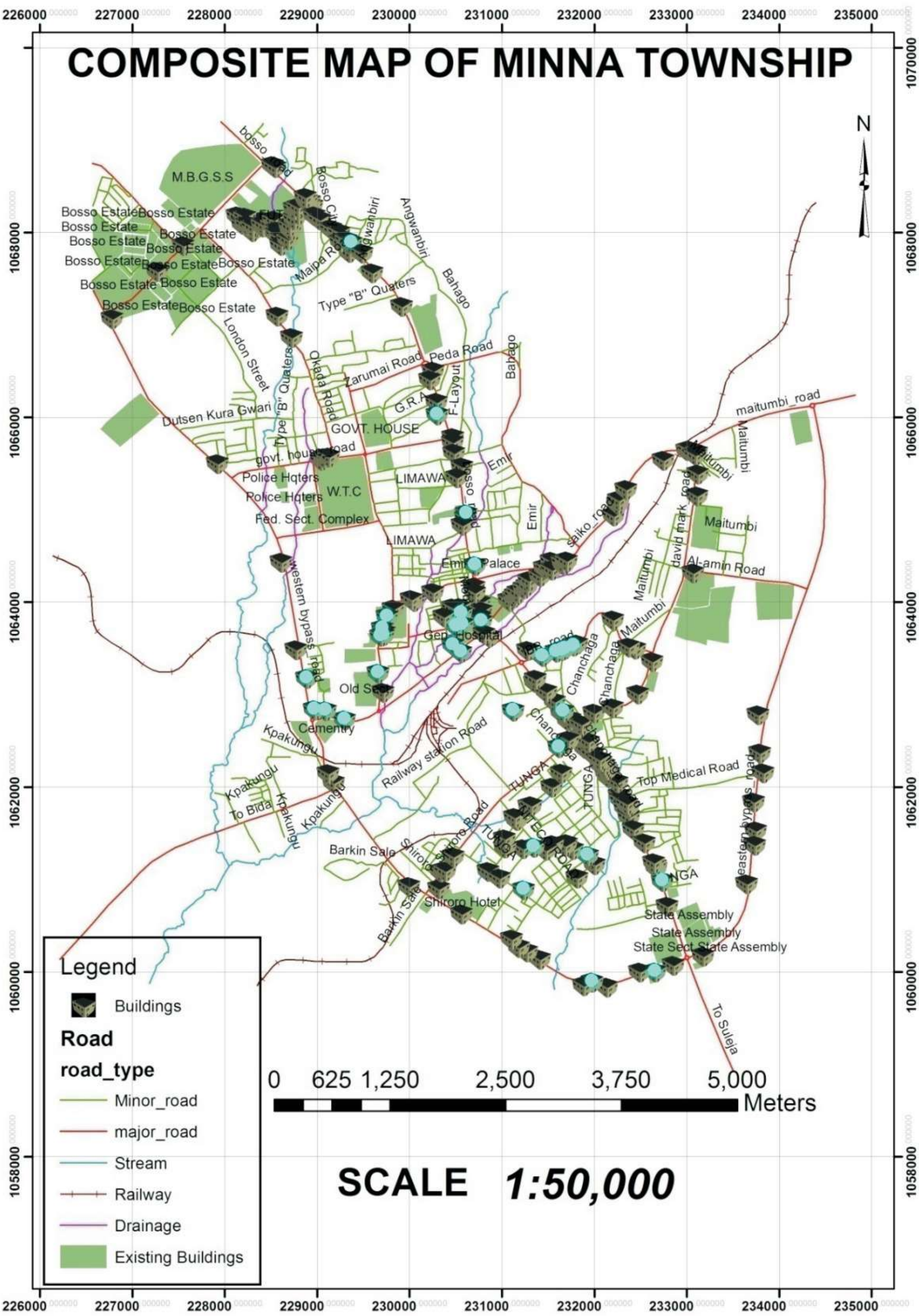

Fig.5. MGIS map with administrative-buildings sub-layer. (Only the administrative buildings mapped are highlighted in blue.)

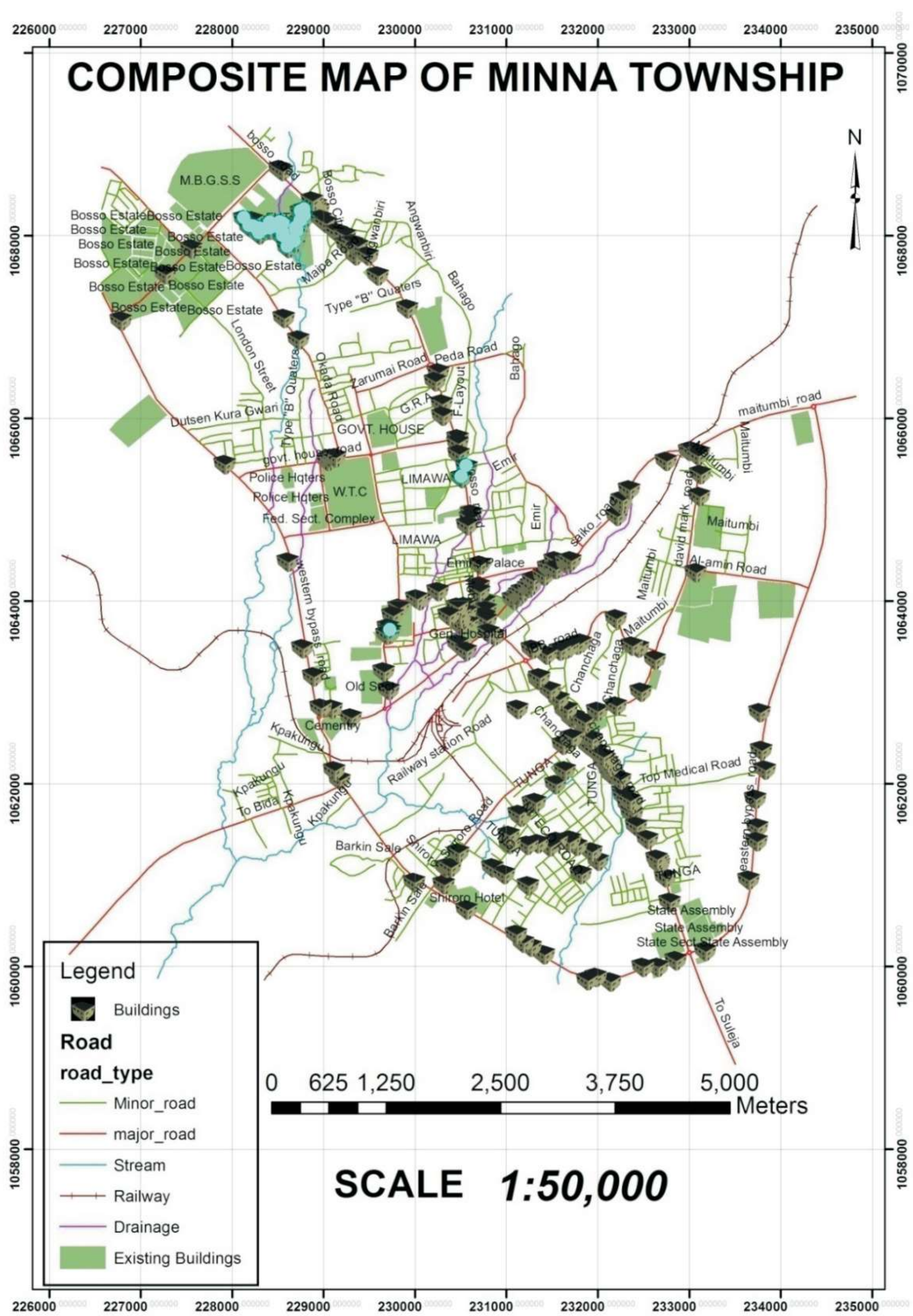

Fig.6. MGIS map with educational-buildings sub-layer. (Only the educational buildings mapped are highlighted in blue.)

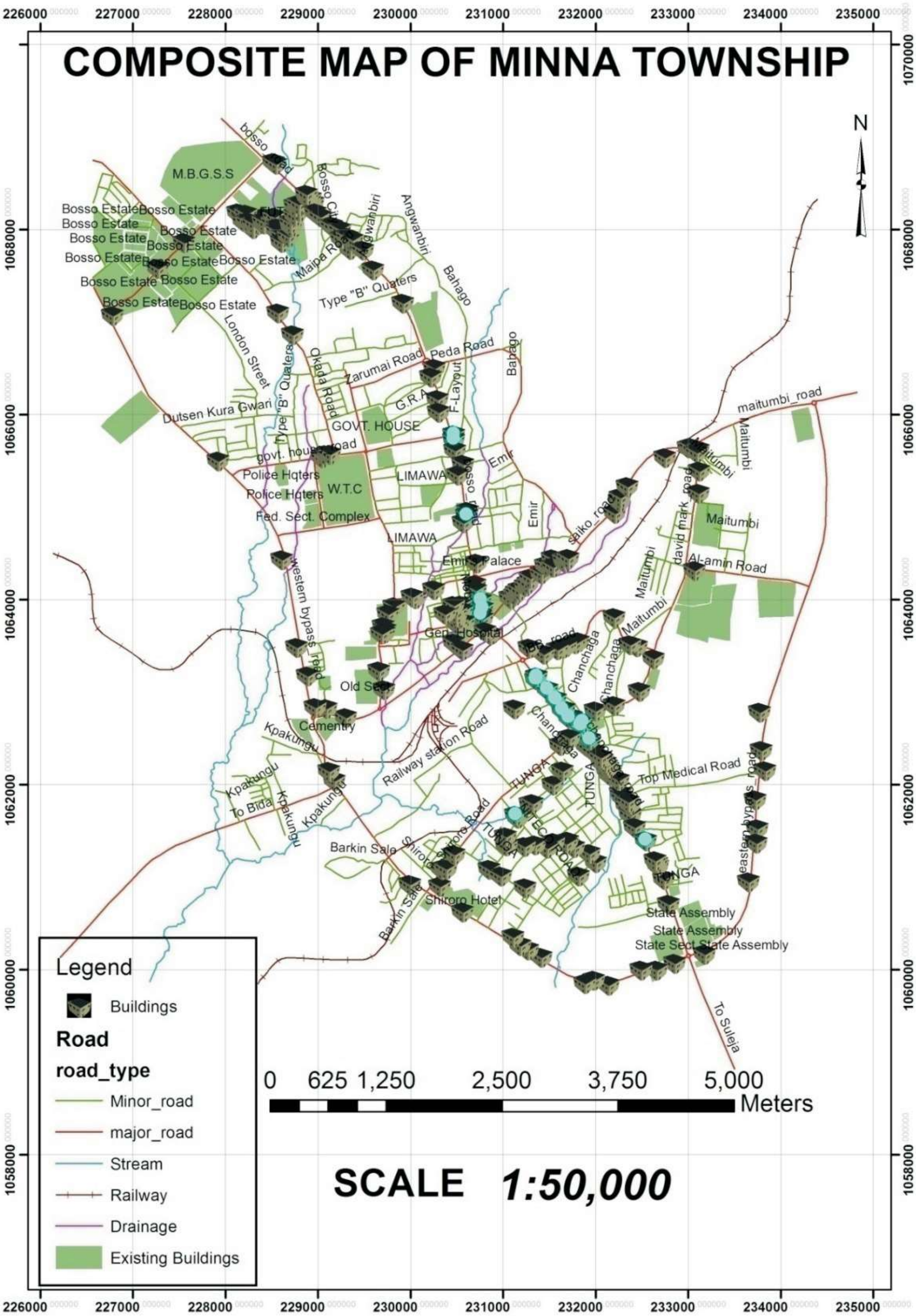

Fig.7. MGIS map with financial institution-buildings sub-layer. (Only the financial institution buildings mapped are highlighted in blue.)

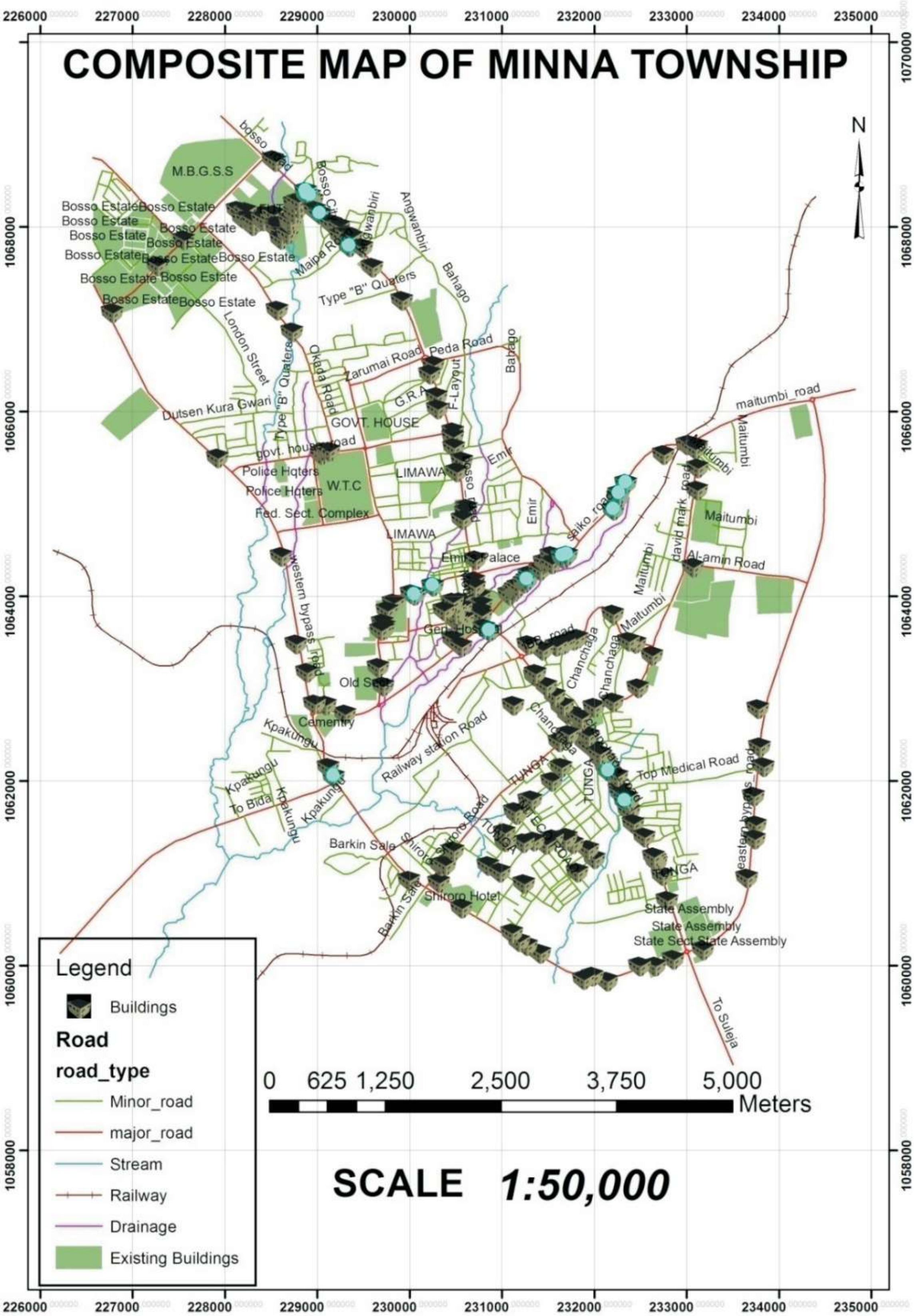

Fig.8. MGIS map with dual commercial/residential-buildings sub-layer. (Only the dual commercial/residential buildings mapped are highlighted in blue.)

Road Network Analysis of the Minna Geographic Information System (MGIS): Network analysis can be done using vector data layer. Line features are associated with a network naturally and could be given typical transportation characteristics like capacity. One of the characteristic of network is to consider whether the network lines are directed or not. Some of the network analyses are optimal path finding, network partitioning and trace analysis. The product of interest was generated, such as best route, for the study area. Fig.10 shows a graphical representation on the best route or the estimated shortest time through the roads networks: for this particular instance, the Maitumbi-F.U.T. Bosso Campus gate route was considered. The trace analysis of the ArcGIS address locator was used to determine the best path.

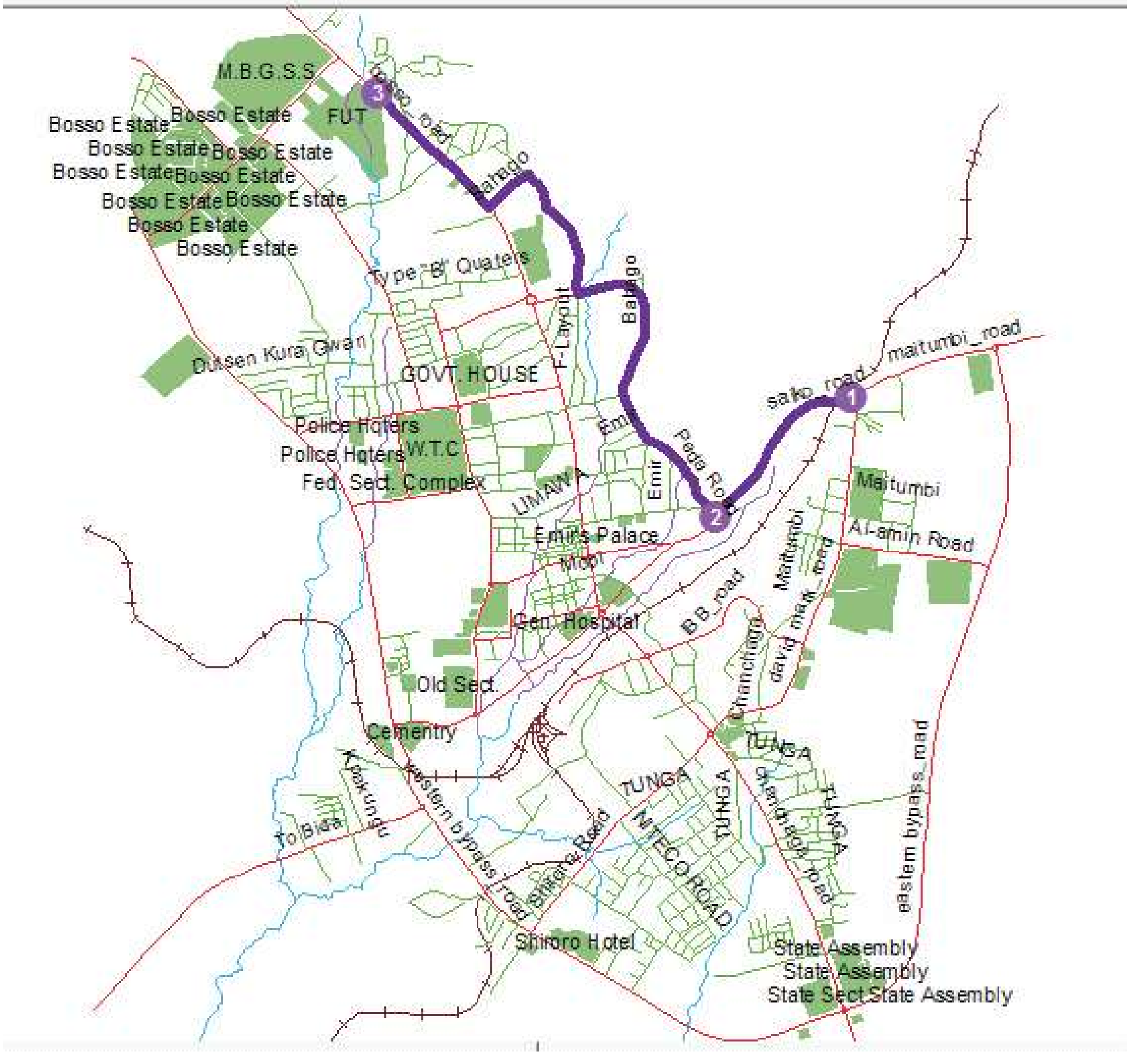

Fig.9 Best route from Maitumbi-F.U.T. Bosso Campus gate

Discussion, Conclusion, and Recommendation

Discussion: Fig.10, in its operational form on the ArcGIS9.1 environment, after digitizing and georeferencing Fig.1, is the Minna Geographic Information System (MGIS) in its barest format (i.e. without associated discernible layers). Fig.10 is interactive and it is a veritable platform by which a number of other tasks in the fields of engineering, planning, management, and analysis may be performed. For this study, the MGIS format exists in a file-sharable format so that other workers whose primary area of interest is Minna town may have a tool by which their data analysis procedures could be greatly enhanced. The operational form of a building-layer for the MGIS was also created: these buildings correspond to residential, educational, government or administrative, commercial, financial institutions, Fig.2.

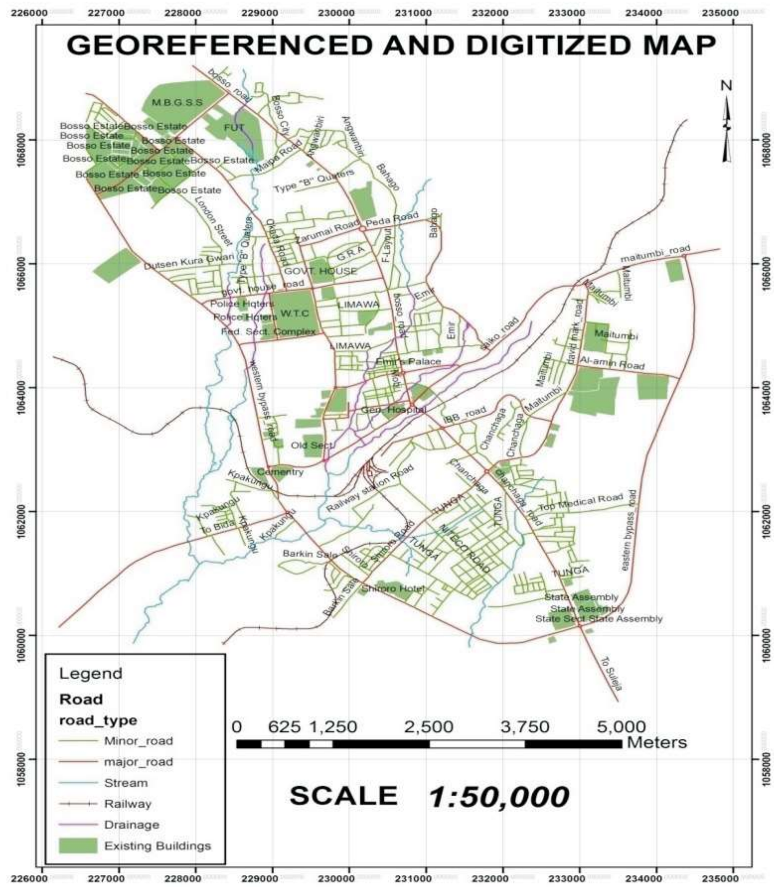

Fig.10 Operational form of the Minna Geographic Information System (MGIS)

The MGIS was also tested for its query fidelity (Figs 3-8): this study made use of the connectivity functions in the accessibility of the layers using the network analysis-to-retrieval functions which involved the spatial query of attributes. From the database prepared for this study, the single criterion query shows that 37 out of 235 buildings are residential, 104 are commercial, 17 are both commercial and residential, 33 are administrative, 27 are educational and the remaining 17 are financial institutions. The MGIS was also subjected to road network analysis in order to determine the best and alternative routes between two defined principal locales of Maitumbi and the F.U.T. Bosso Campus gate.

Conclusion: For the first time, a file-sharable format of the MGIS has been created with the accompanying building layer. Thus we now have a protocol that is a veritable portal by which a lot of operations could be implemented: this MGIS plus its building layer is now a veritable audit mechanism tool in the hands of GIS managers that finds ready application especially in the area of monitoring and managing internally-generated revenues (IGRs) within the area covered in Fig.1.

Recommendation: Since a file-sharable GIS format has been developed for Minna with its attendant possibilities, it is recommended that the other major towns of Niger State (i.e. Bida, Kontagora, and Suleja) be brought into this scheme.

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