DEVELOPMENT OF GIS-BASED ROAD TRANSPORT INFORMATION MAMAGENMET SYSTEM FOR ADAMAWA CENTRAL, ADAMAWA STATE, NIGERIA

BY

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JULY, 2014

DECLARATION

I hereby do solemnly declare that the work in this thesis entitled "Development of GIS-Based Road Transport Information Management System for Adamawa Central, Adamawa State, Nigeria" was conducted by me, it has not been presented in the department or anywhere for a degree. All quotations and source of information are duly acknowledged by means of references.

_____ _____

Sunday Richard THLAKMA **Date**

CERTIFICATION

This thesis entitled "*Development of GIS-Based Road Transport Information Management System for Adamawa Central, Adamawa State, Nigeria*", by Thlakma Sunday Richard meets the regulations governing the award of the degree of Master of Science (GIS and Remote Sensing) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis work is dedicated to God Almighty for His love, guidance and protection throughout my education career, and also my sponsor Supol Daniel Richard, my father Mr. Richard Wada, my beloved mother Mary Richard and sister Miss Serah Richard. They have seen much to have given everything that worth more than gold to me.

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ABSTRACT

GIS-Based TRIMS provide a mechanism for data integration, development, management and output generation in its spatial environment. The aim of this research is to develop a GIS-Based road transport information management system for Adamawa Central. In order to achieve the aim and objectives of this research, Satellite images, road transport map, road transport documents, picture of; bridges, road, roundabout and their coordinates were obtained. The road transport infrastructures were mapped using the satellite imageries. File-geodatabase was created in ArcCatalog. The feature dataset was populated using the road transport documents that served as an inventory of the dataset and the database was finally created. RTIMS was built using ArcGIS 10.1. Query analysis was carried out on the results. The study revealed that the federal road covered 7.94% length, state road 22.27% while the LGA road was the longest of (77.73%). It also reveal that 78% of the LG roads ware untarred while only 22% were tarred, the tarred roads were mostly located in the Yola north which is the state capital. It also there were twelve roundabouts in the study area and three of them were under construction. Also, there were seven bridges in the area, with Gerei LGA having two with one under construction. The results also shows that there was no traffic light at all. It is therefore, recommended that government should establish GIS unit in the federal and state ministry of transport board and also encourage the local government areas to do the same for proper planning, development and management of road transport infrastructure.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Geographic information systems for road transport information management system can be defined as interconnected hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analysing, communicating and managing particular types of information (i.e., transportation systems and geographic regions) about the Earth (Vonderohe, Travis, Smith and Tsai, 1993). GIS based road transport information can be viewed as the product of the interaction between improved concepts of both Geographic Information System (GIS) and Transportation Information System (TIS).

GIS based road information management system applications are currently used broadly by transportation analysts and decision makers in different areas of transportation planning and engineering, from infrastructure planning, design and management, traffic safety analysis, transportation impact analysis, public transit planning and operations to intelligent transportation systems (ITS) such as Advanced Traveller Information Systems (ATIS) and Commercial Vehicle Operations (CVO) (Vonderohe, Travis, Smith and Tsai, 1993).

Road transport information system is the system that collects, organises and stores data about the road network, and provides facilities for reports to be produced on these data, in a variety of formats (Robinson, Danielson, and Snaith, 1998). Road Transport information which include: road inventory, traffic statistics, construction, maintenance data, etc. could be organized and integrated properly by using GIS techniques. Roads transport are networks that connect infrastructure facilities and accommodates lifeline facilities. The provision, operation and maintenance of the physical infrastructure of a transportation sector and its related social

services require a prior knowledge and manipulation of GIS (Hassanain, Froese and Vanier, 2003).

The UK Highways Agency has taken on building virtual showrooms, presenting the road by displaying a 3D drive-through along a highway or a bird's eye view of the landscape from any angle the user wants to hover (Sinclair, 1999). This can be presented to a planning board or the public using ordinary PCs, or it can even be published on the Internet for open access to everybody. The road transport agency in the French department de la Loire has been using GIS since 1989 for many purposes: Traffic accident patterns are visualised and safety improvements are made where they are most needed. By collecting significant data for the whole network, repairs and works budgeting have become more reliable and calculated in advance. First creating the optimal route between locations and then using GIS to decide how and where to sign, improved directions and movements in the road network and helped avoiding congestion (Marshall, 1995).

Road transport is by far the most dominant mode of transport in Nigeria, carrying well over 90% of passenger and freight traffic and serving as a true backbone for Nigeria's economy (TRB, 2004). Because a well maintained road transport asset is very important for the economic development of the nation, Road Management Information System is a prerequisite for the successful management of road transport. Geospatial data are foundation for relevant and critical information for planning, engineering, asset management, and operations associated with every transportation mode at all levels of government and administration, (TRB, 2004).

Nigeria has the largest road network in West Africa and the second largest south of the Sahara, with roughly 108,000 km of surfaced roads in 1990 (67,112 miles) of roads. Of this total, 30,000 kilometers (18,642 miles) were paved, 25,000 kilometers (15,535 miles)

were gravel, and 53,000 kilometers (32,935 miles) were unimproved earth. Much of the road system is in disrepair and barely useable. Massive traffic jams are very common in the large cities. There are also long delays in the movement of goods. Highway accidents and deaths are frequent, and number more than 30,000 and 8,000, respectively. However they are poorly maintained and are often cited as a cause for the country's high rate of traffic fatalities. In 2004 Nigeria's Federal Roads Maintenance Agency (FERMA) began to patch the 32,000-kilometre federal roads network, and in 2005 FERMA initiated a more substantial rehabilitation. The rainy season and poor equipment pose challenges to road maintenance (LCCS, 2008).

The World Economic Forum report, 2011-2012, in terms of the quality of overall infrastructure, ranked Nigeria at 125 out of 142 countries, with a value of 3.0 (1.3 below the mean value). Cameroon was ranked at 122 and Ghana at 90. With regard to road quality, Nigeria was ranked at 120, with port infrastructure at 117, railroad quality at 104 and air transport quality at 104. There are almost 200,000 km of roads in Nigeria, 15 % of them paved (2012). There are over 3,500 km of railway and much of the network is single track (TIO, 2014).

Transportation is by far one of the most important developmental needs of the people in Adamawa Central. The Adamawa government in realisation of the importance of transportation in development has since the creation of the state in August 1991 been allocating large sums of money towards improving the road sectors and between 1985 to 1998 about N500 million was allocated to the transport in the budgetary plan period for construction, rehabilitation and maintenance works (Ogunsanya and Galtima, 1993). The development of road transport in Adamawa Central could be traced to the colonial period, road were built to facilitate the administrative of the area and for economic resource

exploitation. The road development effort continued under the various political dispensation in the area under the independed Nigerian State as from 1960. The existing modern system of transport in the state are the road, air and the inland waterways. The total road network capacity in Adamawa state stands at 1507 km in length. This comprise of 668 km of major tarred roads that link most of the local government headquarters and the minor roads measuring 839 km, which are mostly untarred, facilitating movement between localities. The density of the road development is higher in the central part of the state and this may be due to the influence of the state capital, and the high level of urbanisation and the socio-economic activities in the region (Ogunsanya and Galtima, 1993).

However, the efficient development of the transportation infrastructure in Adamawa central poses a serious challenge to the government, the modal problem in particular requires a special attention to accommodate the growing demand for mobility in the region. (Ogunsanya and Galtima, 1993). Transport is vital to the well-functioning of economic activities and a key to ensuring social well-being and cohesion of populations. Transport ensures everyday mobility of people and is crucial to the production and distribution of goods. Adequate infrastructure is a fundamental precondition for transport systems. In their endeavour to facilitate transport, however, decision-makers in governments and international organizations face difficult challenges. These include the existence of physical barriers or hindrances, such as insufficient or inadequate transport infrastructures, bottlenecks and missing links, as well as lack of funds to remove them. Solving these problems is not an easy task. It requires action on the part of the governments concerned, actions that are coordinated with other governments at international level (UNECE, 2008).

Transportation is one of the fastest growing of many fields in which GIS is used (Rodrigue *et al*, 2006). Diverse areas of transportation, including high-way and rail-way infrastructure management, international shipping, airport management, fleet logistics, traffic

management and intelligent transportation systems (ITS), transit bus and rail service planning, transportation modelling, supply chain modelling, and others, are applying GIS to their work (ESRI, 2003). The breadth of the field of integration of GIS and transportation system provides large opportunities for the development of new and innovative applications in transportation system of different transportation organizations (Curtin, 2003). Since GIS have a seamless relation with space and location, given that their main objective as a tool is to store, retrieve, and facilitate the analysis of spatial data (Goodchild and Janelle, 2004), they have become one of the most powerful tools to support transportation studies and applications. The liaison between GIS and transportation is indeed quite natural, given that transportation itself is linked to space organization on the development of networks in space and time, just like geography itself (Haggett, 1965). Capitalizing on this relationship both academics and practitioners have focused their attention on research/work that makes use of GIS in transportation applications. "GIS and Transport" has been of importance in the academic world since the early 1990s (Miller, 1996; Kamal *et al*, 1994). However, besides some early contributions, which aimed at explaining the role of GIS in transportation planning (Sutton, 1996).

GIS have influenced a variety of aspects of transportation science. Goodchild (1998), after recognizing in the discrete entity model and in the network model the GIS data models that are most interesting for transportation purposes, identifies the paradigms leading to their extensive use in transportation modelling. These are: digital map production, inventory and data management, integration of data, spatial analysis, and dynamic modelling. He continues (Goodchild, 1998) by differentiating three stages in the evolution of GIS Transportation: the map view (mainly concerning network visualization and interoperability issues); the navigational view (connected with network modelling and algorithm resolution); and the

behavioural view (linked to the use of the network by people and vehicles, which implies the dynamic modelling of transportation phenomena).

GIS technology serves three distinct transportation needs: infrastructure management, fleet and logistics management, and transit management. It can also be used to integrate mapping analysis into decision support for network planning and analysis, vehicle tracking and routing, asset management, inventory tracking, route planning and analysis, and everything in between (TRB, 2004). The understanding of GIS based Road Transport management Information System, effective use of geographical information and the knowledge of their advantages is critical to the planning and decision making process for asset management and transport departments.

1.2 Statement of the Research Problems

Based on the literature reviewed, a lot of research has been carried out on the research related development of GIS-based Road Transport Information Management System in various parts of the globe but none of such researches was carried out in Adamawa central of Nigeria and as a results, there is need for such research to carry out in area. This is because Adamawa central still faces problems of traffic congestion, high road accidents, lack of road transport geospatial database, weak institutional support leading to poor definition of the problem at hand and differing technology transfer priorities in problem resolution. This could be linked to the non-availability of adequate information on road transport due to increased urbanization, growth of commercial activities and increase road development that is spatially integrating activities. This development comes up with different characterisation of transport infrastructure, operation methods, ownership, peak period moments and capacity volume ratio and even pollutant and environmental problems. This study will provide decisions

makers with a system which could be used for road transport inventory, physical road maintenance, road traffic management as well as any other road-related management issues.

Various researches had being carried out throughout the world related to the development of GIS-based road transport Information management system. Rasdorf *et al*, (2000) in their research building an information system to meet the ever increasing social, economic, and environmental demands placed upon road transport infrastructure for Portuguese. The method they employed was building database of highway corridor and accident spot location. They pointed out that the infrastructure departments of the Portuguese municipalities, including Lisbon, Coimbra, Oliveira do Hospital, Oliveira do Bairro, and other municipalities, manage their infrastructures using a number of systems or programs maintained by different divisions inside the department of infrastructures. Each system or program generates and maintains a large amount of information in separate and independent databases. Many of this information are processed, analysed, and shared/used by more than one division in more than one format. All data about municipal infrastructures have a spatial component. That spatial component represents an area such as a highway corridor, a linear feature such as a road and a point feature such as a sign or the location of an accident. The existing municipal databases and data management system design traditionally have not been effective at allowing division within the departments of infrastructures to use or share data as extensively or as easily as should be the case.

Corberan *et al*, (2002) in their work applied heuristic solutions to the problem of routing school buses with multiple objectives in sparse rural areas of Spain. This specific problem was introduced where a scatter search algorithm was proposed. The authors mentioned several characteristics of this problem that can be summarized as; in a rural area; routes tend to be long and the buses do not reach their maximum physical capacity, due to the definition

of transportation time they ignore the time required to reach the first student and it is a single load problem (routes either pick up or deliver students to a single).

Vasudevan, (2004) research on Implementation of GIS enabled asset management program for small public works agencies for Missouri, Columbia. Implemented a program of road asset management according to (GASB 34) using GIS as a small public works agency for Missouri, Columbia. The tasks of his study are creating condition estimation manual, assets inventory, which include Global Positioning System (GPS) coordinates and asset evaluation then integrate it with GIS. This information inputted into Microsoft Excel and updated it manually at the different levels of program then integrated it with GIS which develop the program by better data query, analysis, and display. The methodology applied in Cole Country Public Work Department in Missouri, Columbia. The study follow the principles of modify asset management method because asset has an expensive maintenance cost and it is need periodic maintenance and can provide a political support, at these factors modify method is better (FHWA, 2000). Asset inventory include roads, sign, culverts, guardrails, and pipes. Road inventory include four types of road in the country: asphalt, gravel, gypsy, and concrete. Each type of road classified as one of five condition levels: excellent, good, fair, poor, and failed. Other assets (signs, culverts, guardrails, and pipes) classified as one of three condition levels: good, fair, and poor. The study provides "Unique Identifier" (UI) to link the program with GIS. He stated that the work will enhance the capability of government to identify asset performance level and help them to estimate the actual needs to maintain roads assets according to their condition. The study recommended the country to inventory one-third of assets every year and check the actual replacement cost for construction costs in the country.

Andre and Villanova (2004), used GIS to develop the network of urban buses for environmental purposes in Paris. In their work, two approaches were envisaged and applied

to the Paris area; both approaches were based on factorial analysis and automatic clustering, to allow optimum description and the identification of a pertinent typology of the bus routes in several classes. The first attempt at characterisation based on statistics relating to bus operations: route characteristics (length, dedicated bus lanes, number of stops, location of stops; schools, tourist sites, hospitals, railways or underground stations), travel time, commercial speed, annual statistics (number of passengers, number of vehicles per hour, total kilometres), the irregularity of travel (variation of travel times, injuries, congestion.), as well as information on the problems encountered (congestion, distribution of the passenger load, junctions, bends). The second approach is based on the analysis of the "urban context" in which buses were driven. Population, employment, housing, road network, traffic and places that generate or disturb traffic (schools, railway stations, shopping areas, etc.) are calculated for the Ile de France region, by cells of 100 x 100 m, and collected in a geographical information system (GIS).

Furthermore, Ferreira and Duarte (2005), in their research titled; develop GIS-Based Integrated Infrastructure Management System for Portugal. The paper focuses on the issues and needs that emerged from some studies developed by the authors involving the implementation of transportation management systems in local municipalities and developing a comprehensive database and design with focused attention given to the types of data analysis functions performed by each division. The paper includes the application of the IMS in road maintenance management and road safety management. The method adopted was based on the two sub-systems, a road maintenance management system and a road safety management system use the same base linear referencing system. In both subsystems, in order to handle dynamic segmentation, the road network model is composed by road segments with (x, y) coordinates and measure (m) values. They recommended that the infrastructure departments of the Portuguese municipalities need to make great efforts in

beginning or continuing to use advanced information technology tools to increase institutional productivity and effectiveness in managing their municipal infrastructures such as independent management systems for each type of infrastructure, i.e., road pavements, bridges, signs, water pipelines, sewer pipelines, parks, etc. In the future, they need to begin the development of an Integrated Infrastructure Management System (IMS).

Similarly, Rao *et al*, (2006) developed a GIS Based Maintenance Management System (GMMS) for major roads of Delhi. This development was made so as to benefit from the realistic representation of real-world entities, an organised data structure and the powerful analysis and presentation capabilities of GIS.

Furthermore, Khali *et al*, (2007) have developed a method for identifying vehicles electronically in USA. Mueller *et al*, (2007) have developed a system for intelligent monitoring and adaptive competence assignment for driver and vehicles in Turkey. And Mohammad *et al*, (2009) have designed a road maintenance data model using the dynamic segmentation technique, on the Iranian road network.

Dike, Ikeogu and Ezenwa (2012), effect of Road Transport Infrastructure Development on Entrepreneurship Success in Nigeria The research aimed to substantiate how entrepreneurship is influenced by road transport development in Nigeria. Data was collected with the aid of structured questionnaires from randomly selected 50 entrepreneurial organizations in the South-Eastern region, Nigeria. Three hypotheses were formulated from the data and analyzed with chi-square statistical tool. Findings revealed that the situation of road transport development in Nigeria has negatively influenced entrepreneurship development; hence entrepreneurship is strongly dependent on good and adequate transport network for its survival. The operational cost of most entrepreneurial organizations have been on the increase due to the bad state of the road transport infrastructures and does not encourage entrepreneurship development in Nigeria.

Most researches were concerned with road infrastructure maintenance, use of GIS in transport management specifically in the information management system to meet the increase of social, economic and environmental demand for road transport by creation of database and accident spot for Portuguese, applied heuristic solutions to the problem of routing school buses with multiple objectives in sparse rural areas of Spain.

Though, Ferreira and Duarte (2005) develop GIS-Based Integrated Infrastructure Management System for Portugal by integrating only spatial and non-spatial data without putting the physical condition in to consideration. Though this research was based on infrastructure management need but stilled considered the physical condition of road transport infrastructure, not only limited to integrating only spatial and non-spatial data but also there conditions, unlike research of Ferreira and Duarte. Again, the Ministry of works Adamawa State managed their road transport infrastructures using archive, that is, traditional way of data management that is limited of integrating spatial and non-spatial because the data cannot be query, analysed and update but this research developed GIS-Bases RTIMS that have the capabilities of integrating the data as well as query, analysed and update them, these were the research gap and knowledge filled in this research work.

This study attempted to answer the following research questions:

i. How can GIS be used for mapping the existing roads infrastructures in Adamawa Central?

ii. How can GIS be used in Building Geodatabase for the roads infrastructures in Adamawa Central?

iii. How can GIS be used for Geodatabase analyses and query for road characteristics?

1.3 Aim and objectives of the study

The aim of this study is to develop a GIS based Road Information Management System for Adamawa Central, Nigeria. This will be achieved through the following objectives which include to:

(i) mapping the existing roads infrastructures in Adamawa Central.

(ii) build Geodatabase for the roads infrastructures in Adamawa Central.

(iii) use the Geodatabase to analyse and query road characteristics.

1.4 **Scope of the study**

The Adamawa central which is the study area and consists of seven Local Government Areas namely; Yola North, Yola South, Fufure, Gerie, Song, Hong and Gombi, with an area coverage of about 12,914 square kilometres see figure 1.1. The study was focus mainly on the federal, state and local government road transport. It covered only road transport infrastructure like; roads, junctions or roundabouts, bridges, culverts and traffic and street lights and symbols, and their attribute information such as referencing (road name, road ID), geometry (alignment, road width, section length, etc.), Category (Federal High way, State High way and Local Government Road), maintenance status, time to be reconstructed, etc. the study covered the road transport infrastructure as of 2013 and it involved the use of Geographic Information System techniques.

1.5 Justification of the Study

Transport forms an essential backbone for socio-economic development, but if not developed sustainably it also imposes significant costs on society in terms of environmental and health impacts (Paving the way for EU enlargement, 2002). Decision makers do not have

an adequate up-to-date information on roads infrastructures in terms of: physical condition, date of construction, date of last renovation; number of lane, condition of culvert and bridges across etc. On one hand a key challenge for the road manager is to find ways in which to describe the problems and impacts of road maintenance that can be understood by the politicians and the general public (Robinson *et al*, 1998).

GIS technique, such as spatial database building, queries and analysis. Traditional database system does not allow the user to manipulate, access, and query the database because of its limitation in integrating spatial and non-spatial aspects of data. GIS-based RTIMS application presents a unique solution for a unique problem that requires management, maintenance and access of large document databases that have to be arranged in such a way that the user can retrieve the required documents for specific geographic location through the use of a GIS-based user interface. The reconnaissance survey showed that the urban and regional planning, ministry of works, road transport authorities, drivers and passengers were in need of road information. Consequently, they supported the idea of developing of GIS based RTIMS.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

This chapter reviews conceptual framework and relevant literatures. Conceptual framework such as; Network data models (Graph Theory), The location based service, GIS Transport Data Representations, GIS Models used in Transportation, Matrices in GIS- Based RTIMS, GIS Road Transport Information Management System Analysis and Modelling and Geodatabase for Road Transport Infrastructure Management. relevant literatures such as; Role of GIS for Transportation, Categories of Road Transport Information Management System works, Function of Road Transport Information Management System, Types of GIS-Based Road Transport Information Management System, Integration of GIS and Road Transport Management System, Application of GIS to Transportation, Development GIS-Based Road Transport Information Management System, Benefits of the Geodatabase for Road Transport Information Management System, 2.3.10 Challenges for GIS-Based Road Transport Information Management System.

2.2 Conceptual and theoretical Framework

The major concepts to this study includes Network data model and the location based service.

2.2.1 Network data models (Graph Theory)

Graph theory gives a topological and mathematical representation of the nature and structure of transportation networks. However, graph theory can be expanded for the analysis of real world transport networks by encoding them in an information system. In the process, a digital representation of the road transport network is created. This digital representation is

highly complex, since transportation data is often multimodal, can span several local, national and international jurisdictions and has different logical views depending on the particular user stated by Haggett and Chorley (1969).

It is thus becoming increasingly relevant to use a data model where a transportation network can be encoded, stored, retrieved, modified, analysed and displayed. Obviously, Geographic Information Systems have received a lot of attention over this issue since they are among the best tools to store and use network data models, Haggett and Chorley (ibid). Network data models are an implicit part of many GIS. There are four basic application areas of road transport network data models:

1. **Topology**. The core purpose of a network data model is to provide an accurate representation of a network as a set of links and nodes. Topology is the arrangement of nodes and links in a network. Of particular relevance are the representations of location, direction and connectivity. Even if graph theory aims at the abstraction of transportation networks, the topology of a network data model should be as close as possible to the real world structure it represents. This is especially true for the usage of network data models in a GIS.

   Furthermore, a location has been encoded in each link to represent roads features. Geographically, each node is located at a coordinate which matches within a tolerated accuracy and the actual intersection it represents. In addition, the links between each node have been decomposed into several segments to represent the positional accuracy of the road transport.

2. **Cartography**. Allows the visualization of a road transport system network for the purpose of reckoning and simple navigation and serves to indicate the existence of a network. Different elements of the network can have a symbolism defined by some of their attributes. For

instance, a federal road link may be symbolized as a thick line with a label such as its number, while a state road may be symbolized as an unlabelled simple line.

The symbolized network can also be combined with other features such as landmarks to provide a better level of orientation to the user. This is commonly the case for road transport maps used by the general public.

By using attributes encoded in the network data model, such as road type, each segment can be displayed to reflect its importance. For instance, the cartographic representation of a network data model displays three road classes (highway, Main Street and street) differently. Descriptive labels for the most important elements and directional signs for one-ways have also been added. Nodal attributes can also have a cartographic utility, such as displaying whether an intersection has traffic lights.

3. **Geocoding**. Transportation network models can be used to derive a precise location, notably through a linear referencing system. For instance, the great majority of addresses are defined according to a number and a street. If address information is embedded in the attributes of a network data model, it becomes possible to use this network for geocoding and to pinpoint the location of an address, or any location along the network, with reasonable accuracy. Geocoding is possible if a linear referencing system is embedded in a network data model. One of the most common linear referencing systems is the address system, where each link has a corresponding street name and address range.

4. **Routing and assignment**. Network data models may be used to find optimal paths and assign flows with capacity constraints in a network. While routing is concerned with the specific behaviour of a limited number of vehicles, traffic assignment is mainly concerned with the system-wide behaviour of traffic in a transport network.

This requires a topology in which the relationship of each link with other intersecting segments is explicitly specified. Impedance measures (e.g. distance) are also attributed to

each link and will have an impact on the chosen path or on how flows are assigned in the network. Routing and traffic assignment at the continental level is generally simple since small variations in impedance are of limited consequences. Routing and traffic assignment in an urban area is much more complex as in determining the impedance of a route it must consider stop signs, traffic lights and congestion.

Routing in a network data model can be simulated if impedance is attributed to links and nodes. For links, impedance is often characterized by travel time, while turn penalties are often used to characterize impedance at nodes that is how difficult (if possible) it is to turn in one direction, as opposed to another. Considering link and node (turn penalties) impedance attributes that are encoded in the network data model, it is possible to plot an optimal route minimizing travel time that would satisfy basic constraints related to the start and end points, pickup and delivery points, as well as link and turn penalty impedances.

2.2.2 The location based service

Vonderohe (1993) pointed out that, Geographic Information Systems (GIS) represent a new paradigm for the organization and design of road transport information management systems, the essential aspect of which is the use of location as the basis for structuring the information management systems. Transportation is inherently geographic and therefore the application of GIS has relevance to transportation due to the spatially distributed nature of transportation related inventory data and the need for various types of network level analysis, statistical analysis and spatial analysis. GIS possesses a technology with considerable potential for achieving dramatic gains in efficiency and productivity for a multitude of traditional transportation applications.

The impact of GIS technology in the development of road transportation information management systems is profound. It completely revolutionizes the decision making process

in transportation engineering. As a good example, road transport guidance and congestion management systems can be most suitably developed in a GIS environment. In this application, GIS is used as a powerful tool for identifying and monitoring congestion in urban areas, and planning optimal roads based on minimum time/distance/cost paths. Its graphical display capabilities allow not only visualization of the different roads but also the sequence in which they are built. This allows the user to understand the logic behind the road design, Vonderohe (ibid).

2.2.3 GIS Transport Data Representations

Data representation is a core research topic of GIS. Before we can use GIS to tackle real world problems, we must properly represent our data in a digital computing environment. One unique characteristic of GIS is the capabilities of integrating spatial and non-spatial data in order to support both display and analysis needs. There have been various data models developed for GIS. The two basic approaches are object-based data models and field-based data models (Lo and Yeung, 2002). An object-based data model treats geographic space as populated by discrete and identifiable objects. On the other hand, a field-based data model treats geographic space as populated by real-world features that vary continuously over space. These two approaches correspond to the widely known vector GIS (i.e., features are represented as points, lines, and/or polygons) and raster GIS (i.e., features are represented as grid cells). Measure locations of features or events along transportation network links (e.g., a traffic accident occurred at the 52.3 milepost on I-75 in the State of Tennessee). Such a 1-dimensional linear referencing system (i.e., linear measurements along a highway segment with respect to a pre-specified starting point of the highway segment) cannot be properly handled by the 2-dimensional Cartesian coordinate system used in most GIS data models. Consequently, the dynamic segmentation data model was developed to address this specific

need of the GIS-T community. Origin-Destination (O-D) flow data are another type of data that are frequently used in transportation studies. Such data have been traditionally represented in matrix forms (i.e., as a two-dimensional array in a digital computer) for analysis. Unfortunately, the relational data model widely adopted in most commercial GIS software does not provide an adequate support of handling matrix data. Some GIS-T software vendors therefore have developed additional functions for users to work with matrix data within an integrated GIS environment. The above examples illustrate how the conventional GIS approaches can be further extended and enhanced to meet the needs of transportation applications.

In recent years, we also have seen the development of enterprise and multidimensional GIS-T data models. Successful GIS deployments at the enterprise level (e.g., within a state department of transportation) demand additional considerations to embrace the diversity of application and data requirements. An enterprise GIS-T data model is designed to allow "each application group to meet the established needs while enabling the enterprise to integrate and share data." (Butler and Dueker, 2001). The needs of integrating 1-D, 2-D, 3-D, and time for various transportation applications also have called for an implementation of multidimensional transportation location referencing systems. The National Cooperative Highway Research Program (NCHRP) Report 460 provides guidelines for the implementation of multidimensional and multimodal location referencing systems.

In short, one critical component of GIS-T is how we can best represent transportation-related data in a GIS environment in order to facilitate and integrate the needs of various transportation applications. Existing GIS data models provide a good foundation of supporting many GIS-T applications. However, due to some unique characteristics of transportation data, we still face many challenges of developing better GIS data models that will improve rather than limit what we can do with different types of transportation studies.

2.2.4 GIS Models used in Transportation

In general, three classes of GIS models are used in transportation, which include (Thill, 2000):

1) Field models of the continuous variation of a phenomenon over space (e.g., land elevation).
2) Discrete models, depending on which discrete entities (points, lines or polygons) populate space (e.g., toll barriers, urbanized areas).

All of these three models are useful in transportation; however, the network model built around the concept of arc and node plays the key role in this application domain because single- and multi-modal infrastructure networks are vital in enabling and supporting passenger and freight movement. In fact, many transportation applications only require a network model to represent data. On the other hand, still it is worth noting that advanced transportation applications, particularly disaggregate travel demand modelling approaches and intelligent transportation systems, require representation of complex transportation features that are not well-supported by the node-arc data model. Goodchild (1998) recognized three meaningful extensions to overcome these kinds of deficiencies:

1) Planner versus non-planner model (with different representations for topology versus cartography);
2) Turn tables (for including properties of the turning movements); and
3) An object-oriented view of the infrastructure to define topology between lanes (e.g., links are objects formed of traffic lanes).

GIS-based road transport studies have employed both object-based and field-based data models to represent the relevant geographic data. Some transportation problems tend to

fit better with one type of GIS data model than the other. For example, network analysis based on the graph theory typically represents a network as a set of nodes interconnected with a set of links. The object-based GIS data model therefore is a better candidate for such transportation network representations. Other types of transportation data exist which require extensions to the general GIS data models.

In recent years, the development of enterprise and multidimensional GIS- based road transport data models has occurred. Successful GIS deployments at the enterprise level (e.g. within a state department of transportation) demand additional considerations to embrace the diversity of application and data requirements. An enterprise GIS- based road transport data model is designed to allow "each application group to meet the established needs while enabling the enterprise to integrate and share data". The needs of integrating 1-D, 2-D, 3-D, and time for various transportation applications also have called for the implementation of multidimensional transportation location referencing systems.

In short, one critical component of GIS- based road transport is how transportation-related data in a GIS environment can be best represented in order to facilitate and integrate the needs of various transportation applications. Existing GIS data models provide a good foundation of supporting many GIS-based RTIMS applications. However, due to some unique characteristics of transportation data, many challenges still exist of developing better GIS data models that will improve rather than limit what we can do with different types of transportation studies (Zeiler, 1999).

2.2.5 Matrices in GIS- Based RTIMS

Generic GIS packages usually store attribute data in the tabular form associated with traditional spreadsheet and database technology (Waters 1995). In such tables the row is often a geographical place such as a city or county and the columns represent attributes of that

place such as the population and various socioeconomic characteristics. This is commonly known as the data view.

In a GIS-Based RTIMS an equally useful form of storage is the matrix in which both rows and columns represent the same set of geographical features, either points such as cities or areas such as traffic analysis zones (TAZs and Nyerges 1995). The rows are usually regarded as the origins and the columns the destinations. Thus each element of the matrix can store such information as traffic or commodity flows, travel time or distance measures, and migration patterns. This is known as the matrix view. Because such matrices are the basis of many forms of analysis in transportation research (Taaffe *et al,* 1996) the GIS-Based RTIMS should be able to create, modify, and edit such matrices. Traditionally, these matrices are square but some GIS-T packages such as TransCAD allow the user to select sets of columns which may not be identical to the rows, and thus rectangular matrices are also possible.

2.2.4.1 Shortest path analysis (SPA)

SPA is an essential precursor to many GIS-Based RTIMS operations. It is critical for route location models for determining the minimum environmental cost route (MERC, Lee and Tomlin, 1997) for determining allocations in a location–allocation model, for trip assignment in transportation planning models (Nyerges, 1995), and for automatic vehicle dispatch systems. Densham (1996) discusses the importance of SPA routines within his visual interactive location system which is part of an interface with the TransCAD GIS-T. With the advent of massive municipal and regional road databases, a major concern in recent years has been the size of problems which can be handled by existing algorithms and the solution speed.

2.2.6 GIS Road Transport Information Management System Analysis and Modelling

GIS- based road transport analysis and modelling have benefited from many of the standard GIS functions (query, geocoding, buffer, overlay, etc.) to support data management, analysis, and visualization needs. Like many other fields, transportation has developed its own unique analysis methods and models. Examples include shortest path and routing algorithms (e.g. traveling salesman problem, vehicle routing problem), spatial interaction models (e.g. gravity model), network flow problems (e.g. user optimal equilibrium, system optimal equilibrium, dynamic equilibrium), facility location problems (e.g. p-median problem, set covering problem, maximal covering problem, p-canters problem), travel demand models (e.g. the four-step trip generation, trip distribution, modal split , and traffic assignment models), and land use –transportation interaction models.

It is essential for both GIS-RTIMS practitioners and researchers to have a thorough understanding of transportation analysis methods and models. For GIS-RTIMS practitioners, such knowledge can help them evaluate different GIS software products and choose the one that best meets their needs. It can also help them select appropriate analysis functions available in a GIS package and properly interpret the analysis results. GIS-RTIMS researchers, on the other hand, can apply their knowledge to help improve the design and analysis capabilities of GIS-T (Thill, 2000).

2.2.7 Geodatabase for Road Transport Infrastructure Management

Transportation science has undoubtedly taken advantage of the possibilities to handle and manage large amount of data with GIS within their geodatabase framework such as roads, bridge, culverts, roundabout, traffic lights etc. The most important sign of this is the widespread use of geodatabases in every road transport application. Transportation researchers use geodatabases for different purposes. These include: solving data

interoperability issues; performing query optimization, resolving map matching issues, using these databases as a basis for road transport models and for creating data repository to build decision support systems, integrating GPS data and sharing data by means of web tools. Because of the diversity in applications, scientists can exploit transportation data by storing such data in georeferenced databases. Applications of geodatabases in road transport include: query definition for the optimal resolution of multiple path algorithms and other kinds of network problem, and the creation of efficient spatial query resolution engines, specifically designed for transportation models (Mainguenaud, 2000; Huang *et al*, 2000). The first implementation of a network model was based on a relational database, which could easily be adapted to the abstraction of a network represented by a graph. This model, typically referred to as the "arc-node model", besides modelling the network allowed topological relations to be created (Thill, 2000; Shaw and Rodrigue, 2006).This model was then expanded to handle linear referencing, thus facilitating the modelling of point events within the network. However, the arc-node model was still limited in its capabilities, restricting what transport researchers could do with it.

Claramunt *et al*, (2000); Dueker and Butler (2000). First attempts to create geodatabases for road transport lacked common definitions of the transportation elements and of interoperability between traditional GIS and road transportation-related models. But, as the models became more sophisticated and widely used, new integration frameworks were proposed. New frameworks considered geodatabases and their relational structure as suitable to store spatial data and maintain a shared digital world model.

Geodatabases have been used to integrate GIS and road transport modelling for particular purposes, such as travel time forecasting (You and Kim, 2000), congestion management (Quiroga, 2000), traffic entity estimating for different road categories (Blume et al., 2005), and to build spatial decision support systems (SDSS), mainly to help public

agencies to make efficient transportation planning decisions. Frank et al. (2000) led an interesting application related to hazardous material truck routing. More recent experiences, mainly led by the US Department of Transportation.

US Department of Transportation (DoT), deal with the implementation of spatial information system infrastructures that provide planners with the right and most up-to-date information for efficient decision making (Hall *et al*, 2005; Bejleri *et al*, 2006). In this respect, GIS, and geodatabases in particular, are used to integrate data collected from diverse sources, to organize data in exchange and standard formats, to analyse data, and to create information which can be stored in the geodatabase itself and shared amongst public agencies and other stakeholders.

Similar efforts, even if as yet only at an early stage, are also being made by the European Community. The European Transport Information System (ETIS) aims to "identify and accommodate all required policy-driven information related to ETIS in a repository, to be kept up-to-date and controlled by experts and to be accessed through an Internet-based software tool" (Ballis, 2006). GIS technology is used in ETIS for its capability to store georeferenced information in georeferenced data banks and to visualize and represent geographical information, even by means of an Internet independent application.

2.3 Literature Review

Transportation is a facility consisting of the means and equipments necessary for the movement of passengers or goods, and is the means of conveyance to move forces, equipments, personnel and stocks and includes the requisite materials handling equipments, NATO organization (1997). Road Transport information management system focuses on the macroscopic processes on transportation infrastructure and network strategic design and planning. A worthwhile road transport management system enables transportation planners to

make decisions effectively while automating carrier bid, tendering, settlement, and the freight auditing processes, Descartes Systems Group (2005). This may not only improve cost, but also may help to improve customer and public service.

A relevant attempt to collect and organize studies about GIS and Transport was made in 2000 by the academic journal *Transportation Research C* (reviewed by Fotheringham, 2002, Shaw, 2002). In several cases, it is sometimes formally required that public authorities with an interest in transportation build a GIS framework to handle and manage transportation data and projects. For example, the American Association of State Highways and Transportation Officials, together with the US Department of Transportation (DoT) have been organizing a GIS-T symposium for the past 22 years, in order to give practical support to government and private industry organizations interested in the use of GIS for transportation purposes (Fotheringham, 2002 and Shaw, 2002). This shows that in transportation science the spatial approach is naturally integrated, contrary to other disciplines where there is a need to identify the particular role of "geographically oriented sub disciplines" in a distinct way. As an example, transportation scientists have been key players in the application of GIS (Goodchild, 2000; Thill, 2000).

Thill, (2000) highlights the requirements of GIS in transportation applications and the core transportation research themes which employ GIS for "research, planning, and management" (referred to collectively as GIS-T). Like Goodchild, he provides a classification, but gives more attention to the use of GIS to handle large amounts of transport data rather than to the other aspects. According to Thill, (200) GIS-T need a data management system (whose aim is to facilitate the maintenance and the integration of the inventories of transportation infrastructures held by public authorities) data interoperability (in order to allow transportation data sharing among several agencies, each with its own data base) real-time GIS-T (for real time geo-referenced data storage, retrieval, processing, and

analysis) large data sets (which involve the optimization of algorithms and analytical tools, and the discovery of innovative system designs) distributed computing (to allow the spread of GIS-T data over users and community, by means of web services). Identifying the main fields of transport in which GIS could contribute to and how, represented a serious challenge at the beginning of last decade (Thill, 2000). However, not only because of the rapid technology development and computing improvement but also thanks to the increasing interest from public academic authorities, GIS have undergone rapid enhancements in last years, spreading and becoming systematic throughout the scientific world. Shaw and Rodrigue, (2006) reviewed Goodchild and Thill's classifications. They considered that GIS-T studies can be classified into three groups, namely data representations, analysis and modelling, and applications.

Curtin *et al*, (2003) stated that, researchers on transportation professionals are increasingly realizing that the synthesis of traditional transportation research methods with the added value of GIS resources provides a robust platform for both traditional and innovative transportation management activities. ElBehairy and Hegazy (2004) reported that a Decision Support System for Transportation Management systems are used "to prioritize bridges, allocate funds, and select appropriate repair strategies so that a network of bridges is kept serviceable and safe with low cost. The proposed system supplements BMS by providing a simplified but comprehensive model for execution planning of bridge maintenance system. The model uses a genetic algorithm procedure in a spreadsheet environment to determine optimum execution order, considering practical constraints (e.g., deadlines, owner supervision capacity, cash flow), and other political/user constraints.

Karlaftis *et al*, (2004) outline the development of a Decision Support System (DSS) for special events public transport planning, specifically examining the case of the Athens 2004 Summer Olympics. The purpose of the DSS was to aid in: monitoring and managing

information regarding the network, supporting decisions about planning and operations, deriving information that are useful for planning and real-time decision support. The DSS utilizes spreadsheet and database software packages, a programming language, and model optimization procedures to assist users in data management, complex calculations, development and application of "special algorithms," and production of "pictorial reports" for planning and real-time operation decision making.

The methodology for developing the DSS involved six steps: user needs; data collection; definition of assumptions and scenarios; DSS framework setup; building the system; and validation. The DSS "has been demonstrated to be an efficient and effective tool that aids decision makers and planners" in selecting appropriate courses of action. The system provides a "user-friendly environment" and can be "easily reprogrammed" to accommodate other similar planning needs.

Li, *et al,* (2004) developed a transit asset management system (TAMS) using GIS intended to support decision-making for rural and small urban transit systems. The purpose of the TAMS is to: Identify current maintenance deficiencies, predict the future bus conditions and estimate the investment requirements and Recommend a cost effective maintenance strategy to sustain or improve vehicle condition. They found out that Knowledge of the current and future condition of transit vehicles is "valuable in budget planning processes to identify cost-effective maintenance policies." The spreadsheet-based decision analysis model provides quantitative measurements and optimization procedures to help allocate sufficient funding to sustain future wellbeing of transit vehicles.

Li and Sinha (2004) present a methodology for "multicriteria decision-making using GIS involving trade-off analysis between candidate projects and optimal project selection in highway asset management under alternative scenarios of certainty, risk, and uncertainty." The methodology includes:

i. Identification of highway asset management system goals. For the study, system goals were defined and weighted by both highway agency groups and road user groups. The goals included system preservation, agency cost, user cost, mobility, safety, and environment.

ii. Classification of performance indicators for each goal. Performance indicators were weighted by both highway agency groups and road user groups.

iii. Analysis of benefits achieved under different goals as a result of project implementation. These benefits "may be governed by any of three alternative scenarios: certainty, risk, and uncertainty." Certainty "implies that the possible project outcomes occur deterministically." Risk is defined as the "situation where the set of all possible outcomes of an action is known and the probability distribution of the outcomes is also known." Uncertainty is defined for the "situation where only part or all possible outcomes of an action is known, but the probability distribution of such outcomes is not fully definable for a lack of reliable information.

The calibrated models were tested in the study area and the results compared with actual programming practice of the Indiana Department of Transportation. The findings "demonstrate that the proposed methodology provided reliable results" and that the methodology "could indeed be used by state transportation agencies for asset management practice.

Goodchild, (1998) stated that routing problems require certain classes of attributes that may not be present in databases created from the perspective of the map view. It is important to identify one way streets as attributes of links, and barriers to through traffic. But entirely new structures are needed to support information about turns between links, or conditions of access from one link to another ESRI's ARC/INFO, for example, extends the basic link/node structure with a *turntable* to record information about turns between links,

and can use it to distinguish between intersections at grade and overpasses. More generally, use of street centreline databases to support navigation requires a more complex view of topology than that of the DIME and TIGER files, which used it simply to establish consistent representations of planar features.

Support for navigation is an indispensable part of intelligent transportation systems (ITS), where it is needed to assist drivers in designing routes, and in modifying routes in response to new information. But such effective navigation requires a massive extension of the attributes provided in the map view, to include dynamic attributes such as levels of congestion and travel speeds, temporary obstructions, and temporary turn restrictions. Geometric representation of lanes is much more expensive than simple representation of street centrelines, and requires a substantially higher level of positional accuracy.

Goodchild (1998) shows how a representation can be built that has the same level of geometric accuracy as the street centreline, but includes a topological representation of the relative positions of lanes and their connectivity. Claramunt *et al, (2000).* Constructed a new framework for the integration, analysis and visualization of urban traffic data with GIS, for promoting a flexible view of multi-layered approach to the integration, analysis, animation, manipulation and visualization of urban traffic data within GIS. Their research aimed to implement the visualization of very dynamic phenomena within very dynamic GIS (VDGIS, a new framework allows the analysis of spatio-temporal phenomena at complementary levels of granularity within GIS). The target is to fill the lack of conceptual and physical interoperability with real-time computing facilities in the management of very dynamic geographical phenomena within current GIS. Adam Etches proposed an integrated transportation database in support of a collaborative Network Information System (NIS) including NIS, GIS and ITS to transportation application.

2.3.1 Role of GIS for Transportation

Geographic Information Systems for Transportation (GIS-T) refers to the principles and applications of applying geographic information technologies to transportation problems (Miller and Shaw, 2001). GIS-T research can be approached from two different, but complementary, directions. While some GIS-T research focuses on issues of "How can we further develop and enhance the GIS design in order to meet the needs of transportation applications?" other GIS-T research investigates the questions of "How can we use GIS to facilitate and improve transportation studies?" (Shaw, 2002) In general, topics related to GIS-T studies can be grouped into three categories: GIS-T data representations, GIS-T analysis and modelling, and GIS-T applications.

There is considerable variation across different contexts and different speakers in usage of the phrases “Geographic Information System”. In its narrowest sense, “GIS” refers only to specialized software for the management and of spatial data and their attributes. In other contexts, the term refers to both hardware and software. Still other usages comprehend hardware, software, and data. Perhaps the nearest to a consensus definition is the one provided by (Dueker and Kjerne, 1989). “*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.” According to this definition, a GIS includes not only computing capability and data, but also managers and users, the organizations within which they function, and the institutional relationships that govern their management and use of information. This broad view establishes a fundamental premise (Vonderohe et al., 1993), the premise that the technology of GIS cannot usefully be evaluated, projected and planned for in isolation from institutional setting, management framework, and staffing resources upon which success or failure of the GIS will depend. GIS

system design and implementation planning are not separable processes. They must occur in conjunction with one another.

The GIS-T conceived as the union of an enhanced Transportation Information System (TIS) and an enhanced GIS. The necessary enhancement to existing TISs is the structuring of the attribute database to provide consistent location reference data in a form compatible with the GIS, which in turn has been enhanced to represent and process geographic data in the forms required for transportation applications. One of the required enhancements to off-the-shelf GIS software is the ability to link with and utilize all or nearly the entire linearly referenced roads data collected and managed by transportation agencies.

What it does imply is that the attribute databases use a database scheme for the concept of location translatable into the location schemas used in the GIS spatial databases (the databases containing the digital base maps) so that the content of the former can be unambiguously correlated with the content of latter, so that queries can span both kinds of databases, and so that separate attribute databases can be integrated through their use of location schemas translatable into the ones used by the GIS software. In addition to improved management of linearly referenced data, necessary enhancements to GIS software include better modelling and analysis of road transport networks Vonderohe (ibid).

Husdal (2000), reported that in Europe, GIS for transportation is emerging as an important planning and management tool for transportation agencies. Many European nations are making huge investments in transportation infrastructure. The highways agency in the Loire of France has been using GIS since 1989 for many purposes: Traffic accident patterns are visualized and safety improvements are made where they are most needed. By collecting significant data for the whole network, repairs and works budgeting have become more reliable and calculated in advance. First creating the optimal route between locations and then using GIS to decide how and where to sign, improved directions and movements in the road

network and helped avoiding congestion, Marshall, (1995). ATAC, the public transportation company in Rome, has successfully implemented a comprehensive GIS-based management system for the city bus network. The system coordinates the work of a number of departments including information control, breakdown management, marketing, and ticket distribution. The departments use and managed the same database, which minimizes redundancy and maximizes efficiency. Integrating the management system with established monitoring procedures allows the collection, visualization, and analysis of disruptions on the transportation network, showing where and when the events take place. The company is also planning a reservation service for the disable. The costumers will indicate their needs by telephone, which then be put into the database. From the database, a daily schedule will be produced for each vehicle required to provide pickup services.

Transportation applications themselves account for visualisation and mapping issues, in order not only to show results, but also to analyse and have an overview of the problems. From this point of view, transportation science has exploited the advances in geographical representation coming from GIS. Transportation applications have relied in GIS to explore new visualisation and mapping possibilities, raising questions regarding issues of map accuracy, map matching, location mapping, and advances in 2-D and 3-D visualisation for road transport infrastructure. Many attempts have been made to use digital maps to better represent road transport infrastructures features and the precise location of their attributes through dynamic segmentation, made possible from commercial GIS packages. Norohna and Goodchild (2000), relate the location expression problem to the interoperability issue and develop methods to compare maps and overcome map accuracy problems when data comes from different sources. Sutton and Wyman (2000) compare dynamic segmentation based on the linear referencing approach, with dynamic location, which stores geometry as a single object in a database field.

A wide range of transportation studies take advantage of the user friendly environment provided by GIS software and of new possibilities from a visualisation point of view (Frank et al., 2000; Welch et al., 2007; Choi and Kim, 1996; Moudon et al. 2005). GIS allows the creation of flexible interfaces for visualisation of road trasport data where map symbols and computer animations are distinguished as possible means to represent dynamic road infrastructure phenomena (Claramunt et al., 2000). More recent advances advocate the use of GIS to handle representations of transport data in more than two dimensions, in particular when studying travel behaviour (Kwan 2000; Kwan and Lee, 2005; Pack et al. 2005, 2007). There is also considerable interest in mapping newer elements associated with networks such as risk and vulnerability (Church and Cova, 2000; Kwan and Lee, 2005). With the development of the Internet and web related services such as Mapquest or GoogleMaps for planning and route-finding, GIS has acquired a new role. Mapping services, some more sophisticated than others, are all over the Internet and are setting a standard for transport planners and agencies to follow (Tang and Waters, 2005).

ArcGIS, has available road transport planning functions such as user equilibrium and system optimal. Transport services focusing on other than passenger transit, such as freight, have also made use of GIS (Southwork and Peterson, 2000; Frank et al., 2000).

2.3.2 Categories of Road Transport Information Management System works

TRL, (1998) outline that the works and activities undertaken as part of road transport information management system are generally categorised by their frequency and budget from which they are funded, Table 2.1

Table 2.1 Categories and examples of Road Transport Information Management System works

Category	*Frequency*	*Budget*	*Example*
Routine	At interval of less than 12 months	Normally recurrent	• Cyclic maintenance • Reactive maintenance
Periodic	At interval of several years	Recurrent or capital	• Preventive maintenance • Resurfacing • Overlay • Pavement reconstruction
Special	Cannot be estimated with certainty in advance	Special or contingency, but sometimes recurrent	• Emergency work • Winter maintenance
Development	Planned at discrete point in time	Normally capital	• Widening • Realignment • New construction

Source: (TRB, 2004).

In performing each of the four road management functions set out in Table 2.1, managers needs to follows a logical and clearly defined sequence of steps. This approach termed the management cycle, as shown diagrammatically in Table 2.1. Each successive steps in the cycle requires an accurate and up-to-date supply of information if the correct decision are to be made. For this reasons, the maintenance of a database of the management information is at heart of the cycle.

2.3.3 Function of Road Transport Information Management System

TRL, (1998) stated that, the management of road information activities is best viewed in terms of four main function: Planning, Programing, Preparation and Operation

Table 2.2 indicates the application of these management functions within a road administration.

The management of these works and activities is best viewed in terms of four main functions as show in Table 2.2 above namely; planning, programing, preparation and operation. The table indicates the application of these management functions within a road administration. The progression from planning through to operations is accompanied by several changes in emphasis.

Table 2.2 Road management function

functions	*Typical management aim*	*Network coverage*	*Time horizon*	*Management staff concerned*
planning	Defining road standards which minimise cost. Determining the budget required to support defined standard	Entire network	Long terms (strategic)	Senior managers and policy-marks
programming	Determining the work programme that can be undertaken within the budgetary period	Sections likely to need treatment	Medium term (tactical)	Managers and budget holders
preparation	Design of work. Preparation and issue of contract or work instruction	Contract or work packages	Budget year	Engineers, technical and contracts staff
operation	Undertaking tasks as part of works activity	Sub-sections where works are taking place	On-going	Works supervisors

Source: (TRB, 2004).

The focus of attention in transferred from the network as whole to the specific locations where works are being undertaken, The time horizon narrows from a span of several years to the individual budget year and then down to the current week or day, The level of management responsibility decreases, the information required for each function change in scope from summary or sampled data about the entire work to detailed and precise data about specific road sector.

2.3.4 Types of GIS-Based Road Transport Information Management System

There are two types of GIS-based road information management system used in road management (TRL, 1998): Network Information System and Decision support system

(i) Network Information System, which correspond to the core of management cycle and are used to assemble, organise and store data about road transport network.

(ii) Decision support system, which are used in each stage of road management to assist in the tasks that form the perimeter of the management cycle- planning, programming, preparation and operations; they process road network data as a basis for decision

about road management activities and almost always require a fully functioning road network information system.

2.3.5 Integration of GIS and Road Transport Management System

Curtin, (2003) noted that over the past years, integration of GIS road transport information management system is a broad expression that encompassed all of the activities that involved the use of GIS for some aspect of road transport planning, management, or science. It appeared to be a promising research area that should contribute to the development of sustainable cities. Government agencies, research institutions, and private sectors are among the actors that look forward for data which are either static or dynamic. The data contains difference transportation modes (bus, tram, metro, car, boat) and traffic related objects (pavement, stop signs, traffic lights, or construction equipment). For instance, integrating GIS and traffic information can be used to monitor traffic accidents, flows or congestions that have occurred, this providing useful insight for transportation planning studies. Increasingly, urban and transportation planners are finding that the integration of traditional transportation research methods with the added value of GIS capabilities including integration of geographical spatial-analysis and cartography, provides a robust platform for both traditional and innovative transportation and traffic activities Curtin (ibid).

Integration of GIS and transportation systems have received a lot of attention in recent years Rodrigue *et al* (2006). A specific branch of GIS applied to transportation issues, commonly labeled as Geographic Information Systems for Transportation Curtin (ibid), has emerged. Miller and Shaw (2001) describes that GIS-based RTIMS refers to the principles and applications of applying geographic information technologies to transportation problems.

Considering the complexities of the integrated transportation data, there is an urgent need to adopt lasted concepts and technologies for designing and developing the information

resource management of transportation infrastructure in Adamawa Central. Presently, GIS is an important tool in transportation engineering, and play an even more important role in providing the capability to perform transportation, planning, management and analyses Lincoln (2005). GIS is the ideal information management and analysis tool for many aspects of the transportation industry including both the public and the private sectors ESRI (2003)

The first advantage of the integration of GIS and transportation system to various transportation organizations is its potential for data integration which provides an integrated source or *data hub* of information for traffic and transportation related data, Etches, A. (2002). In a GIS platform, the RTIMS database is generally extended by integrating attribute datasets and spatial data through its linear referencing system, Gupta *et al* (2003). Moreover, the application of GIS will facilitate integration of all other socio-economic data with road transport system database for wide variety of management functions, such as estimating transportation costs.

The second advantage of the integration of GIS and transportation system relies in its ability to access and analyse spatially distributed data, and respects to its actual geographic spatial data of the area that allows analysis not possible with the other database management systems. The main benefit of using the GIS is not merely the user-friendly visual access and display, but the spatial analysis capability and the applicability. The particular capability and applicability provide standard GIS functionalities (i.e. thematic mapping, charting, network-level analysis, access, manipulation to spatial data and decision making), and even the ability to interface with external program and software for decision-making support, simulation, and user-specific purposes Gupta *et al* (2003).

2.3.6 Application of GIS to Transportation

Miller (2001), found out that GIS-T is one of the leading GIS application fields. Many GIS-T applications have been implemented at various transportation agencies over the last two decades. They cover much of the broad scope of transportation, such as infrastructure planning, design and management, transportation safety analysis, travel demand analysis, traffic monitoring and control, public transit planning and operations, environmental impacts assessment, hazards mitigation, and intelligent transportation systems (ITS). Each of these applications tends to have its specific data and analysis requirements. For example, representing a street network as centrelines and major intersections may be sufficient for a transportation planning application. A traffic engineering application, however, may require a detailed representation of individual traffic lanes. Turn movements at intersections also could be critical to a traffic engineering study, but not to a region wide travel demand study. These different application needs are directly relevant to the GIS-T data representation and the GIS-T analysis and modelling issues discussed above.

With the rapid growth of the Internet and wireless communications in recent years, a growing number of Internet-based and wireless GIS-T applications can be found. Such applications are especially common for ITS and for location-based services (LBS). Another trend observed in recent years is the growing number of GIS-T applications in the private sector, particularly for logistics applications. Since many businesses involve operations at geographically dispersed locations (e.g. supplier sites, distribution centres/ warehouses, retail stores, and customer sites), GIS-T can be useful tools for a variety of logistics applications. Again, many of these logistics applications are based on GIS-T analysis and modelling procedures such as the routing and the facility location problems. Miller (1991).

2.3.7 Development GIS-Based Road Transport Information Management System

Planning offices, everywhere, are using GIS to handle what were what once known as development of road transport information management system. At present, many of the systems are used for map management and for the spatial/indexing of data. In time, GIS will revolutionize development surely as the internal combustion engine revolutionized road transport information system. Accept there is little reason to keep the old word planning development in use. It derives from absolute techniques for representing road, bridge, culvert, roundabout, buildings and land form on flat paper. GIS-Based RTIMS can produce multi-dimensional models or transportation instead of dull all plan development. The models can be social, economic, aesthetic or physical (MC Loughlin, 1999). The spatial depiction of the public amenities and infrastructure facilities can be made quick user friendly with organisation as they can check out the transportation in different regions and develop the organization accordingly. Real time traffic data combine with accurate map can be very effective in reducing the respond time for emergency services. Also GIS can help determine spatial and temporal distribution of natural resources (Galster *et al*, 2001).

Road Information management system starts form the premise that the road network is an asset which need to be maintained and improved so as to secure the best performance and value for money and the maximum service life (Transport Research Laboratory, 1998). They went on to say that the aims of road managers are to enable the network to withstand the damage cause by wear and tear, to prevent substandard conditions from development, and to ensure that traffic can continue to travel, in a manner which is safe, efficient, reliable and which causes the list damage to the environment. These aims are achieved through a series of works and activities which depend for their effective management on the maintenance of up-to-date information about the features and condition of the road network.

Managing the road transport information management system is a function that needs to be treated like any other operational activity undertaken by road administrator. The benefit which is the GIS-based system can offer, improved management of the road transport network, which will be lost if this aspect of its operation is neglected. System management involves the following sectors of activity (Galster *et al*, 2001):

(i) Defining responsibilities.

(ii) Controlling system and data.

(iii) Monitoring and feed-back.

Defining responsibilities; there are two possible approaches to the operation of road transport information management system within a road administration. One approach is to make the used of the system widely throughout the organisation and the other is to concentrate its use inside a specialise unit which supplies system output as reports to decision- makers.

Regardless of the mode of operation, there is usually a need to appoint system administrator. This person should be a GIS specialist who has overall responsibility for the functioning of the system. The responsibilities of the post will include ensuring that the system is running correctly, maintaining data security, assess control, back-up and achieving, issuing passwords and managing modifications and upgrade to the system. Controlling system and data; include user access, road transport data updating and road transport data control. And Monitoring and feed-back; include institutional issues and technical issues e.g. data, model, system operation and audit.

2.3.8 Importance of GIS for Road Transport Database Management

The importance of robust GIS database as a sin-qua-non to the efficient solution of environmentally related problems is no longer in dispute. John (1994) reported how the city

of Canberra (Australia) used GIS to reduce cost and increase productivity. The manager of the GIS had been able to minimize staff and save a lot in terms of cost and quality development planning. Also GIS had enabled other agencies to avoid duplicating efforts on data and resource and to meet their objectives economically and easily. Memm (1995) also reported how GIS helps in exploring diamond (kimberlites and lamproties) in the central United States. GIS database including geological, geographical and remote sensing information relevant to the development of infrastructure. In yet another report, Anderson (1992), described how GIS were instrumental to the efficient refuse disposal system in the city of Portland (Northwest Oregon, USA). It provides the investment which a powerful tool for posing "what-if" question and also enable block map with associate customers value to be created.

2.3.9 Benefits of the Geodatabase for Road Transport Information Management System

Zeiler (2003) Pointed out Some of the benefits of the geodatabase model which are are:

i. Uniform collection of geographic data. All geographic data can be stored and managed centrally in one database.

ii. Users work with more intuitive data objects. Instead of generic points, lines and polygons, users work with objects if interests, such as roads, bridge, culver, roundabout and traffic signs.

iii. Data entry and editions are more accurate. Most of data entry and editions error can be prevented by intelligent validation of behaviour. For many users, this alone is enough reason to adopt geodatabase model.

iv. Features have a rich context. With smart features you not only define a feature's qualities, but its context with other features. This lets you specify, what should happen when a related feature moved, splinted, deleted or so.

v. Better maps can be made. You have more control over how features are drawn, and you can add intelligent drawing behaviour.

vi. Features on a map display are dynamic. The features can respond to changes neighbouring features.

vii. Sets of features are continuous. The geodatabase can accommodate very large sets of features, raster's without spatial partitions.

viii. Many users can edit geodatabase simultaneously. This data model permits work flows where many people can edit features in a local area and reconcile any conflict that emerge.

2.3.10 Challenges for GIS-Based Road Transport Information Management System

GIS-based RTIMS applications cover much of the broad scope of transportation; however, is still facing a lot of challenges. Thill (2000) categorized major GIS challenges brought by RTIMSs as follows: Legacy data management system (need for data integration, i.e., transferring disparate data into a unified data management system), Data interoperability (need for map matching algorithms, error models in transportation data, and data quality/exchange standards), Real-time GIS-RTIMS (need for quicker access data models, more powerful spatial data combination techniques, and more powerful dynamic routing algorithms), Large data sets (need for pioneering system designs in order to optimizing speed and accuracy of the display of information as well as the run time of algorithms, and better analytical tools of network analysis), and Distributed computing (need for more powerful

analytical tools to fit the limited distributed computing resources, wise design of system architectures to make efficient use of local and remote computing resources, and geo-referencing of remote service users and real-time tracking of their movements).

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter give a description of the study area and the methods involved in achieving aim and objectives of the study.

3.2 The Study Area

3.2.1 Location of the Study Area

The Adamawa central which is the study area consists of seven Local Government Areas namely; Yola North, Yola South, Fufure, Gerie, Song, Hong and Gombi, with an area coverage of about 12,914 square kilometres, its located between latitudes 8^{o}30'N and 13^{o}00'N of the equator and between longitudes 10°30'E and 13°00'E of the Green which meridian with an elevation of 135 metres above sea level. Adamawa central is bordered by Borno State and Shelleng LGA to the northwest, Demsa, Mayo-Belwa and Jada LGA to the southwest, Mubi north and Maiha LGA to the northeast, its eastern border also forms the national eastern border with Cameroon. Adamawa central occupies about 12,914 square kilometres, See figure 3.1.

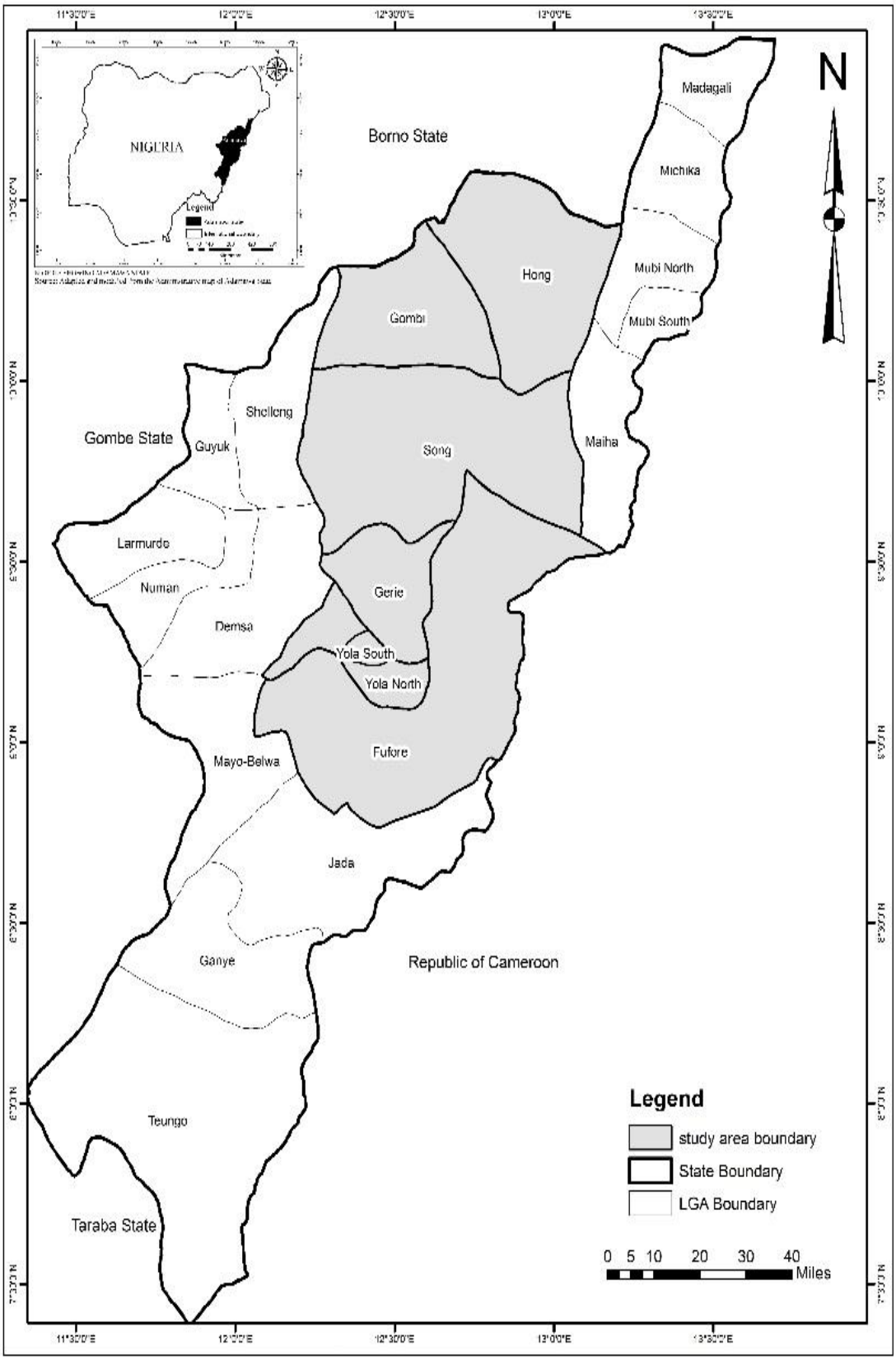


Figure 3.1 Adamawa state showing Adamawa Central
Source: Adopted and modified from Administrative map of Nigeria (12)

3.2.2 Geology and Relief

The relief of Adamawa central is that of the cretaceous rocks overlying Bima Sandstone underlies restricted area of low-lying plains in the Benue valley between the Lamurde and the Ini Rivers. They consist of a series of predominantly marine strata in which six formations have been recognized (Carter, Barber, and Tait, 1963). The Yoide formation consists of an alternating series of sandstone and grey sheles, they marks the transition from the continental conditions of deposition of the Bima sandstone to marine condition. The latter are predominantly argillaceous and consist of alternating shales with some sandy mudstones, siltstones and sandstones.

3.2.3 Drainage

The river network of north drains from the highland and north easterly trending rivers flowing into the Benue across plains, which have a lower rainfall, a longer, dry season and contribute little to the total drainage. Yola is drained by the Benue River which rises from the Cameroon Republic and flows from east to west along the northern borders of the area to join the River Niger at Lokoja. All water supplies are at present obtained from rivers and streams.

3.2.4 Weather and climate

The climate of the study area is typical of the West African Savanna climate. Temperature in this climatic region is high because of the radiation income, which is relatively evenly distributed. However, there is usually a seasonal change in the temperature. There is gradual increase in temperature from January to April. There is also a distinct drop in temperature at the onset of rains due to the effect of cloudiness. A slight increase after the cessation of rain (October to November) is common before the onset of harmattan in December the temperature in Yola reach 40^{o}C particularly in April and while minimum

temperature can be as low as 18^{o}C in the south to 27.8^{o}C in the northeastern part in December (Adebayo and Tukur, 1999).

2.2.5 Vegetation and Soil

The vegetation of Adamawa central is categories in the Sudan Savannah zone of Nigerian, most of which is subjected to regular cultivation. Restricted areas of *anogeissus /combertum/ propopsdis* woodland occurred but the farmland carry a mixed shrub dominated by *pilostigma reticulation*. Under dense cultivation open *parkia/butryospermum* Park and developed belt in some areas a mixture of *balanites aegypyica* and *ziziphus species, (*Akosim, Tella and Jatua, 1999)

Like most areas of northern Nigeria, most of the soils of the area have sub-surface horizons with high content of iron concretions and fissile iron stone occurring in many areas; the soils are drained from basement complex, while few other places are on sandstone, sheles and alluvium. The most important factors influencing soil formation in Adamawa central are the climatic one of temperature and rainfall. The soils are generally richer in weatherable minerals. The soils of Adamawa state include luvisols, legosols, cambisols, vibisols, and lithosols (Helen, 1999).

Luvisols; have a typical clay-ended horizon with high base saturation of more than 50%, they are the most common soils after Regosols in Adamawa state and cover the 213, 222, 228, 229 and 240 units. These soils are generally found on foot slopes of nearly 10% slope around Gerie, Madagali, Gombi and Hong area. Legosols form a greater part of the state and is found on units 201 and 231. These are the immature week developed soils consisting of rock fragments which occur in isolated hilly areas and are derived from basement complex. They are found from Bajabure up to Song River, then to the outskirts of Michika, the flood plains of river Yadzaram at Uba, flood plains of Loko river between Sulti-

Gamadio. Cambisols; found on units 213 and 232. They are also found at the outskirts of Gurin, along Gurin-Fufore, Ngurore-Mayo-Belwa, Gamadio-Dong and Fufore-Mapeo area. Vibisols; are found within the 230 unit. These soils are found around Malabu-Wurobokki, Guyuk, Borrong-Shelleng on a topography of flat crest of about 0% slope and are derived from cold alluvium calcareous shale in the Benue Gayola valleys. Lithosols; are found within the 201 unit and are found within a radius of 2km from Bajabure village (Helen, 1999).

3.2.6 Population

Population constitute a vital component of the resource base and the development potential of any country. The size, rate of growth, spatial distribution, demographic structure and quality determine the direction and pattern of development. The total population of Adamawa Central, as recorded in 2006 population census was 1,030,606 (Pollard *et al.*1991).

There are two areas with high population concentrations. Yola North and Yola South Local Government Areas, with only 3.1% of the total landmass and had a population density of 226.2 persons per square kilometre (Pollard *et al.*1991). This is the highest for the state. Madagali, Michika, Maiha, Mubi North and Mubi South Local Government Areas constitute the second group of most populated Local Government Areas in the state. They displayed a combined population density of 131.2 persons per square kilometre. Guyuk Local Government Areas is the third in rank with 23.6% of the landmass and a population density of 80.9 persons per square kilometre. Ganye, Tongo and Jada Local Government Areas were sparsely populated with 27 persons per square kilometre covering about 27.1% of the total landmass of the state (Pollard *et al.*1991). 44.8% of the population of the state was made up of the children below the age of 15 years age. Within this range, males under 15 years age accounted for 50.9% and the female 49.1%, thus displaying a broad-based population pyramid.

3.2.7 Transportation

Transportation is by far one of the most important developmental needs of the people in Adamawa state. The existing modern system of transport in the state are the road, air and the inland waterways. The total road network capacity in Adamawa state stands at 1507 km in length. This comprise of 668 km of major tarred roads that link most of the local government headquarters and the minor roads measuring 839 km, which are mostly untarred, facilitating movement between localities. The density of the road development is higher in the central part of the state and this may be due to the influence of the state capital, and the high level of urbanisation and the socio-economic activities in the region. The road development in the northeast part is moderate, centred on Mubi the nucleus city in the area, the network is adequate in satisfying the needs of modern mobility. The density in the south of the state area council is low, accounting for only about 5% of the main and 14% of the minor roads. This ill development is not unconnected with the low population growth and the mountainous nature of the terrain in the area (Ogunsanya and Galtima, 1993).

However, the road can be classified in to the asphalt and the lateritic or sandy surface type. Inter-urban transport travels are carried on the asphalt trunk-A roads, which are owned and maintained by the federal government as part of the national network system. The lateritic or sandy roads are owned and maintained by the state (trunk-B) and the local government (trunk-C), together these roads are responsible for almost all the rural freight and passenger connection, (Ogunsanya and Galtima, 1993).

3.2.8 The Economy

Adamawa central is one of the fastest growing area in the Adamawa state. Apart from its central location in the Adamawa, it has distinguished itself as a home for some important

groups of activities. It is esteemed for hosting the establishments like Nigerian Army, the Air force. Nigerian police, and other Paramilitary establishments like the Customs Excise, Immigration Service, Prison Service and Civil Defense Corps.

The Adamawa central is also known for myriad of manufacturing industries and traditional industries, manufacturing industries; such as coils, chalk, burnt bricks, animal feed, soft drink, rice milling, cotton ginning, vegetable oil, foam and polythene, flour mill, sugar, domestic appliance and many others (Mirchaulum, 1994). Traditional industries; such as weaving raffia and zana mat, calabash decoration, black smithing, pottery, leather work, hand weaving cloth, bronze casting, metal work, wood carving and many others. However, it serves as a major commercial centre for locally manufactured goods and agricultural produce from within and the neighbouring states. Agricultural commodities and manufactured goods from other parts of the country and those imported are also found in the commercial centre of the of the Adamawa central.

3.3 Methodology

In order to achieve the various objectives of this research as stated above, a research method workflow was designed to and adopted in doing that and it is illustrated in figure 3.2. the first step was reconnaissance had carried out to get acquainted with the study area and during the period, bridge, roundabout and roads picture and coordinates were taken. The second step involved materials use among which included; the hardware and software. The third step is types and sources of data which was determine by the method and techniques of data collections which divided into spatial and non-spatial data that form the forth step. The fifth step is method of data analysis and presentation of results include; mapping designing and building of goedatabase for road infrastructures. The final stage is the data analysis and it further categorise in to GIS database and map analysis which is directly link to the final output such as maps, Microsoft documents, ArcMap document, etc.

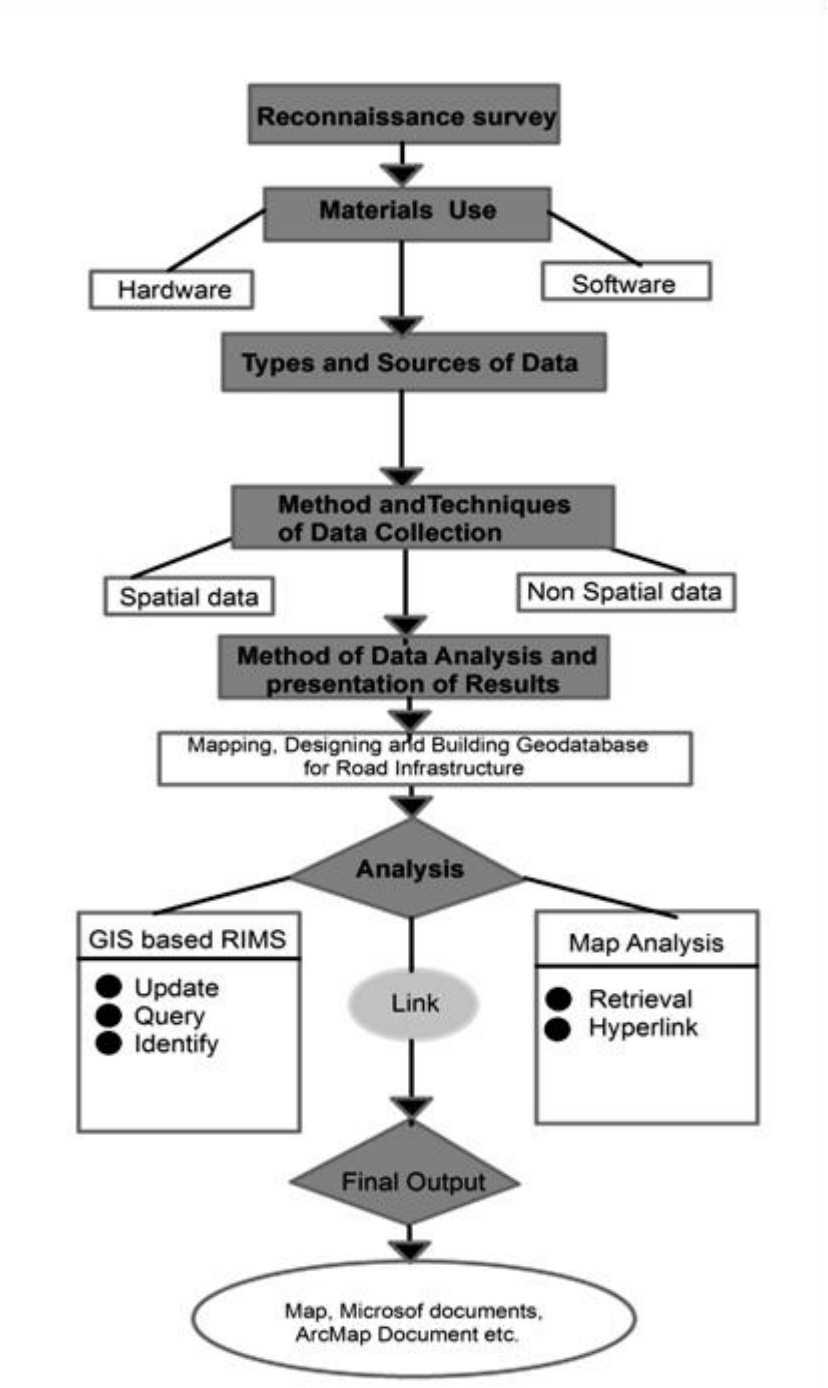


Figure 3.2: The workflow of the research methodology
Source: Author

3.3.1 Reconnaissance Survey

Reconnaissance survey was carried out to get acquainted with the study area and also to assess the requirement of the road transport users. Discussions were made with the Directors of Urban and Regional Planning, Ministry of Works Adamawa State, Road Transport Authorities, drivers and the public road ways.

3.3.2 Materials used for the Study

3.3.3.1 Hardware

The hardware used are show on table 3.1

Table 3.1 the hardware required and the usage

Hardware	**Usage**
A hand-held Garmin 76CSX GPS	Used for capture of control points of the road transport junctions (Y and T)
A digital camera	Used for capture picture of some road infrastructures
An A0 scanner	Used for scanning hardcopy topographic map of the study area in order to convert it in to digital format in ArcGIS 10.1 environment.
An A0 scanner	Used to print out hardcopy maps of the GIS based RTIMS
A digital electronic Laptop computer	Used for processing all the information gathered in this study

3.3.3.2 Software

The software to be used are show on table 3.2

Table 3.2 the software required and the usage

Software	**Usage**
Microsoft Word 2013	Used for compiling and documentation of the research document
ESRI ArcGIS 10.1	Used as for mapping, designing and creation of geosdatabase analysis, querying, and production of road transport maps, chart and tables of the Adamawa central.

3.3.2 Types and Sources of Data

In order to achieve the stated objectives, the following data were obtaind; Spot5 satellite images of 2012, with 1m resolution, road transport map of Adamawa state, documents on road information and attributes, GPS coordinates of the junctions (X and Y) and culvert of Adamawa central. See Table 3.3 for types, sources and usage.

Table 3.3 Data type, sources and usage

Dada required	**Sources**	**Usage**
Road transport base map	Ministry of Urban and Regional Planning Yola	Serve as base map which is digitize and delineate the roads transport for geospatial database creation.
Google Earth image	Google dawnload	The base road map will be overlay on the image in order to update the road map.
Spot5 satellite images (2012) of 2.5m resolution	National Centre of Remote Sensing Jos	Also the base road map and Google Earth image will be overlay on the image in order to update the road map.
Road information Documents (attribute data)	Ministry of Works Yola	It provide attribute data to be used as an inventory for creation and populating database
Spatial data	Field survey	For taking coordinates points of the roundabout that were used to show location of road infrastuctures.
Digital camera data (picture)	Field survey	Provide road pictures for hyperlinking in order to see the nature of some of the roads and roundabout.

Source: Author

3.3.3 Method and Technique of Data Collection

Road map was obtained from Ministry of Urban and Regional Planning Yola. Spot5 image of 2012 was acquired from the National Centre of Remote Sensing Jos and Field work was carried out in order to take the coordinates of the road infrastructure using GPS as well as snapping some of the road infrastructures pictures using digital camera. Field work, these included the collection of road transport information documents from Ministry of Urban and Regional Planning and Ministry of Works Adamawa State.

3.3.4 Data Processing

i. Vector Data Creation (Road Map)

The road transport base map, Google Earth image and Spot5 satellite images high resolution imagery covering the study area was used and the subsetting of the image

for the study area was carried out using ArcGIS 10.1 Software. The road infrastructure map (vector map) was generated in ArcGIS 10.1 Software.

ii. Creation of Database

All vector data (i.e. line and point features) contained separate attribute tables. Here the road was labelled with its name. Similarly the road infrastructure location attribute table contained the records from the Ministry of Works Yola. The coordinates and their attributes was entered in Microsoft excel and then saved as CSV (comma delimited) format and imported into the ArcGIS environment. The x and y coordinates defined the position of road infrastructures location on the map as a point feature and each point have its own attributes. The database was used for query and analysis on the data.

3.3.5 Methods of Data Analysis

Methods of data analysis and presentation of result adopted in this research work formed the basis for the mapping, building, creation and the development of a GIS based road information management system in Adamawa central.

3.3.5.1 Mapping the existing road infrastructures in Adamawa Central (Objective I).

In achieving the objective, Remote Sensing Data: Road base map was scanned, georeferenced, digitised and the roads maps delineated and together with Spot5 (2012) with 2.5m resolution and Google satellite images used to overlay the two maps in order to update the road transport map for Adamawa central so as to generate an up-to-date road map . Necessary spatial layers of road transport network were generated from the sport5 image and road maps.

3.3.5.2 Designing and Building Geodatabase of road infrastructures in Adamawa Central (Objective II).

This was achieved through the use of ArcCatalog Tool. Designing and building Geodatabase involve three stages; conceptual, logical and physical design.

Conceptual design; was the starting point of database design, the purpose of conceptual data modelling was to define in broad and generic terms the scope of a database (Lo, Albert and Yeung, 2007). The approaches to conceptual data modelling involve; Entity Relation (E-R) model (see fig 3.3), Entity Relation (E-R) schema (see fig 3.4), identification of attributes, determination of relationships and the drawing of an E-R diagram, as show on Figure 3.5.

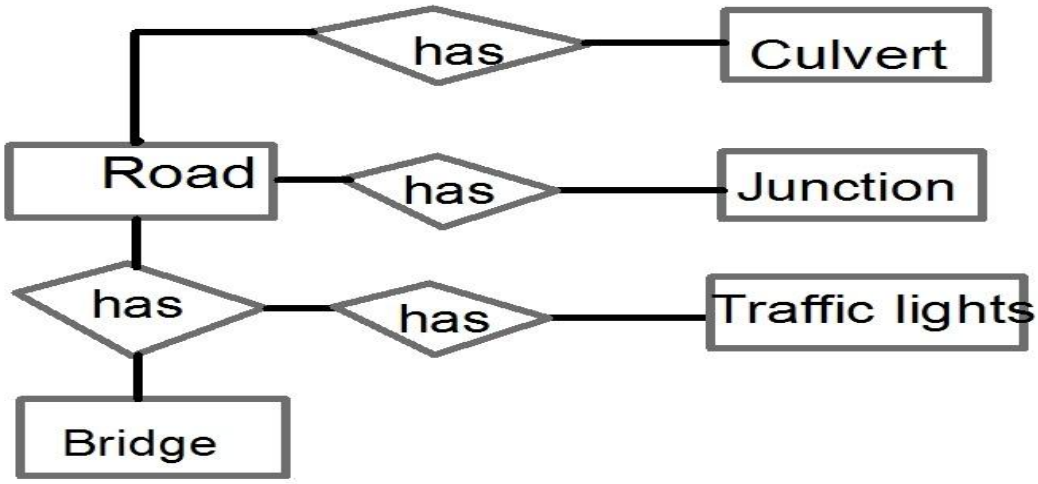


Figure 3.3 Entity Model of Database
Source: Author

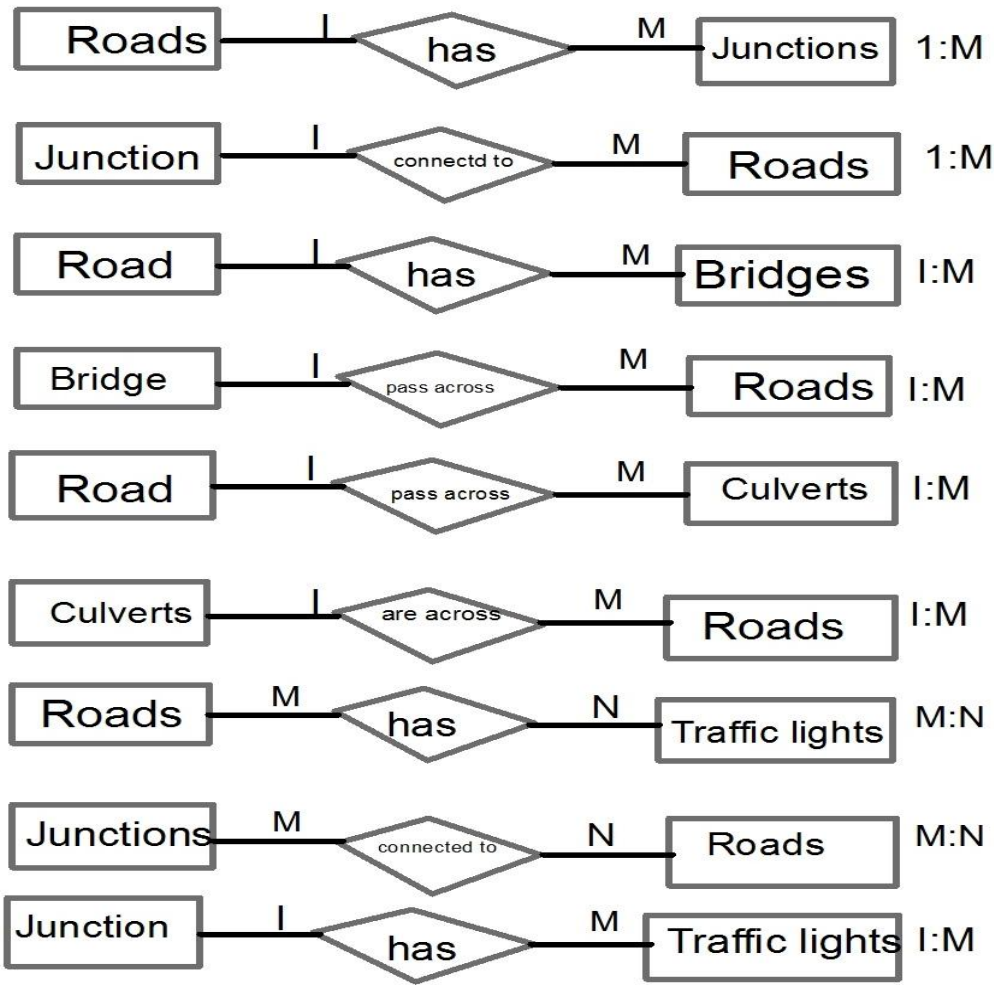


Figure 3.4 Entity Relationship Schema of the Database

Source: Author

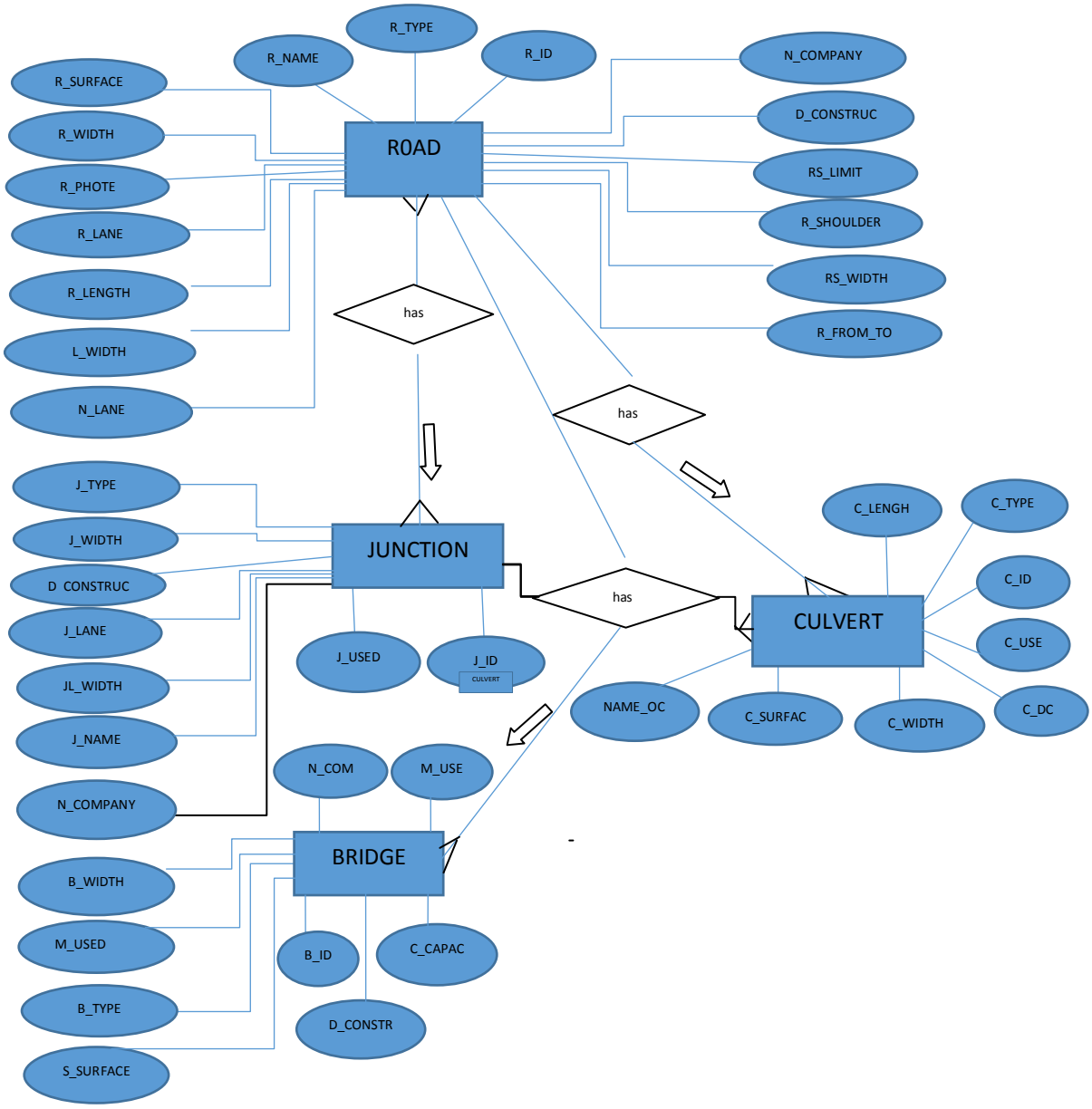


Figure 3.5 Conceptual Model of the Geodatabase.
Source: Adopted and modified from the work (Lo, Albert and Yeung, 2007).

Logical design, logical data modelling is the process by which the conceptual schema is consolidated, refined, and then converted to a system-specification logical schema (Lo, *et al*, 2007). It involved mapping the conceptual schema to the logical schema, identification of primary key, foreign key and normalising the attribute table as shown on figure 3.4.

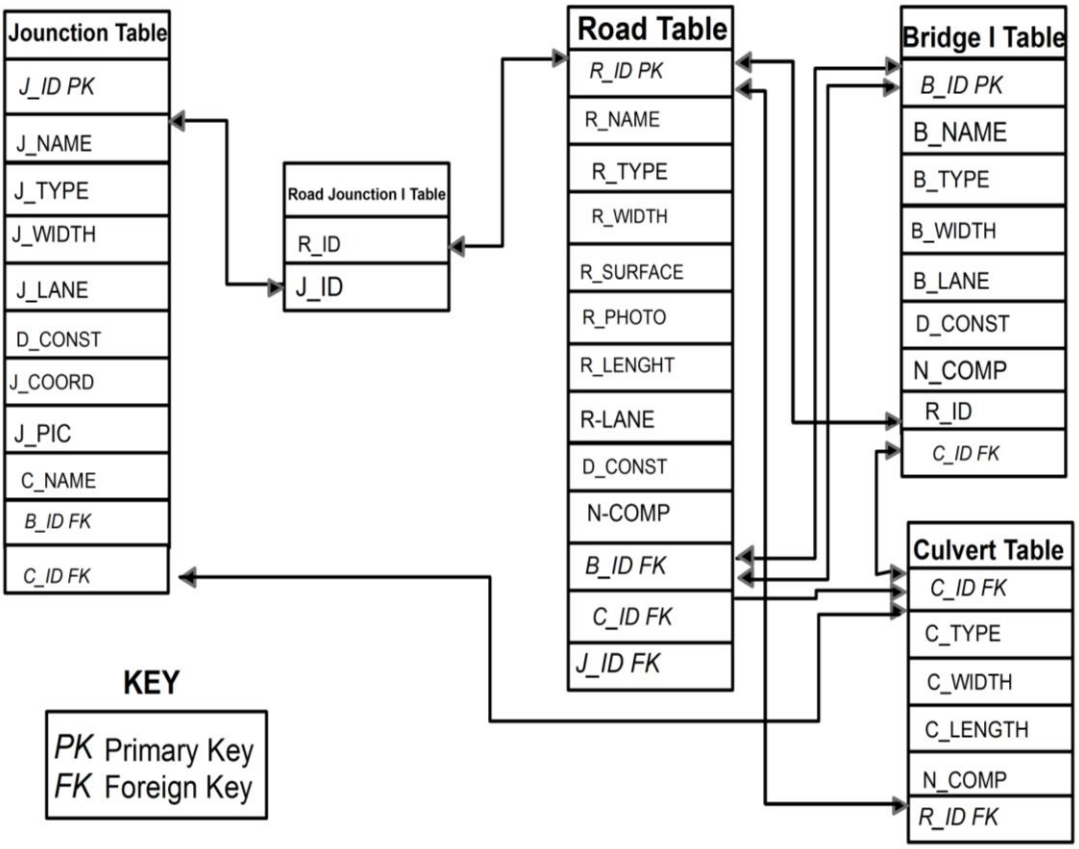


Figure 3.6 showing the logical model of the Road Transport geodatabase
Source: Author

In the physical design, the physical data modelling is concerned with defining specific storage structure and access paths to the database (Lo, Albert and Yeung, 200), as showing in Table 3.4.

Table 3.4 Characteristics of Field and Attributes in Physical Designed of the Road Transport Geodatabase. Created in ArcGIS 10.1 environment.

Attributes	Field Name	Field Discription	Field Type	Domain	Fielf Length
Road (feature class): Line feature type					
Road ID	R_ID	A unique Road Identification number of theRoad	Double	R_USE	10
Road Name	R_NAME	Full name of the Road	Text		25
Road Type	R_TYPE	Federal Road, State Road and L.G. Road	Text	R_TYPE	25
Road Width	R_WIDTH	Road Width (meter)	Numeric		12
Road Surface	R_SURFACE	Nature of the Road Surface (paved, unpaved),	Text		15
Road Photo	R_PHOTO	The Road Picture	Raster		<100kb
Road Length	R_LENGTH	The length of the Road	Numeric		10
Road Lane	R_LANE	Lane of the Road	Numeric		10
Lane Width	L_WIDTH	Width of the Road Lane	Numeric		10
Number of Lane	N_NAME	Number of Lane	Numeric		10
Road Shoulder	R_SHOULDER	Road Shoulder (yes or no)	Text		5
Road from - to	R_FROM_TO	Road Starting from and to	Text		20
Road Speed Limit	RS_LIMIT	The speed Limit of the each Road	Numeric		10
Date of Construction	D_CONSTRUCTION	Date of Road Construction	Date		Date
Name of Company	N_COMPANY	Name of the Company that Construct the Road	Text		30
Materials Used	M_USED	Materials used for the Road Construction	Text		30
Shoulder Width	S_WIDTH	Width of the Road Shoulder	Numeric		10
Subtype	SUBTYPE	Various road used type	Text		25
Junctions (feature class): Point feature					
Junction ID	J_ID	A unique Identification number of Junction	Double		10
Junction Name	J_NAME	Full name of the Junction	Text		30
Junction Type	J_TYPE	(cycle, t-junction), others	Text	J_TYPE	30
Junction Width	J_WIDTH	Junction Width (meter)	Numeric		10
Date of Construction	D_CONSTRUC	Date of Construction	Date		Date
Number of Lane	N_LAME	Number of the Junction Lane	Numeric		Num
Lane Width	L_WIDTH	Width of the Junction Lane	Numeric		Num
Maretials Used	M_USED	Materials used for the junction construction	Text		Text
Bridge (feature class): point feature					
Bridge ID	B_ID	A unique Identification Number of Bridge	Double		10
Bridge Width	B_WIDTH	The Bridge Width (meter)	Numeric		10
Carrage Capacity	C_CAPACITY	The carrage capacity of the Bridge	Numeric		10
Date of Construction	D_CONSRUCT	Date at which the Bridge was Constructed	Date		Date
Name of Company	N_COMPANY	The company that constructed the Bridge	Text		30
Material Used	M_USED	used for the Bridge	Text		30
Bridge Surface	B_SURFACE	The nature of Bridge surface	Text		20
Bridge Type	B_TYPE	The subtype of the Bridge	Text	B_TYPE	20
Culvert (feature class): point feature					
Culvert ID	C_ID	A unique Identification Number of Culvert	Double		10
Culvert Width	C_WITH	The Culvert Width (meter)	Numeric		10
Culvert Type	C_TYPE	The subtype of the Culvert	Text	C_TYPE	20
Culvert Surface	C_SURFACE	The nature of Culvert surface	Text		20
Culvert Name	C_NAME	Name of the Culvert	Text		20
Culvert Use	C_USE	used for the Culvert	Text		30
Name of CC	NAME_CC	The company that constructed the Culvert	Text		30
Date of Construction	D_CONSTRUC	Date at which the Culvert was Constructed	Date		Date
Jounction Coordinate (Feature class): Point feature type					
Coordinate ID	COORD_ID	A unique identification number of the coordinate	Double		20
XCoordinate	X_COORD	X Coodinate (Longitude) of the Jounction point	Float		20
YCoordinate	Y_COORD	Y Coodinate (Latitude) of the Jounction point	Float		20
ZCoordinate	Z_COORD	Z Coodinate (Hight) of the Jounction point	Float		20
Projection	PROJ	Coordinate system Projection (WGW_1984_UTM_Zone_32N	Double		30

The GIS techniques were used to integrate the spatial and non-spatial data by linking the attribute data to create road layers so as to develop the GIS-based RTIMS.

3.3.5.3 Use the Geodatabase to analyse and query road characteristics (Objective III).

This was achieved through the use of Standard GIS functions tools such as (query, geocoding, selection by attributes and by location, identify tools, network analysis tool, Hyperlink tool, measurement tool etc.), was used to support data management, analysis and visualization needs.

Queries: The queries tool applies SQL to queries a database and the results were represented in a layer or table view. It was used for showing various results for Adamawa Federal highway, State highway and local government road, bridges and roundabouts, etc. Identify tool: was used to identify the road system information like, type of the road, length, width etc. Hyperlink tool: was used to display a picture showing the nature or condition of the road for proper management of the system once a road is click using the tool.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The chapter shows the analysis that was perform on the Road Transport Infrastructures, presented the results such as; existing Road Infrastructure in Adamawa Central, Geodatabase of road infrastructures, Road characteristics, Locating of Roads, Roundabout and Bridges Address using Selection Tool, physical nature of the Road, Bridge and Roundabout on the Map using Hyperlink Tool, Selecting Roads that are Single or Dual Carriage, Road Surfaces that are untarred, Roads that is 150m from a Roundabout using Buffering, Identify Information on a particular Road, Bridge and Junctions using Identify Tool, measure Road Distances using measurement Tool, finding the Roads Surface Types, etc. and their discussions.

4.2 Existing Road Infrastructure in Adamawa Central

The existing road transport infrastructure map of Adamawa central is represented in Figure 4.1

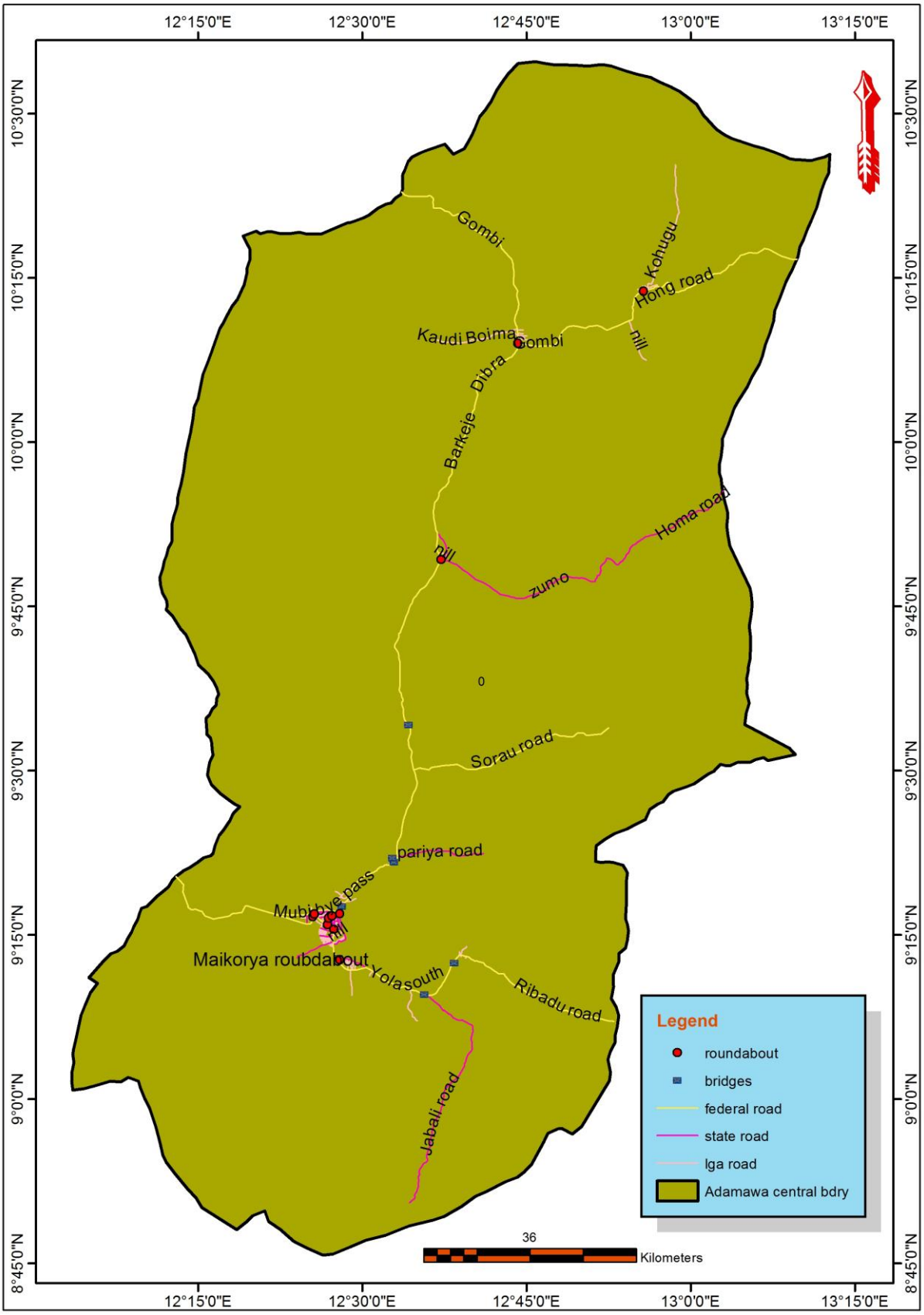


Figure 4.1 up-dated Road Transport map of Adamawa Central
Source: Author's analysis

Figure 4.1 above represent, the digitized up-to-date road transport map of Adamawa central at scale at the scale of 1:800,000. Various symbols in the ArcGIS software were used to represent dynamic feature of road transport infrastructures map as supported by Claramunt *et al*, (2000), the road are categories into three classes that is the federal, state and local government roads, different colours were also used to represent each category of the road; solar yellow line colour represents federal road, ultramarine line colour represent state road and black line colour represents local government road. The roundabouts were represented by ultra-blue point colour and the bridge were represented by citron point colour. All these were represented in the legend on the map. The representation of all these models are useful in transportation as support by (Thill, 2000) in the literature review that discrete models depend on discrete entities (i.e points) such as the representation of bridge and roundabout, also linear models to represent topological linear entities (i.e roads). Also, transportation application relied in GIS to explore new mapping possibilities. Issue of map accuracy, map matching for road transport infrastructure and there need to use digital map to better represent road transport infrastructure features as supported by Goodchild (2000). The final output of the road map is obtained in using AO scanner.

4.3 Geodatabase of road infrastructures

To Geodatabase of road infrastructures involves the design and building of Database of road infrastructures information on road transport infrastructures were collected from various ministries in the study area and field work. All the data collected were used as inventory for the designed and building of the geodatabase in ArcCataloge environment in ArcGIS software presented in table 4.1, 4.2, 4.3, and 4.4).

Table 4.1 Some of the Federal Roads Attributes of Adamawa Central Road Transport Geodatabase.

federal_road

FID	Shape *	OBJECTID	road_name	road_surfa	road_shoul	road_fron_	SHAPE_Len	Carage_cap	Road_type	surfacing
0	Polyline	2	Mubi bye pass	tired road	surface dress	mubi bye pass to gerei	0.632103	single	fed road	surface dres
1	Polyline	4	Dibra	tierd road	surface dress	dibra to gombi	0.144574	single	fed road	surface dres
2	Polyline	5	Gombi	tired road	surface dress	gombi roundabout to market	0.066054	single	fed road	surface dres
3	Polyline	6	Hong road	tired road	surface dress	gombi-hong to mararaba mubi	0.455246	single	fed road	surface dres
4	Polyline	7	Barkeje	tired road	surface dress	barkeje to song to Dibra	0.528117	single	fed road	surface dres
5	Polyline	8	Gombi	tired road	surface dress	gombi to garkida junction	0.352031	single	fed road	surface dres
6	Polyline	9	Abdulahi Bashir road	tired road	surface dress	police roundabout to yola town	0.04988	dual	fed road	surface dres
7	Polyline	11	Jambutu road	tired road	surface dress	roundabout mai doki to jambutu	0.004654	dual	fed road	surface dres
8	Polyline	12	Galadima Aminu road	tired road	surface dress	police roundabout to roundabout mai doki	0.03786	dual	fed road	surface dres
9	Polyline	13	Numan road	tired road	surface dress	mai doko roundabout to numan	0.065962	dual	fed road	surface dres
10	Polyline	15	Fufore road	tired road	surace dress	fufore to ribadu	0.075325	single	fed road	surface dres
11	Polyline	16	Ribadu road	tired	surface dress	ribadu to gurin	0.191212	single	fed road	surface dres
12	Polyline	17	Yola south	tired	surface dress	roundabout mai korya to fufore	0.240933	duai, single	fed road	surface dres
13	Polyline	18	Sorau road	tired road	surface dress	jeberu to sorau	0.323592	single	fed road	surface dres

Source: Author's Analysis

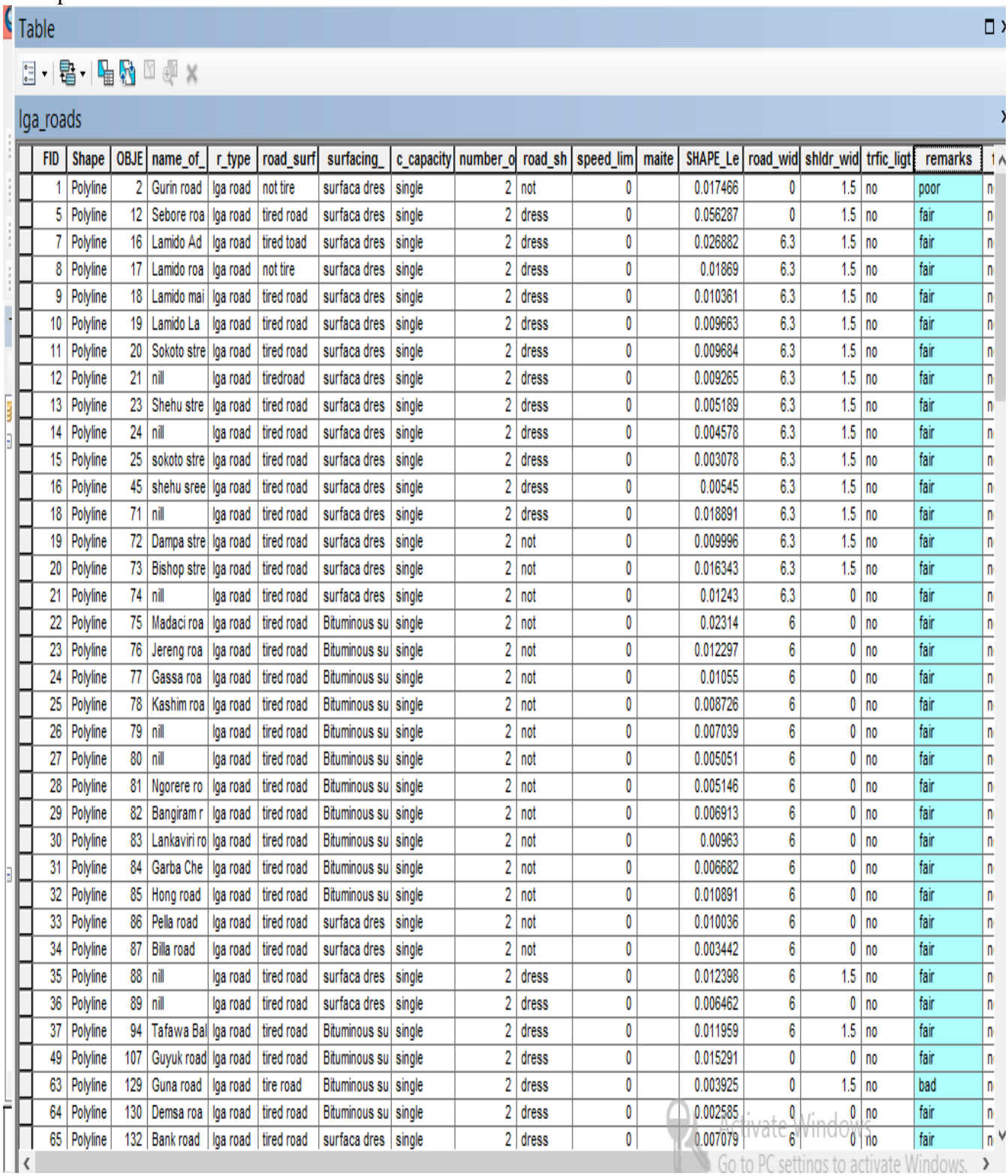
Table 4.2 Some of the State Roads Attributes of Adamawa Central Road Transport Geodatabase.

state_road

FID	Shape *	OBJECTID	name_of_ro	road_from_	r_type	road_surfa	road_lan	road_shoul	type_of_ma	remark	SHAPE
0	Polyline	1	Mubi byepass	mubi byepass to roundabout mai doki	state road	tired road	3	surface dress	not plan	good	0.00
1	Polyline	2	Mohammadu mustafa road	Galadima junction to noma da kiwo roundabout	state road	tired road	6	surface dress	not plan	good	0.03
2	Polyline	3	kashim Ibrahim way	moh mustafa rd to Abdullahi bashir road	state road	tired road	3	surface dress	not plan	good	0.06
3	Polyline	4	Ahmadu Bello road	moh mustaf junction to Ahmodu b way	state road	tired road	3	surface dress	not plan	good	0.02
4	Polyline	5	Mubi road	mubi roundabout to mubi byepass	state road	tired road	6	surface dress	not plan	good	0.00
5	Polyline	6	Mubi road1	mubi road continue	state road	tired road	3	surface dress	not plan	good	0.02
6	Polyline	7	Justice Buba Ardo road	police roundabout to KI WAY	state road	tired road	6	surface dress	not plan	good	0.01
7	Polyline	8	Jabali road	yola south to jabali	state road	tired road	3	surface dress	not plan	fair	0.39
8	Polyline	9	Toruwa Bolowa road	Abdulahi road to TB road	state road	tired road	3	surface dress	not plan	good	0.02
9	Polyline	10	Waziri road	Abdulahi road towaziri road	state road	tired road	3	surface dress	not plan	good	0.02
10	Polyline	11	Galadima Aminu way	Bekaji roundabout Galadima Away	state road	tired road	3	surface dress	not plan	good	0.0
11	Polyline	13	Modibo Adama way	mai koyya roundabout to MA way	state road	tired road	3	surface dress	not plan	good	0.04
12	Polyline	15	Barrack road	Abdulahi bashir road	state road	tired road	3	surface dress	not plan	good	0.0
13	Polyline	16	Nepa road	Ahmadu Bello way	state road	tired road	3	surface dress	not plan	good	0.02
14	Polyline	17	Jambutu street	jambutu street	state road	tired road	2	surface dress	not plan	fair	0.00
15	Polyline	18	Sarkin wuta street	sarkin wuta	state road	tired road	2	surface dress	not plan	good	0.00
16	Polyline	19	Guwa road	Guma road to	state road	tired road	2	surface dress	not plan	fair	0.01
17	Polyline	20	Gimba road	Hospital road	state road	tired road	2	surface dress	not plan	fair	0.01
18	Polyline	22	Bekaji road	Galadima aminu wat	state road	tired road	2	surface dresse	not plan	fair	0.00
19	Polyline	23	Jambutu street extention	mubi byepass	state road	tired road	2	surface dress	not plan	fair	0.01
20	Polyline	24	Bole street	moh mustafa road	state road	tired road	2	surface dress	not plan	fair	0.01
21	Polyline	28	Demsawo street	moh mustafa road	state road	tired road	2	surface dress	not plan	fair	0.01
22	Polyline	29	pariya road	Gerei to pariya	state road	tired road	2	surface dress	not plan	bad	0.13
23	Polyline	31	zumo	song to zumo	state road	tired road	2	surface dress	not plan	fair and bad	0.41
24	Polyline	33	Homa road	zumo to masagala to sorau	state road	untired	2	earth road/foot	not plan	bad	0.12
25	Polyline	34	song town road	song town to gombi road	state road	tired road	2	surfacedress	not plan	fair	0.05

Source: Author's Analysis

Table 4.3 Some of the Local Government Roads Attributes of Adamawa Central Road Transport Geodatabase.



Table

lga_roads

FID	Shape	OBJE	name_of_	r_type	road_surf	surfacing_	c_capacity	number_o	road_sh	speed_lim	maite	SHAPE_Le	road_wid	shldr_wid	trfic_ligt	remarks
1	Polyline	2	Gurin road	lga road	not tire	surfaca dres	single	2	not	0		0.017466	0	1.5	no	poor
5	Polyline	12	Sebore roa	lga road	tired road	surfaca dres	single	2	dress	0		0.056287	0	1.5	no	fair
7	Polyline	16	Lamido Ad	lga road	tired toad	surfaca dres	single	2	dress	0		0.026882	6.3	1.5	no	fair
8	Polyline	17	Lamido roa	lga road	not tire	surfaca dres	single	2	dress	0		0.01869	6.3	1.5	no	fair
9	Polyline	18	Lamido mai	lga road	tired road	surfaca dres	single	2	dress	0		0.010361	6.3	1.5	no	fair
10	Polyline	19	Lamido La	lga road	tired road	surfaca dres	single	2	dress	0		0.009663	6.3	1.5	no	fair
11	Polyline	20	Sokoto stre	lga road	tired road	surfaca dres	single	2	dress	0		0.009684	6.3	1.5	no	fair
12	Polyline	21	nill	lga road	tiredroad	surfaca dres	single	2	dress	0		0.009265	6.3	1.5	no	fair
13	Polyline	23	Shehu stre	lga road	tired road	surfaca dres	single	2	dress	0		0.005189	6.3	1.5	no	fair
14	Polyline	24	nill	lga road	tired road	surfaca dres	single	2	dress	0		0.004578	6.3	1.5	no	fair
15	Polyline	25	sokoto stre	lga road	tired road	surfaca dres	single	2	dress	0		0.003078	6.3	1.5	no	fair
16	Polyline	45	shehu sree	lga road	tired road	surfaca dres	single	2	dress	0		0.00545	6.3	1.5	no	fair
18	Polyline	71	nill	lga road	tired road	surfaca dres	single	2	dress	0		0.018891	6.3	1.5	no	fair
19	Polyline	72	Dampa stre	lga road	tired road	surfaca dres	single	2	not	0		0.009996	6.3	1.5	no	fair
20	Polyline	73	Bishop stre	lga road	tired road	surfaca dres	single	2	not	0		0.016343	6.3	1.5	no	fair
21	Polyline	74	nill	lga road	tired road	surfaca dres	single	2	not	0		0.01243	6.3	0	no	fair
22	Polyline	75	Madaci roa	lga road	tired road	Bituminous su	single	2	not	0		0.02314	6	0	no	fair
23	Polyline	76	Jereng roa	lga road	tired road	Bituminous su	single	2	not	0		0.012297	6	0	no	fair
24	Polyline	77	Gassa roa	lga road	tired road	Bituminous su	single	2	not	0		0.01055	6	0	no	fair
25	Polyline	78	Kashim roa	lga road	tired road	Bituminous su	single	2	not	0		0.008726	6	0	no	fair
26	Polyline	79	nill	lga road	tired road	Bituminous su	single	2	not	0		0.007039	6	0	no	fair
27	Polyline	80	nill	lga road	tired road	Bituminous su	single	2	not	0		0.005051	6	0	no	fair
28	Polyline	81	Ngorere ro	lga road	tired road	Bituminous su	single	2	not	0		0.005146	6	0	no	fair
29	Polyline	82	Bangiram r	lga road	tired road	Bituminous su	single	2	not	0		0.006913	6	0	no	fair
30	Polyline	83	Lankaviri ro	lga road	tired road	Bituminous su	single	2	not	0		0.00963	6	0	no	fair
31	Polyline	84	Garba Che	lga road	tired road	Bituminous su	single	2	not	0		0.006682	6	0	no	fair
32	Polyline	85	Hong road	lga road	tired road	Bituminous su	single	2	not	0		0.010891	6	0	no	fair
33	Polyline	86	Pella road	lga road	tired road	surfaca dres	single	2	not	0		0.010036	6	0	no	fair
34	Polyline	87	Billa road	lga road	tired road	surfaca dres	single	2	not	0		0.003442	6	0	no	fair
35	Polyline	88	nill	lga road	tired road	surfaca dres	single	2	dress	0		0.012398	6	1.5	no	fair
36	Polyline	89	nill	lga road	tired road	surfaca dres	single	2	dress	0		0.006462	6	0	no	fair
37	Polyline	94	Tafawa Bal	lga road	tired road	Bituminous su	single	2	dress	0		0.011959	6	1.5	no	fair
49	Polyline	107	Guyuk road	lga road	tired road	Bituminous su	single	2	dress	0		0.015291	0	0	no	fair
63	Polyline	129	Guna road	lga road	tire road	Bituminous su	single	2	dress	0		0.003925	0	1.5	no	bad
64	Polyline	130	Demsa roa	lga road	tired road	Bituminous su	single	2	dress	0		0.002585	0	0	no	fair
65	Polyline	132	Bank road	lga road	tired road	surfaca dres	single	2	dress	0		0.007079	6	0	no	fair

Activate Windows
Go to PC settings to activate Windows.

Source: Author's Analysis

Table 4.4 Attributes of Adamawa Central Roundabout Geodatabase.

Table

roundabout

FID	Shape *	LATITIDE	LONGITUDE	latDD	lonDD	NAME_OF_RO	NAME_OF_LG	R_SUFACING	DATE_CONST	REMARKS	NAI
0	Point	9°12'43.8"	12°28'27.06"	9.212167	12.474183	Maikorya roubdabout	Yola south	surface dressed	<Null>	good	nill
1	Point	9°15'31.68"	12°27'23.22"	9.258778	12.45645	Police roundabout	Jimeta	surface dressed	<Null>	good	nill
2	Point	9°15'56.34"	12°26'49.38"	9.265639	12.44705	Bekaji roundabout	Jimeta	surface dressed	<Null>	good	nill
3	Point	9°16'39.72"	12°25'28.2"	9.277694	12.4245	Mai Doki roundabout	Jimeta	surface dressed	<Null>	good	nill
4	Point	9°16'54.48"	12°25'35.64"	9.281778	12.426567	Janbutu y-junction	Jimeta	Bituminous surfacing	26/05/2013	under construction	CW
5	Point	9°16'55.56"	12°27'56.88"	9.282083	12.4658	Noma da Kiwa roundabout	Jimeta	surface dressed	<Null>	good	nill
6	Point	9°16'44"	12°27'1"	9.278889	12.450278	Mubi roundabout	Jimeta	surface dressed	<Null>	good	nill
7	Point	9°16'31"	12°26'53"	9.275278	12.448056	Hospital roundabout	Jimeta	surface dressed	<Null>	require construction	nill
8	Point	9°16'43"	12°27'15"	9.278611	12.454167	Ibadan roundabout	Jimeta	Bituminous surfacing	26/05/2013	under construction	CW
9	Point	9°49'16.08"	12°37'10.56"	9.821111	12.6196	Song roundabout	Song	surface dressed	<Null>	fair	nill
10	Point	10°9'3"N	12°44'13.08"E	10.144	12.741	Gombi y-junction	Gombi	surface dressed	<Null>	fair	nill
11	Point	10°13'50.1"N	12°55'40.26"E	10.147	12.738	Hong y-junction	Hong	surface dressed	<Null>	require reconstruction	nill

bridges

FID	Shape *	OBJECTID	bridge_nam	bridge_wid	carrage_ca	date_of_re	name_of_co	bridge_sur	type_of_br	lga_name	c_capacity	remark	long
0	Point	0	Yola south	14	14	00:00:00		surface dress	iron bridge	Yola south	dual	require re	
1	Point	0	Babandi bridge	7	7	00:00:00		surface dress	iron bridge	Fufore	single	good	
2	Point	0	Gere bridge	7	7	00:00:00		surface dress	concreate bridg	Fofure	single	good	
3	Point	0	Jimeta bridge	14	14	00:00:00		surface dress	iron bridge	Jimeta	dual	good	
4	Point	0	Geride bridge 1	7	7	00:00:00		surface dress	iron bridge	Gerei	single	good	
5	Point	0	Geride bridge 2	7	7	00:00:00		surface dress	iron bridge	Gerei	single	under con	
6	Point	0	Gerei to song br	7	7	00:00:00		surface dress	iron bridge	Gerei-song	single	good	

Source: Author's Analysis

Tables (4.1, 4.2, 4.3 and 4.4), show some of the database attribute information of road infrastructures with an attribute table; Attribute of each theme interrelates with the themes once the theme is active as shown above in the tables. The results in the table were generated from the ArcGIS database and all the information are linked to the geographic location of the road transport infrastructures and having the same file geodatabase format as supported by Micheal, (2003) and again, all the data are stored and can be managed contrary

in the one file geodatabase (Micheal, 2003), unlike the research of (Rasdorf, 2000) that was designed traditional having different file format and the information is on separate and independed database. The difference of this research work with Vasudeven (2004) as carried out in Missouri State of USA is that, this work was built in ArcGIS and its linked with geographic location of the roads transport infrastructures whereas in the research of Vasudeven (2004) the database was built in Microsoft excel with did not linke to the geographic location of the infrastructures. This is one of the gaps this research filled.

4.3.1 Road characteristics

Analyses of road characteristics (Objective Three Results). Since a comprehensive geodatabase was developed, it becomes easier to make decision as regards managing the road transport infrastructure in map. In this regard, the Query Tools, Identify Tool, Hyperlink Tool, Location Address Tools and Find Tools, were used for the analysis.

4.3.2 Locating of Roads, Roundabout and Bridges Address using Selection Tool

To locate roads, roundabout and bridges, the geodatabase built for the road transport infrastructure in the ArcGIS software was used and the addresses of the infrastructures can found using selection tool of the software as presented in Figures 4.2, 4.3, 4.4.

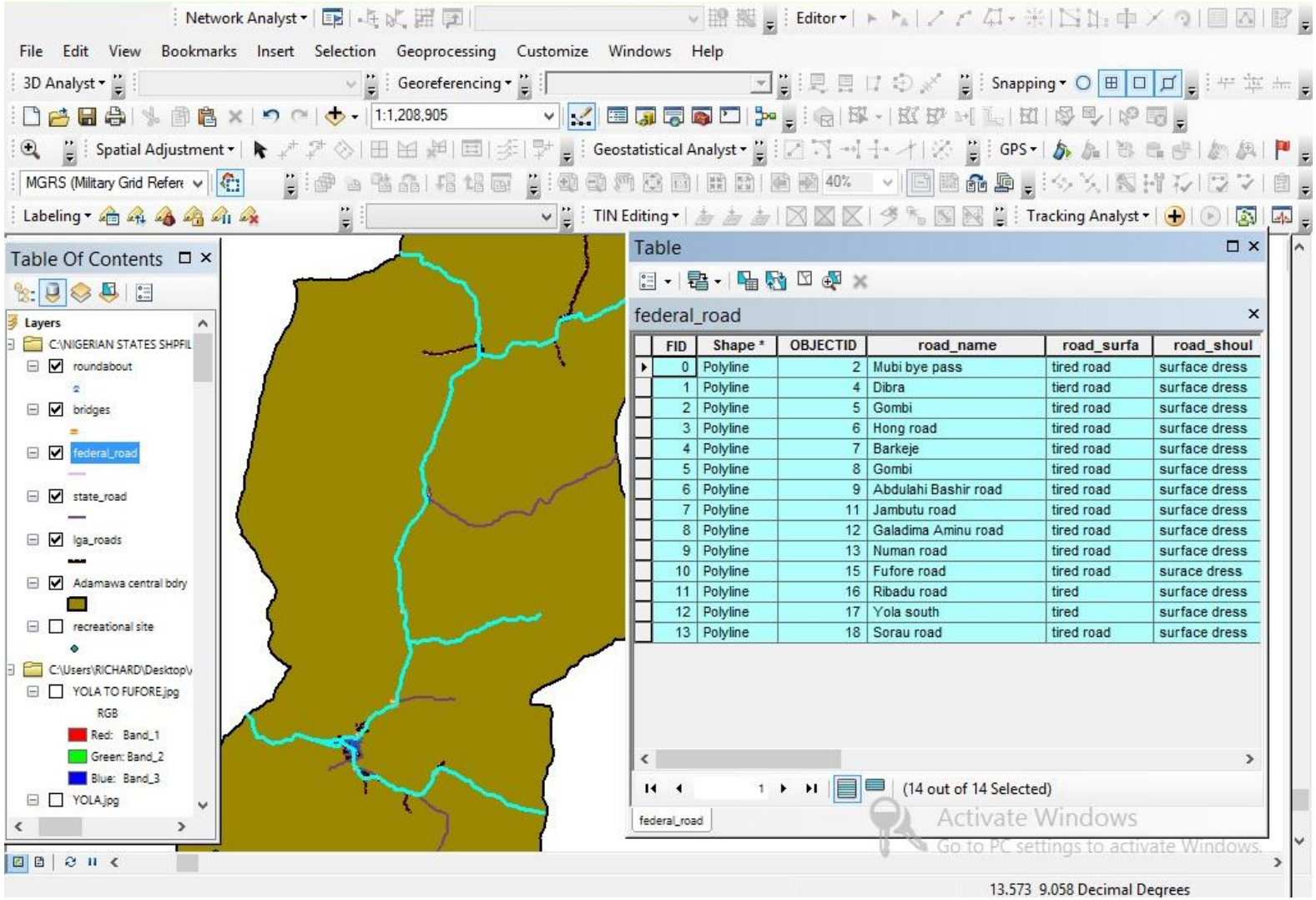


Figure 4.2 All the Federal Roads in Adamawa Central
Source: Author's Analysis

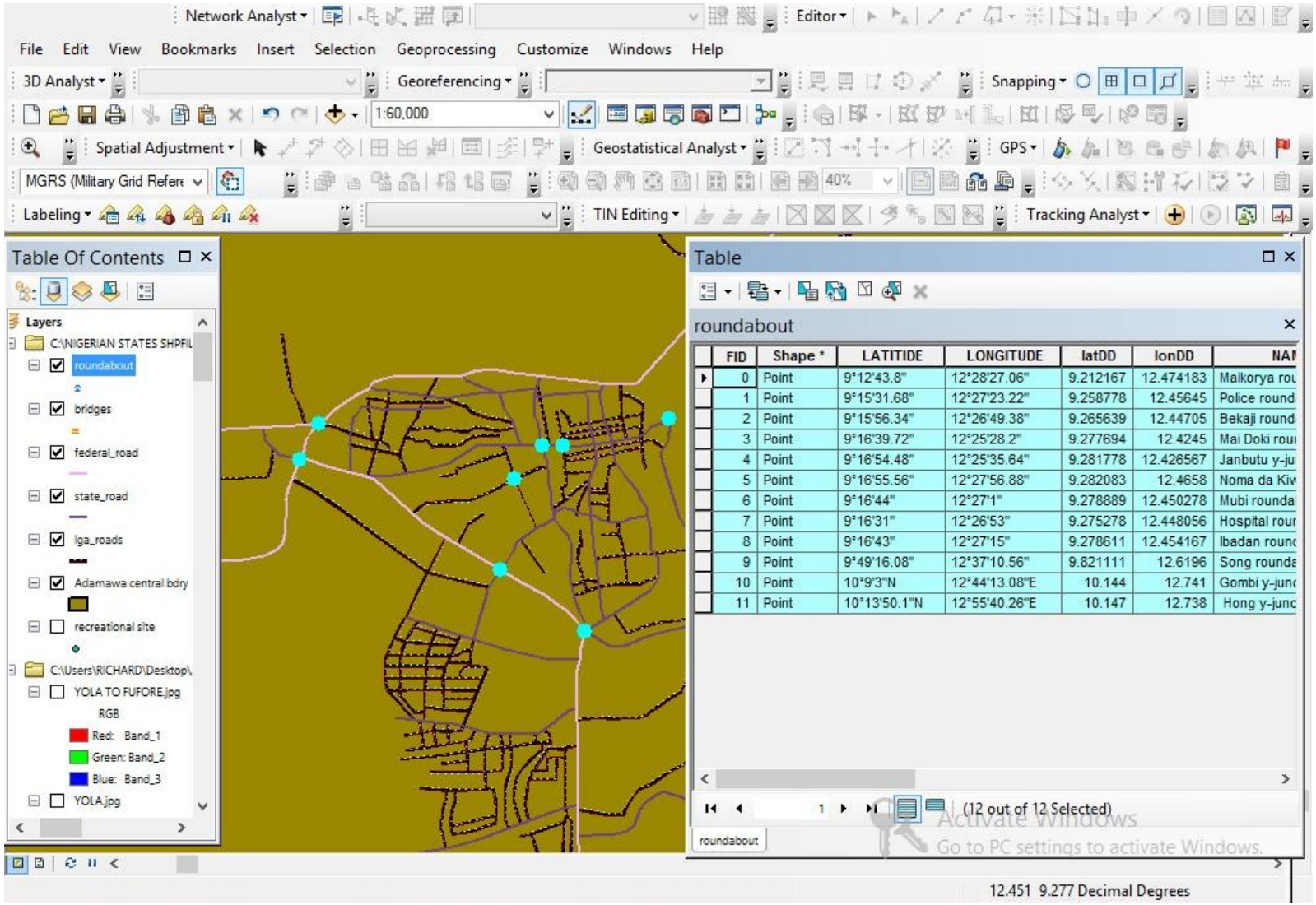


Figure 4.3 All the Roundabouts in Adamawa Central
Source: Author's Analysis

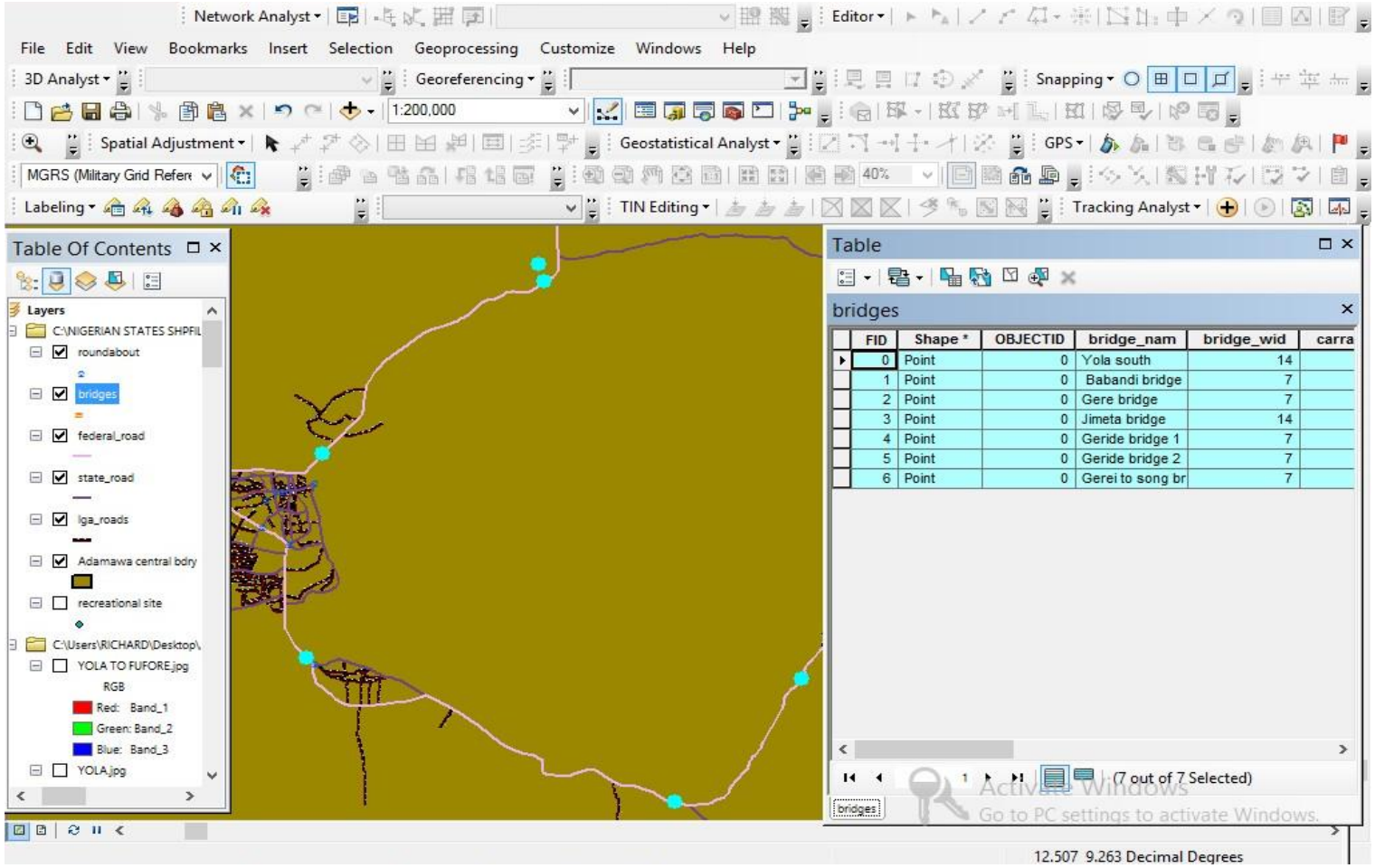


Figure 4.4 The Federal Roads in Adamawa central.
Source: Author's Analysis

As shown in Figure 4.2, the selection tool was used in order so select any road of interest on the map, the selected roads are show with beryl green colour line feature on the map. The beryl green colour showed the locations and attributes of the federal roads in Adamawa central. Same processes can be used for the state and local government roads in order to know the extent of roads for developments. The federal roads covered 7.94% of the total roads in the area, state road was 22.27% while the LGA roads constituted the highest proportion of (77.73%). In figure 4.3, the dot spot beryl green colour points on map in the figure automatically found the location and attribute of the roundabouts in the Adamawa central and it showed that there was only twelve roundabouts in the area with Song and Yola south having one and Yola north having ten. Yola north was having largest number of roundabouts. Figure 4.4, the dot spot beryl green colour point on map in the figure automatically found the spatial locations and attributes of the bridges in the area. On the bases of the select, the analysis revealed that there were seven bridge in the study area with one located in Yola north, Song, Fufore and two in Yerei and Yola south. These analysis was based on object-based data model and field based data model. The object-based data model treats geographic space populated by discrete and identifiable object and the field-based data model treats geographic space by real world features as supported by Lo and Yeung (2002). This, unlike the research of Vasudeven (2004) which based was mainly on the object-based data model.

4.4.2 The Physical Nature of the Road, Bridge and Roundabout on the Map using Hyperlink Tool.

To coordinates and pictures of the road, bridge and junction collected from the field was used. The coordinates use for locational base to hyperlink the pictures captured on the field. Some of the physical nature of the roads, bridges and roundabouts are presented in figure 4.5, 4.6, 4.7, 4.8, 4.9 and 4.10, and 4.11, 4.12 and 4.13.

The physical nature of the road, bridge and junction on the map using hyperlink tool. By making the building themes active, the HYPERLINK TOOL was used, the selected road in white pops out an image of the structure of the road above by clicking it out. The analysis was carried out to show physical nature of the road for decision making in terms of maintenance and to see whether the road is due for reconstruction. There is no need of physical site visitation thought there is need for updates. Every detail was shown on the screen of the computer reference to spatial reference figure 4.5, 4.6 and 4.7, supported by ElBehairy and Hegazy (2004) that a Decision Support System for Transportation Management systems are used "to prioritize bridges, allocate funds, and select appropriate repair strategies so that a network of bridges is kept serviceable and safe with low cost.. Hyperlink tool is used for the analysis, the selected bridge in beryl colour pops out an image showing the pictorial representation of the structure of the bridge above by clicking it out. And the attribute table indicate by beryl colour shows the details of the bridge in respect to the spatial reference as showed in figure 4.8 and 4.9 above while figure 4.10 shown that the bridge was still under constructions. Hyperlink tool was also used in performing these analysis and beryl green colour also shown the point at which the picture is represented as showed in figures 4.11, 4.12 and 4.13.

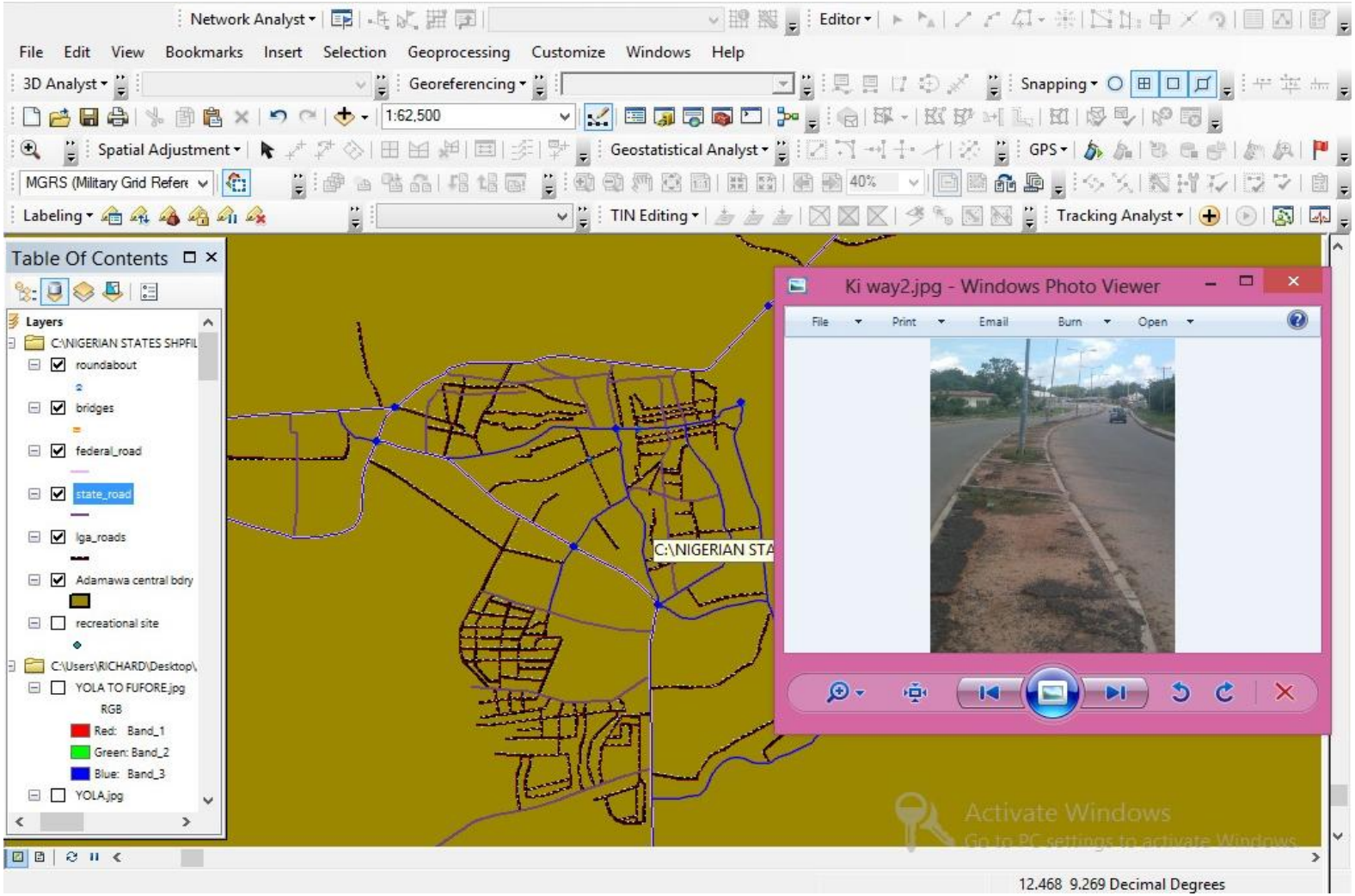


Figure 4.5 The Physical Structure of a Kashim Ibrahim road Yola South.
Source: Author's Analysis

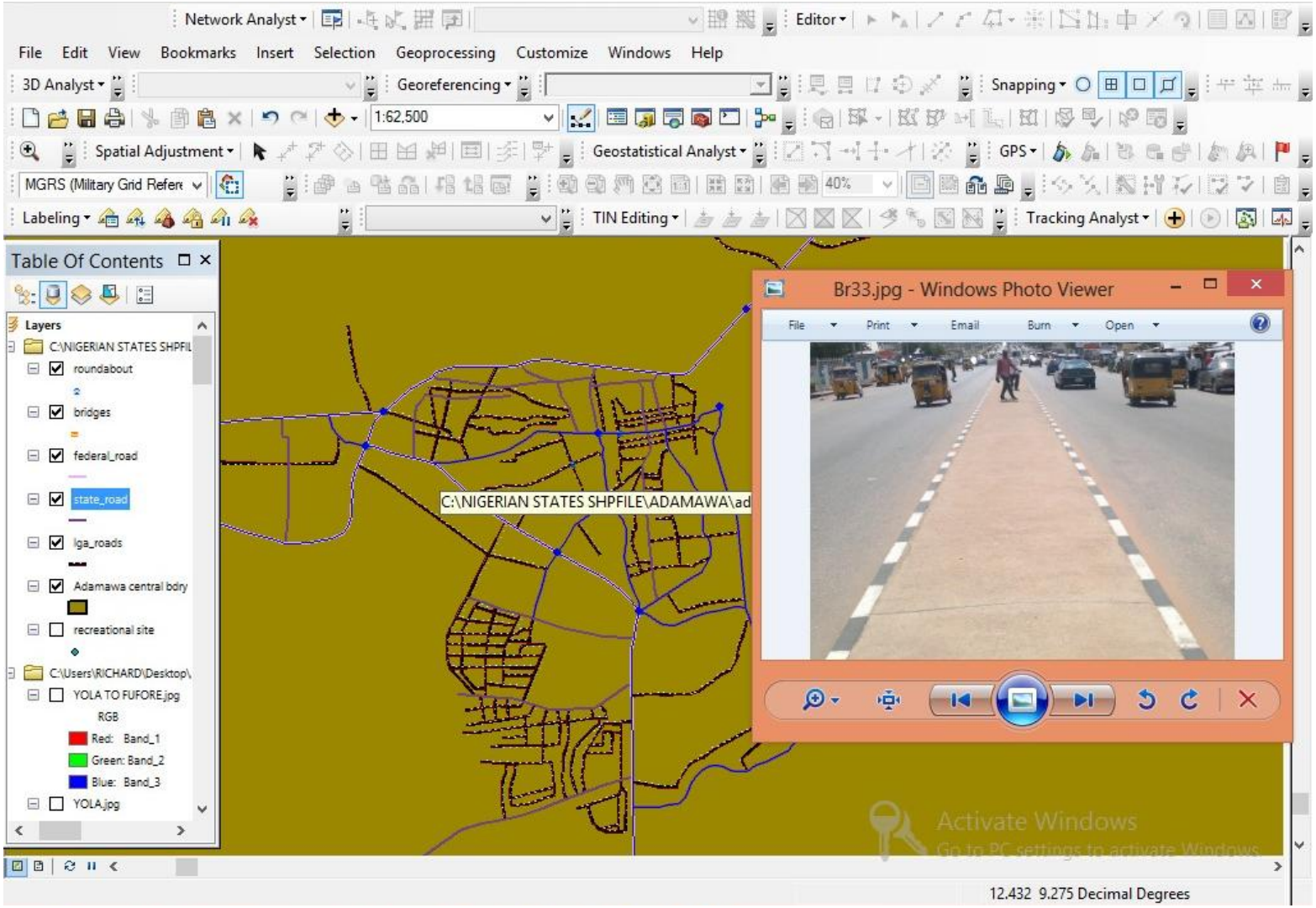


Figure 4.6 The Physical Structure of a Galadima Aminu Road in Yola South LGA.
Source: Author's Analysis

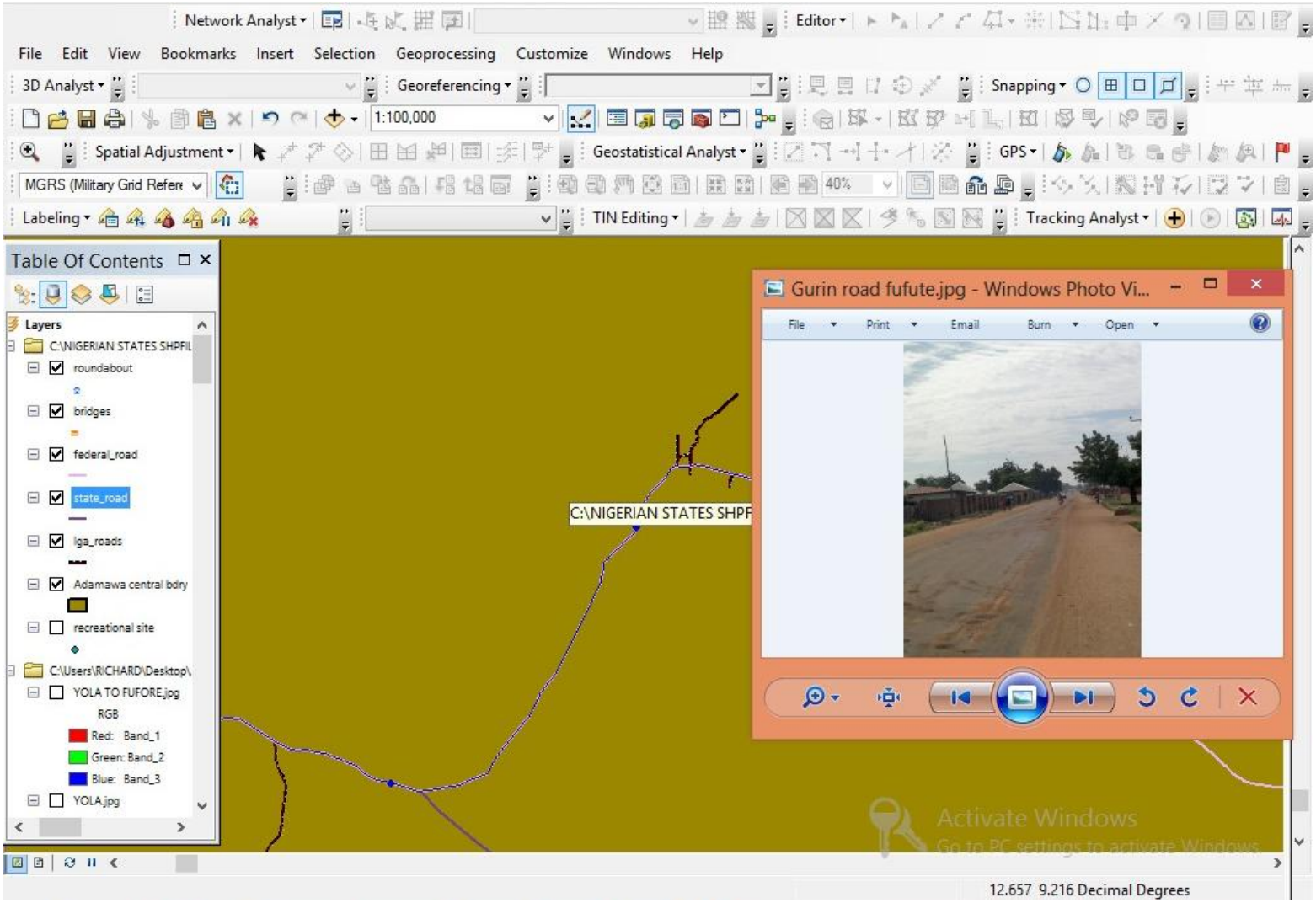


Figure 4.7 The Physical Structure of a Gurin Road in Fufore LGA.
Source: Author's Analysis

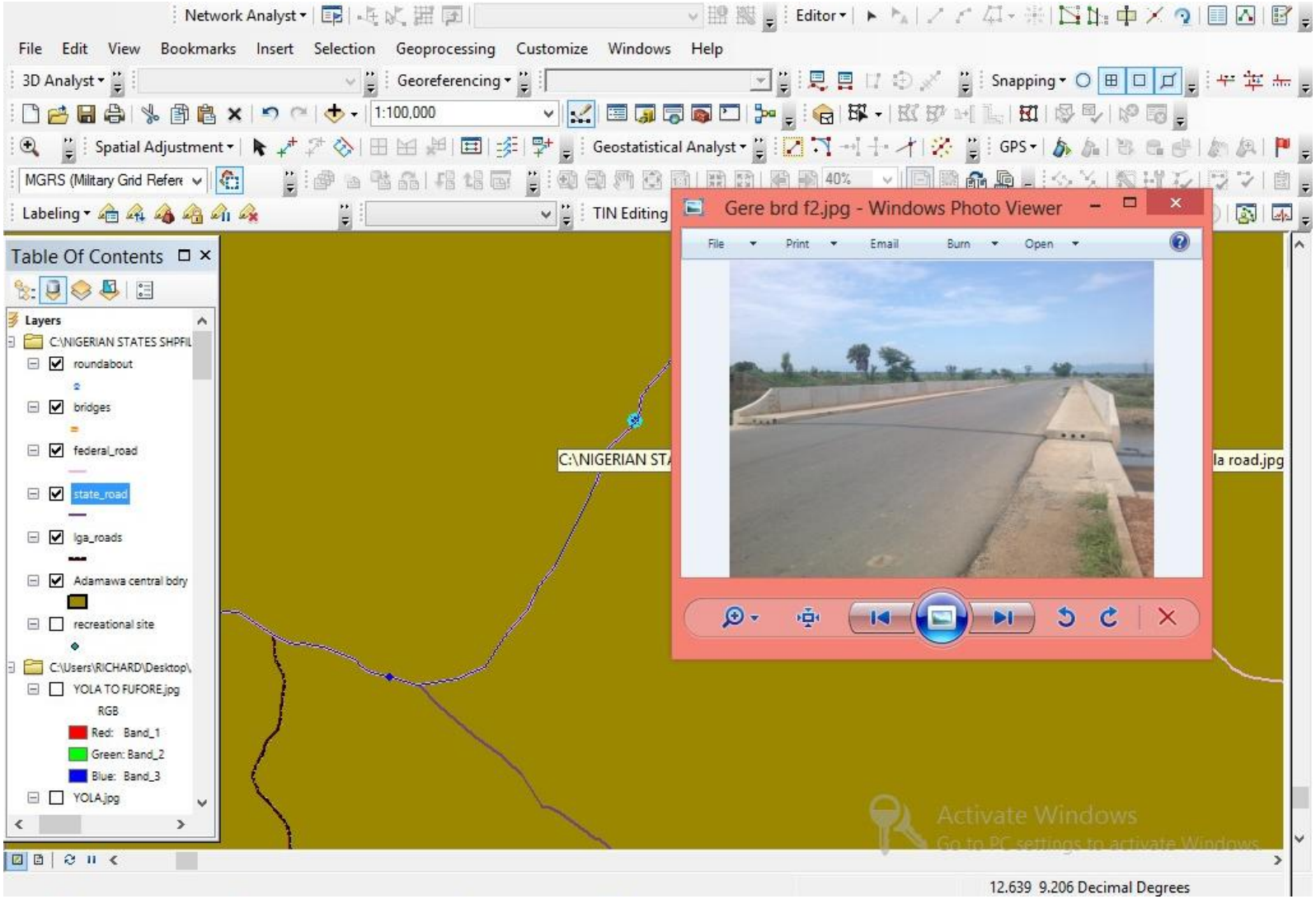


Figure 4.8 The Physical Structure of a Gere Bridge in Fufore LGA.
Source: Author's Analysis

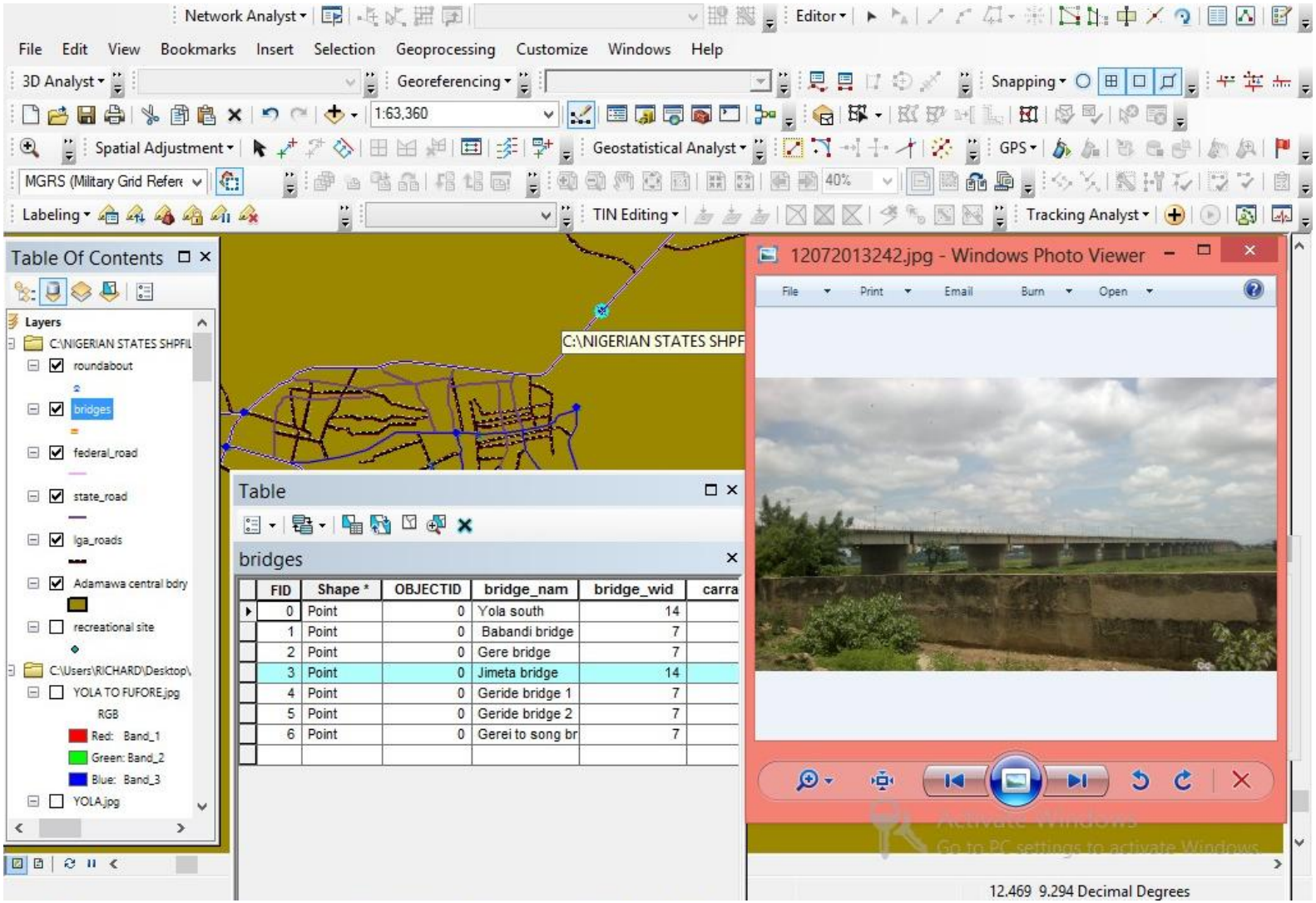


Figure 4.9 The Physical Structure of a Jimeta Bridge, Yola North LGA.
Source: Author's Analysis

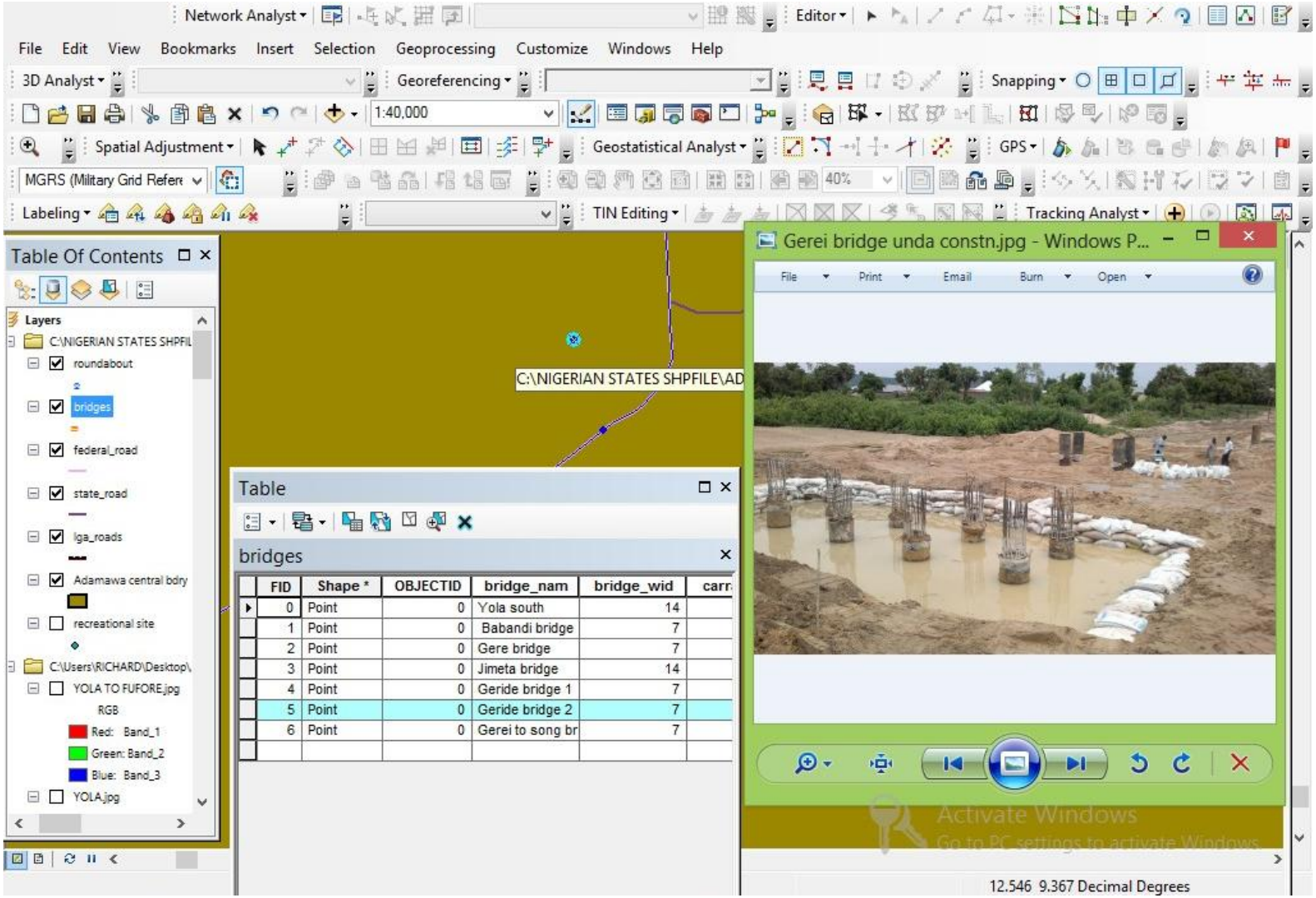


Figure 4.10 The Physical Structure of a Geride Bridge, Gerei North LGA.
Source: Author's Analysis

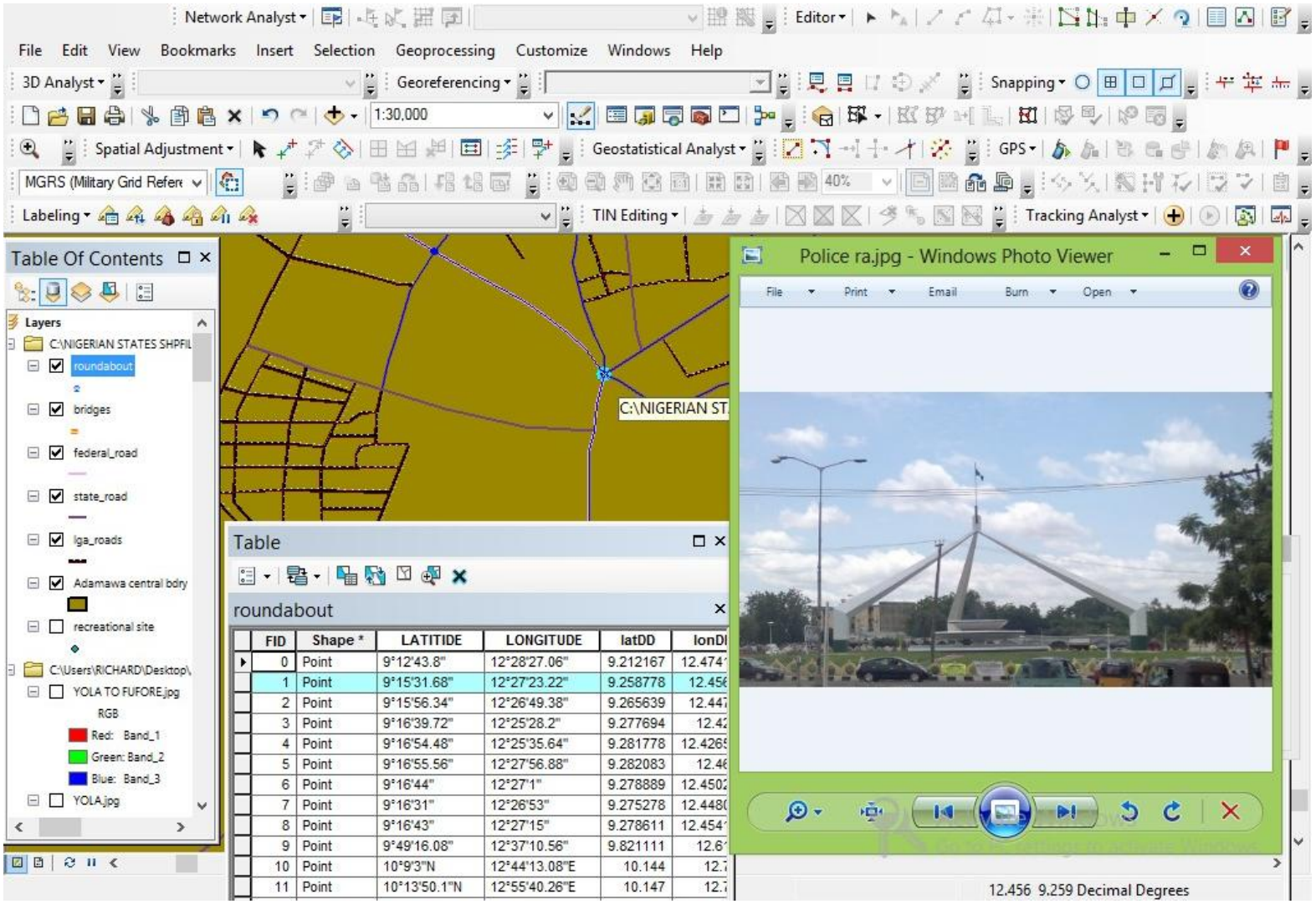
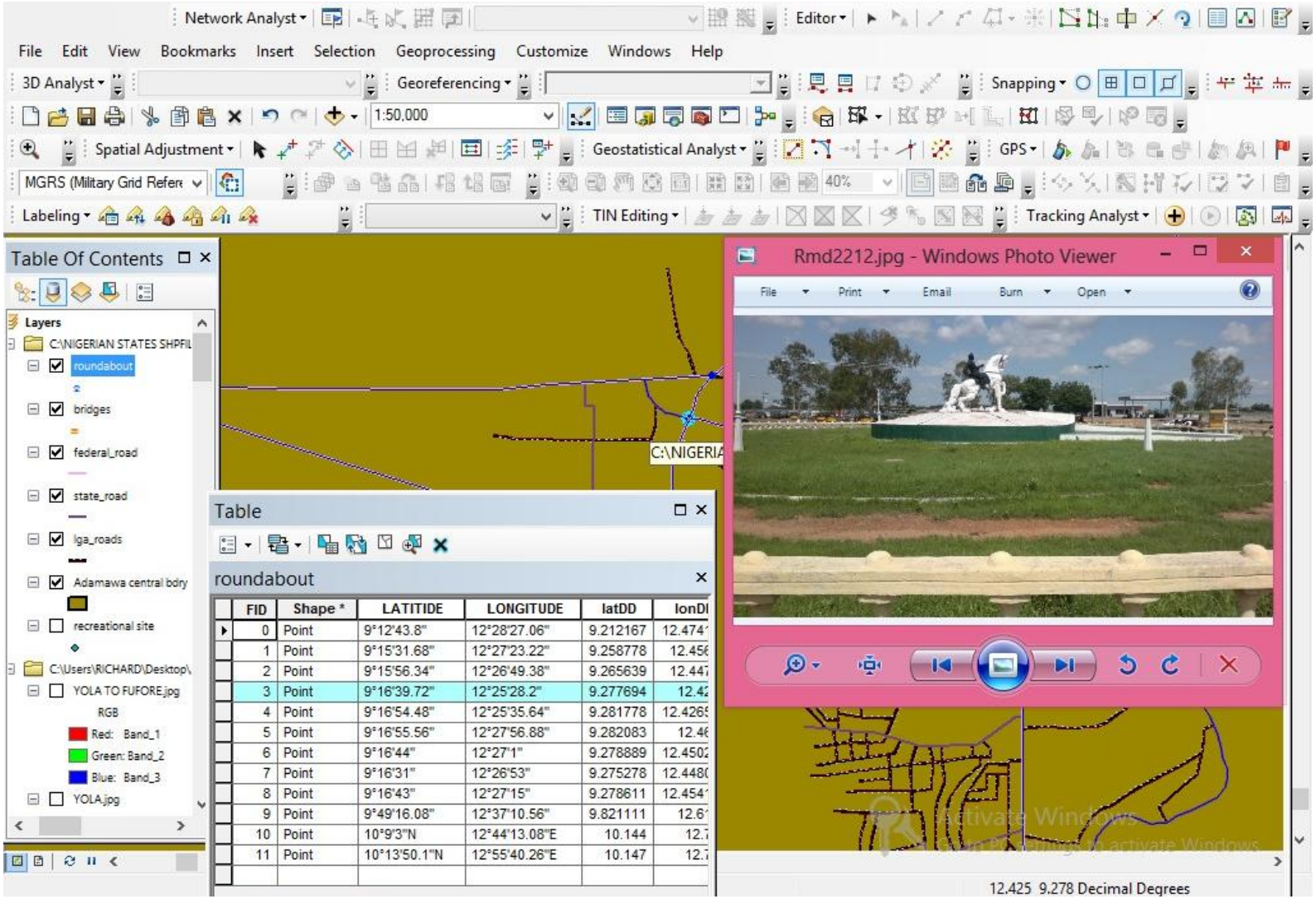


Figure 4.11 The Physical Structure of a Police Roundabout, Yola North LGA.
Source: Author's Analysis



FID	Shape *	LATITIDE	LONGITUDE	latDD	lonDI
0	Point	9°12'43.8"	12°28'27.06"	9.212167	12.474
1	Point	9°15'31.68"	12°27'23.22"	9.258778	12.456
2	Point	9°15'56.34"	12°26'49.38"	9.265639	12.447
3	Point	9°16'39.72"	12°25'28.2"	9.277694	12.42
4	Point	9°16'54.48"	12°25'35.64"	9.281778	12.426
5	Point	9°16'55.56"	12°27'56.88"	9.282083	12.46
6	Point	9°16'44"	12°27'1"	9.278889	12.450
7	Point	9°16'31"	12°26'53"	9.275278	12.448
8	Point	9°16'43"	12°27'15"	9.278611	12.454
9	Point	9°49'16.08"	12°37'10.56"	9.821111	12.6
10	Point	10°9'3"N	12°44'13.08"E	10.144	12.7
11	Point	10°13'50.1"N	12°55'40.26"E	10.147	12.7

Figure 4.12 The Physical Structure of a Maidoki Roundabout, Yola North LGA.
Source: Author's Analysis

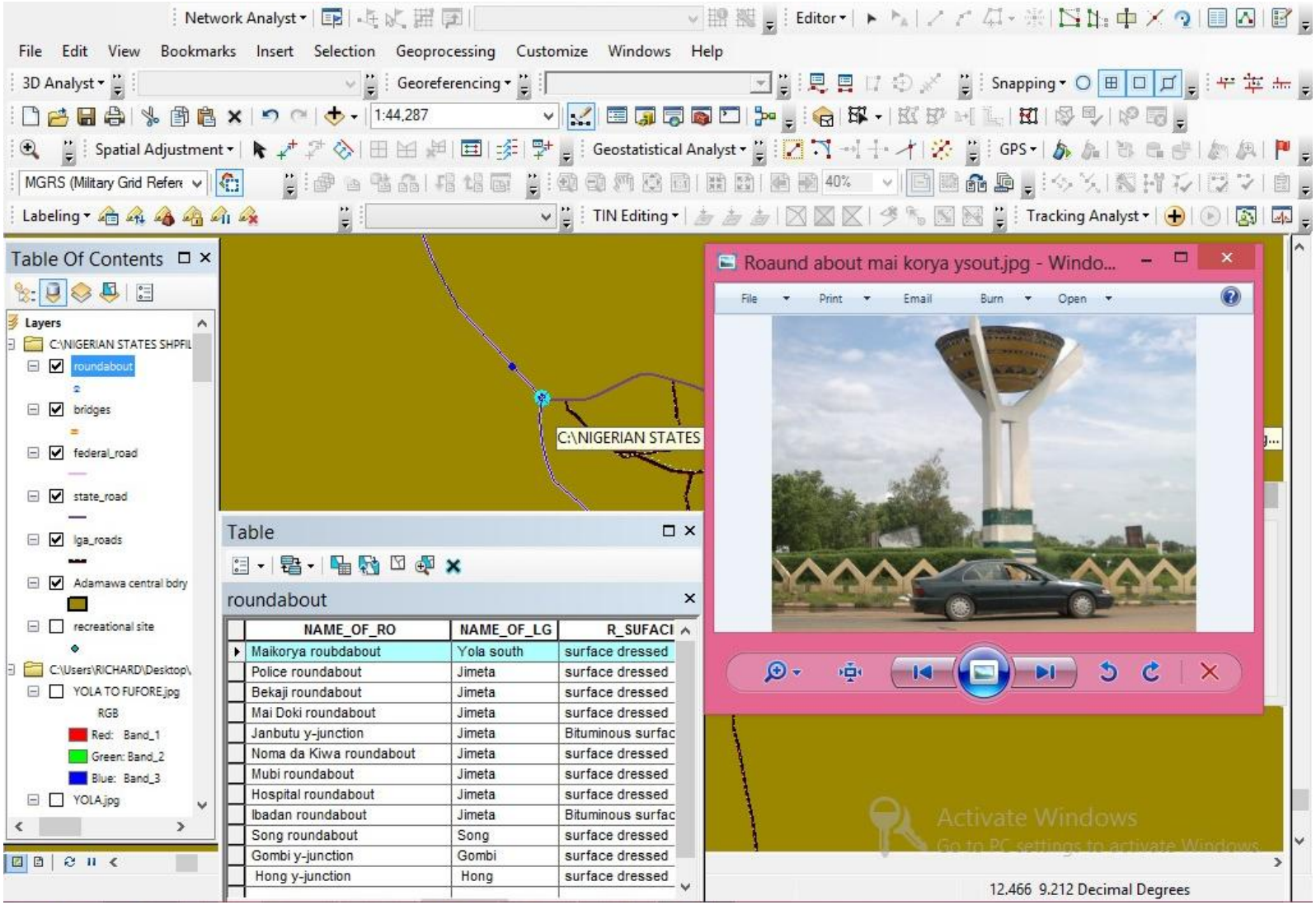


Figure 4.13 The Physical Structure of a Maikorya roundabout, Yola South LGA.
Source: Author's Analysis

4.4.3 Selecting Roads that are Single or Dual Carriage

To select the roads that has single or dual carriage, the inventory of the attribute tables in the geodatabase that was created for the road transport infrastructures was query using the selection tools as presented in figure 4.14. The selection was made using query language such as select where federal road is equal to single or dual carriage and the beryl green colour line on the map and geodatabase table in figure 4.14 showing the federal roads that has single carriage capacity. The result showned that nine of the road are dual carriage whereas five of the roads are single carriage. The dual carriages are the once that linked the local government headquarters whereas the single carriage roads was found mostly in the state capital (Yola north). This query can help the road transport authorities, managers and decisions maker in terms of development in order to expand the road to dual carriage and the geodatabase table will help in showing the information and the number of federal roads that need to be expanded. The same analysis can be applicable to state and federal roads transports as the case may be, supported by (Thill, 2000).

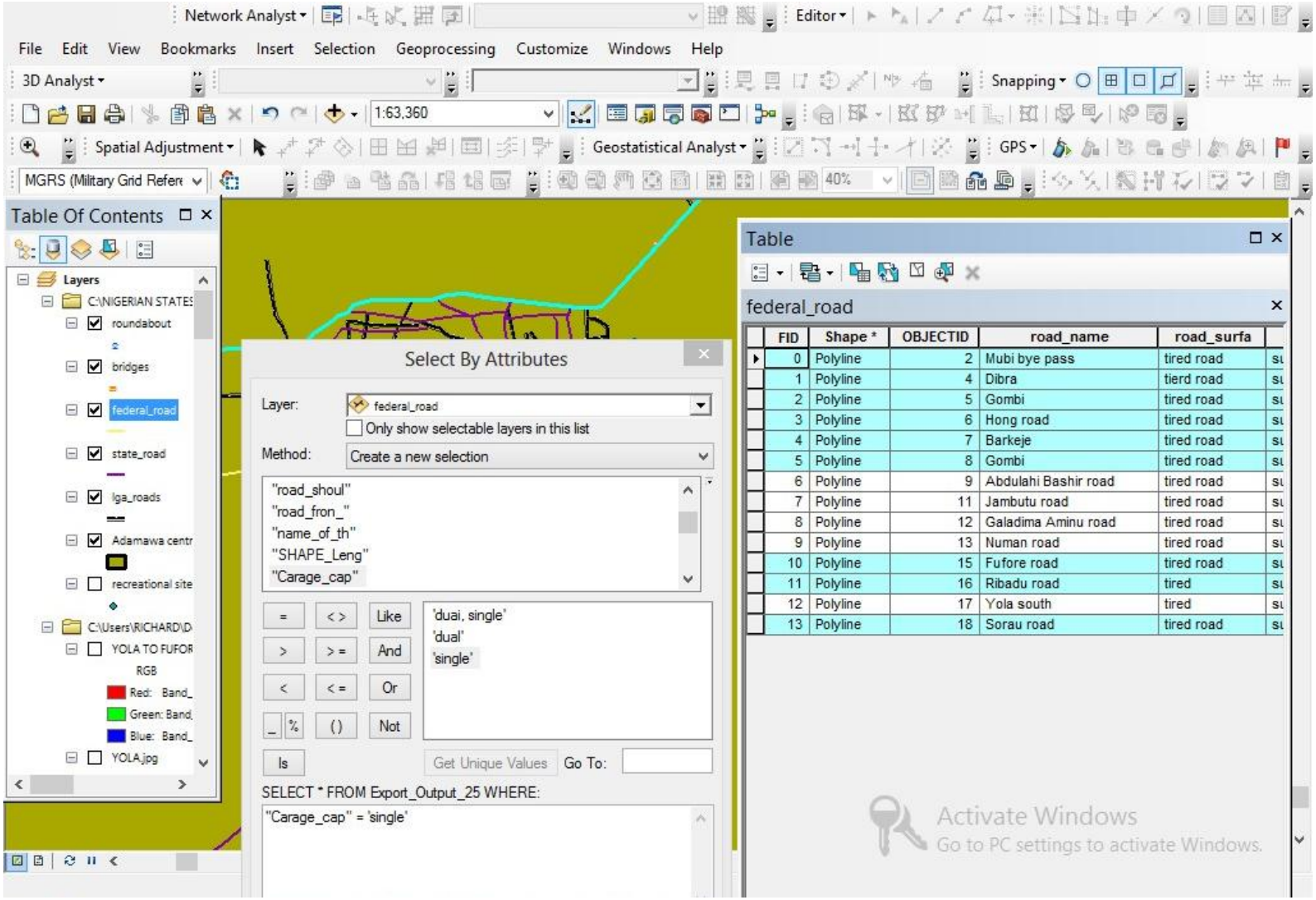


Figure 4.14 the Federal Roads that are Single and Dual Carriage Capacity.
Source: Author's analysis

4.4.4 The Road Surfaces that are Untarred.

To select the roads that are not tired, the inventory of the attribute tables in the geodatabase that have been created for the road transport infrastructures will be query by using the selection tools as presented in figure 4.15.

The selection by attribute were made using query language such as select where road surface is equal to tarred and by using the query tool, the road surfaces that are untarred highlighted beryl green colour on the map and on the geodatabase table, while those that are tired are black and ultramarine colour on map and white colour on the geodatabase table. The analysis showned that, 78% of the local government roads are untarred while only 22% of the roads are tarred, also, all the federal and state road are tarred road. This analysis was carried out to provide necessary information on road surfaces that are untarred before allocating a contracts and for proper road transport information managements as supported by (Thill, 2000).

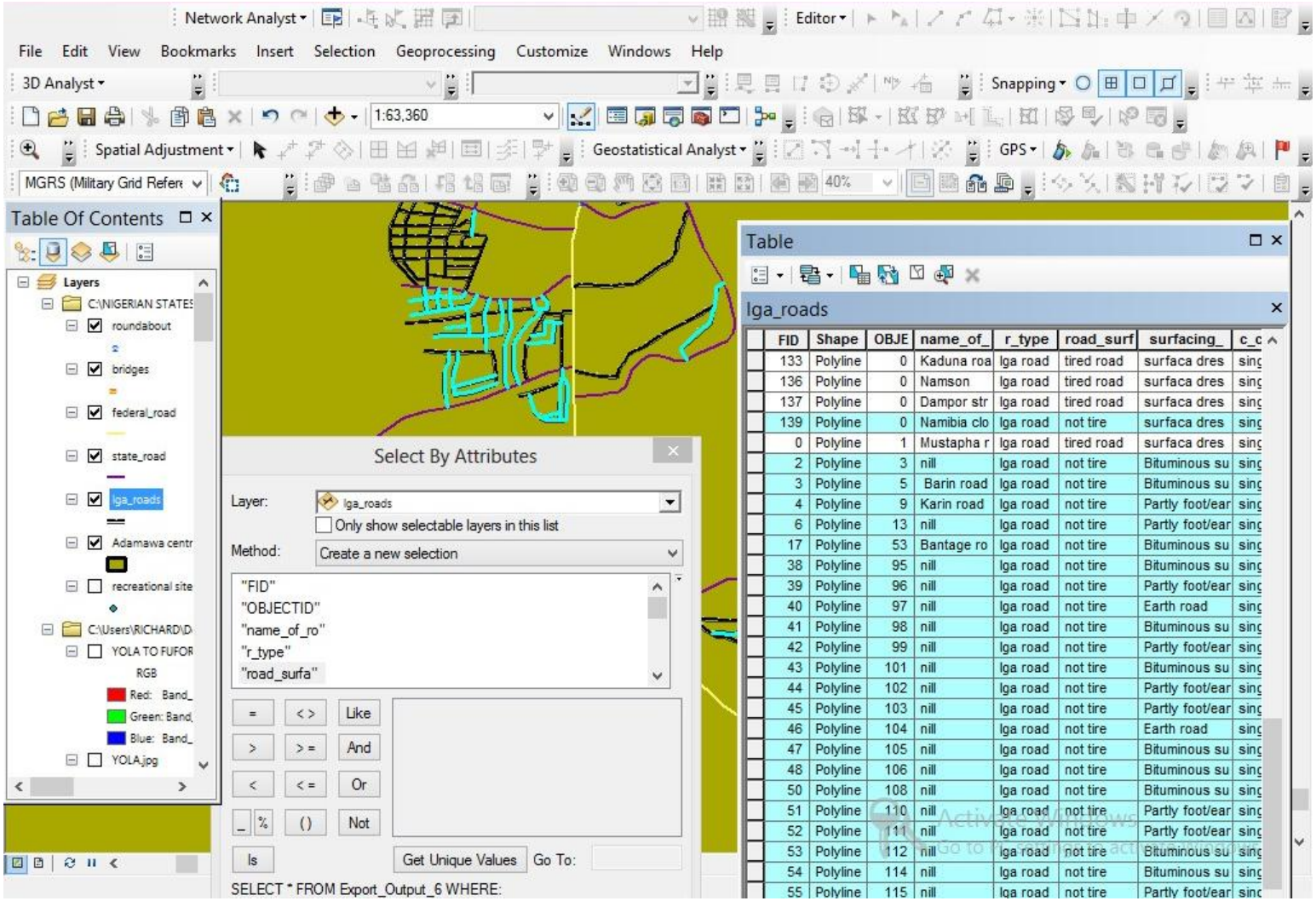


Figure 4.15 The Roads Surface that are Untarred.
Source: Author's Analysis

4.4.5 Roads that is 150m from a Roundabout using Buffering

In order find roads that is 150m from a roundabout, the location of the roundabout was geographically referenced to the coordinate collected from the field, and way point method was carried out to superimpose the coordinate on the map. It is all the roads that are directly linked to the roundabout. The result finding the roads that is 150m from a roundabout on the map is presented in figure 4.16.

By using the BUFFER TOOL, the roundabout that was highlighted red was the one selected for the analysis. The analysis was carried out to show how powerful GIS is in selecting features that are within a specific range for any decision pertaining road infrastructure development and management. This analysis was carried out to provide necessary information on the nearest roads and building around the roundabout within a distance of 150m which will help road transport planner with management information to know the various houses that will be affected within the 150 radius when allocating a contracts on expanding the roundabout for proper development and management and supporting decisions about planning as supported by Karlaftis *et al*, (2004).

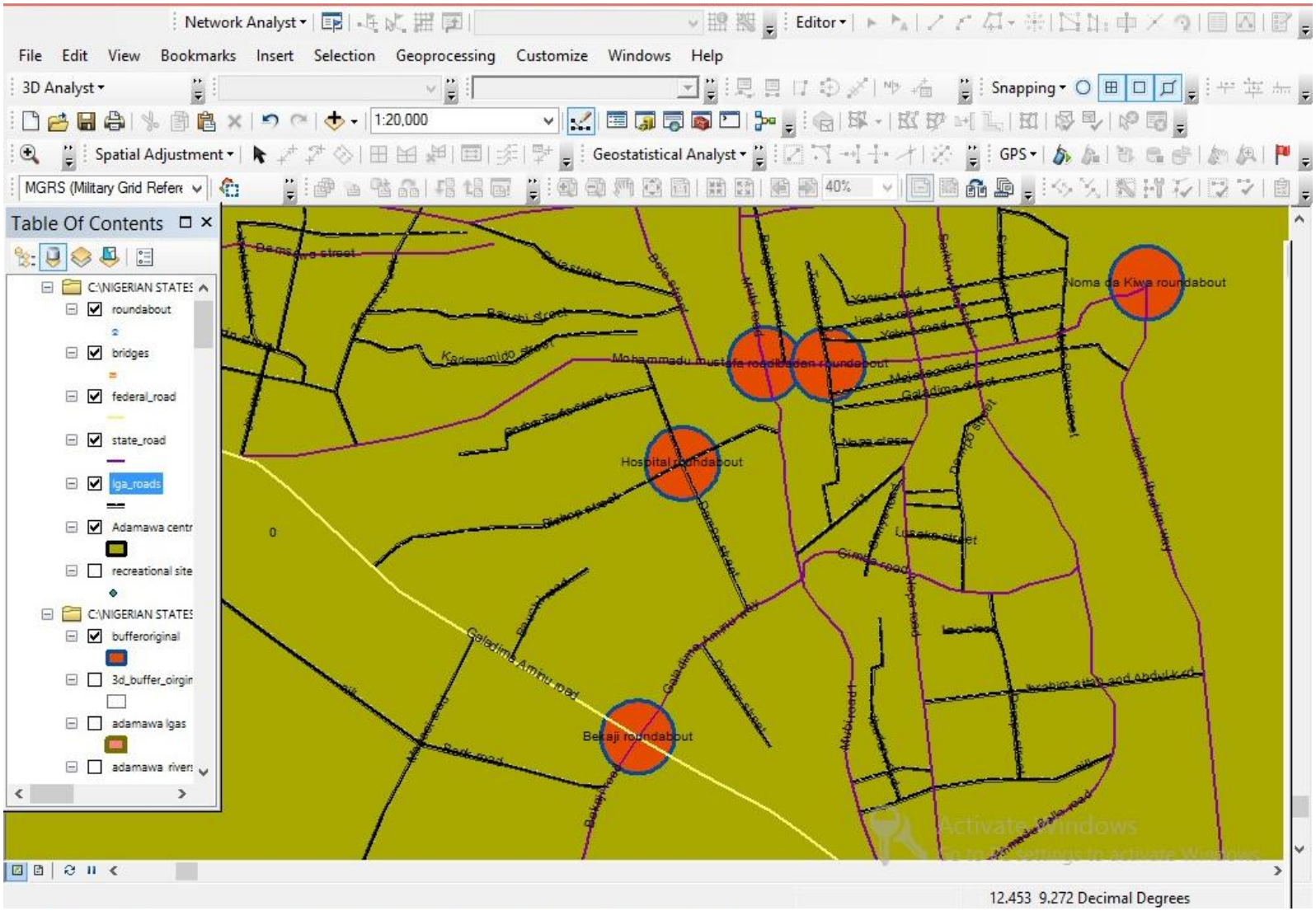


Figure 4.16 The area that fall within a Radius of 150m around Roundabout.
Source: Author's Analysis

4.4.6 Identifying Information on a particular Road, Bridge and Junctions using Identify Tool.

To identify information on a particular road, bridge and junctions, the road transport infrastructures used as sources of inventory for the geodatabase creation and uptodate digital map of the study area were used. The results of the road, bridge and junctions information is represented in figure 4.17.

As showm on figure 4.17, IDENTIFY TOOL was used in order to identify information's on Mubi road and the beryl green line on the map is the Mubi road while the geodatabase table beside it was the information about the road. The analysis gave information on how to manage and develop the road. The same analysis can be applicable to bridges and roundabouts. The result gave a uniform collection of information on the road that were stored and can be manage, as supported by (Michael, 2003)

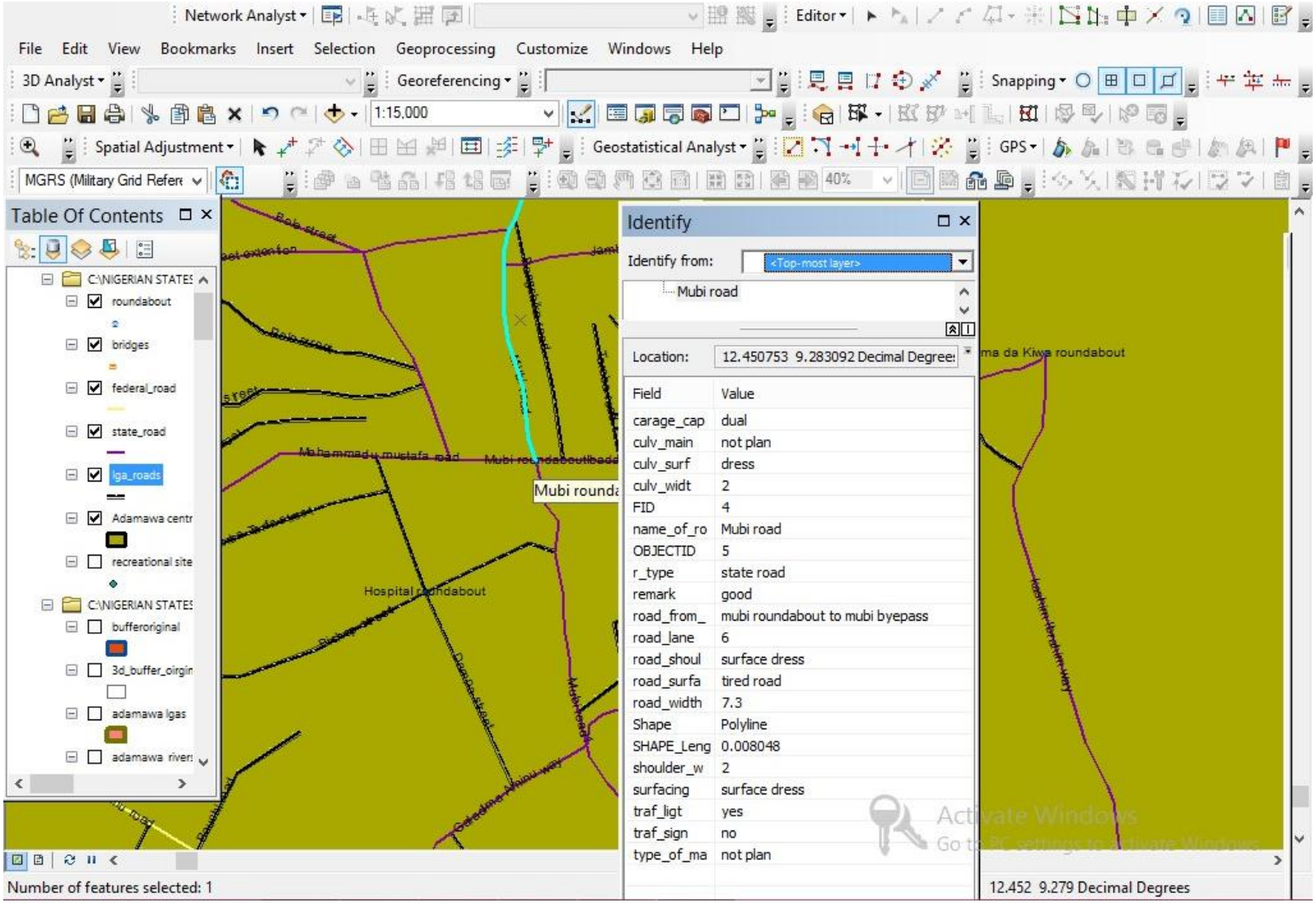


Figure 4.17 Information about a particular Road (Mubi road).
Source: Author's Analysis

4.4.7. Measurement of Road Distances

To Measure the road distances, the updated digital road transport map of the study area generated from the sport image of 2012 and Google image were used. The result is presented in figure 4.18 using the measurement tool.

From the figure 4.18, measurement tool was to measure the Bishop road and this analysis showned the distance of the road which was about 1,795.200743 meters. This give measurement information on the road without going to the field for surveying in terms of development and allocation of found for the road infrastructure management when developing the road. The result show that, distance measurement are also attributed to each link and node as supported by Haggest and Chorley (1969).

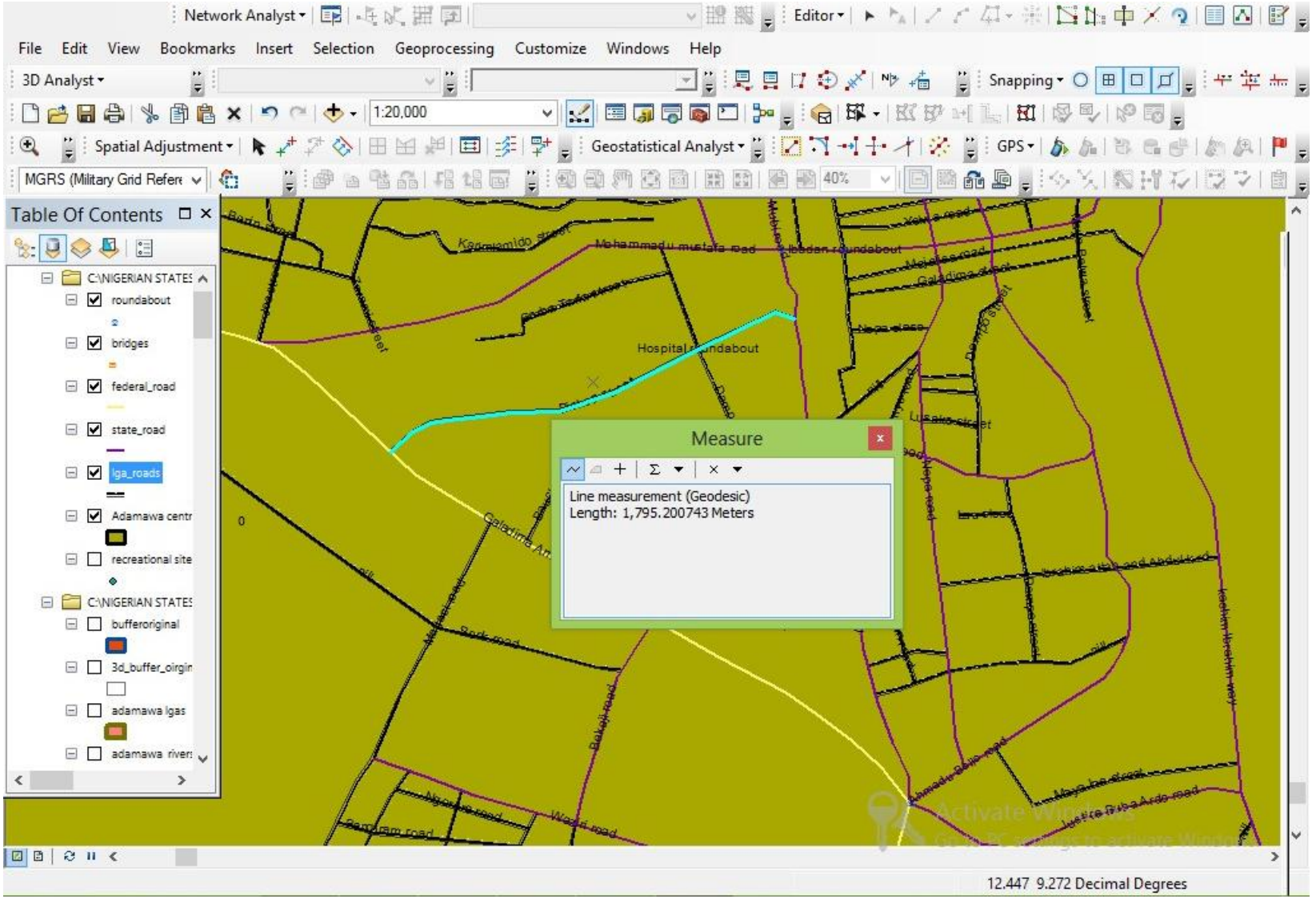


Figure 4.18 The length of a Bishop Road.
Source: Author's Analysis

4.4. 8 Finding the Roads Surface Types

In finding the road surface type, the map view and geodatabase of road transport infrastructures was used and the result is presented in figure 4.19 and 4.20. In the figures above, the beryl green line on figures 4.19 on the map shows the roads that has earth surface while the figures 4.20 showned the roads with bituminous surfacing and the geodatabase table showned the attributes of the place name. The result showned that certain classes of attributes present in the geodatabase was created by map view, as supported by Goodchild (1998). This result will help the road managers of the roads infrastructure when developing the to enable them knowing the numbers of the with such surfaces for proper decision makings for the road transport information managements. The uptodate digital road transport infrastructures map generated from the study area was used to characterise the results in form of road transport map. The result are representing in figure 4.21, figure 4.22, figure 4.23 and figure 4.24.

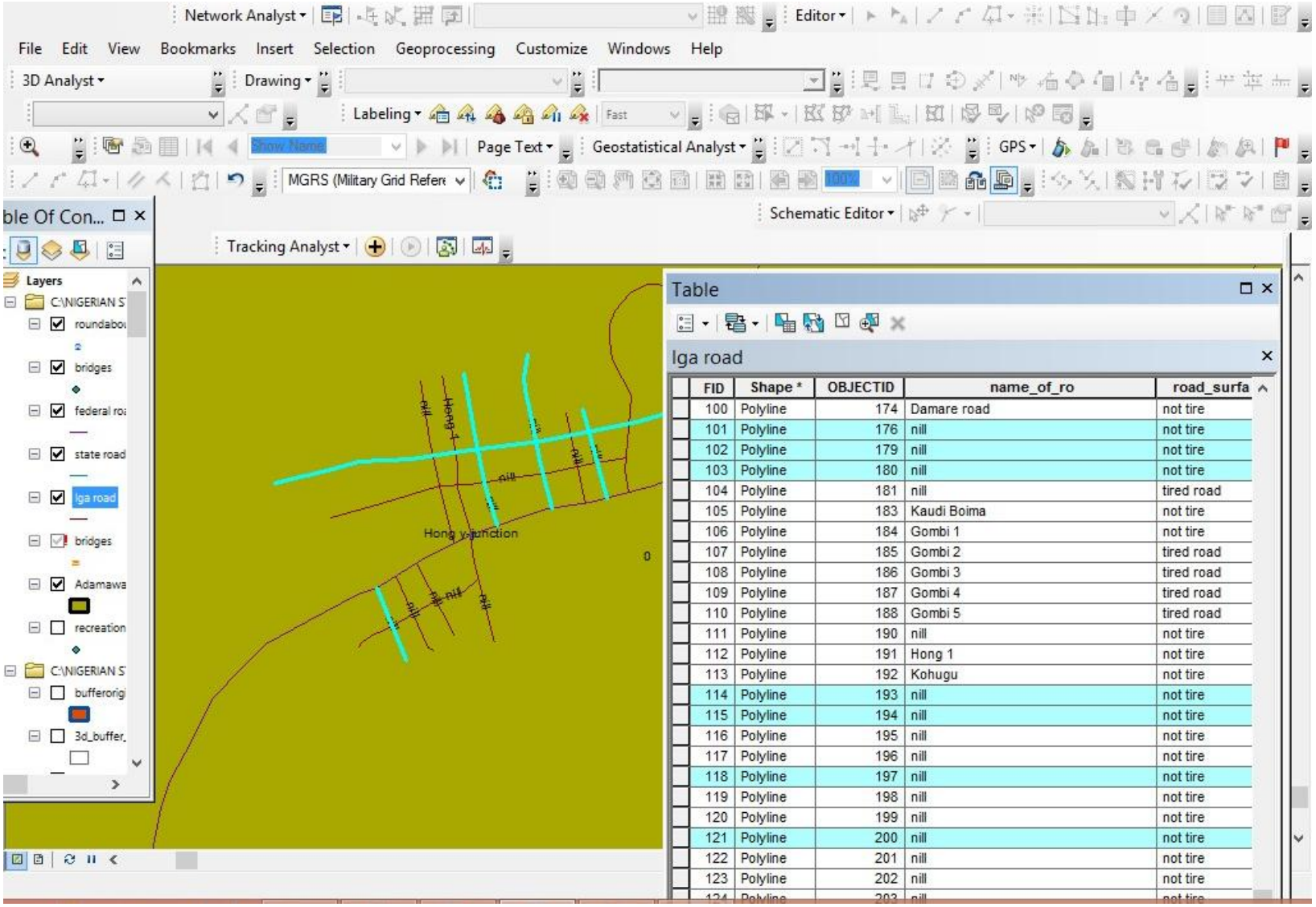


Figure 4.19 The Roads with Earth surfaces.
Source: Author's Analysis

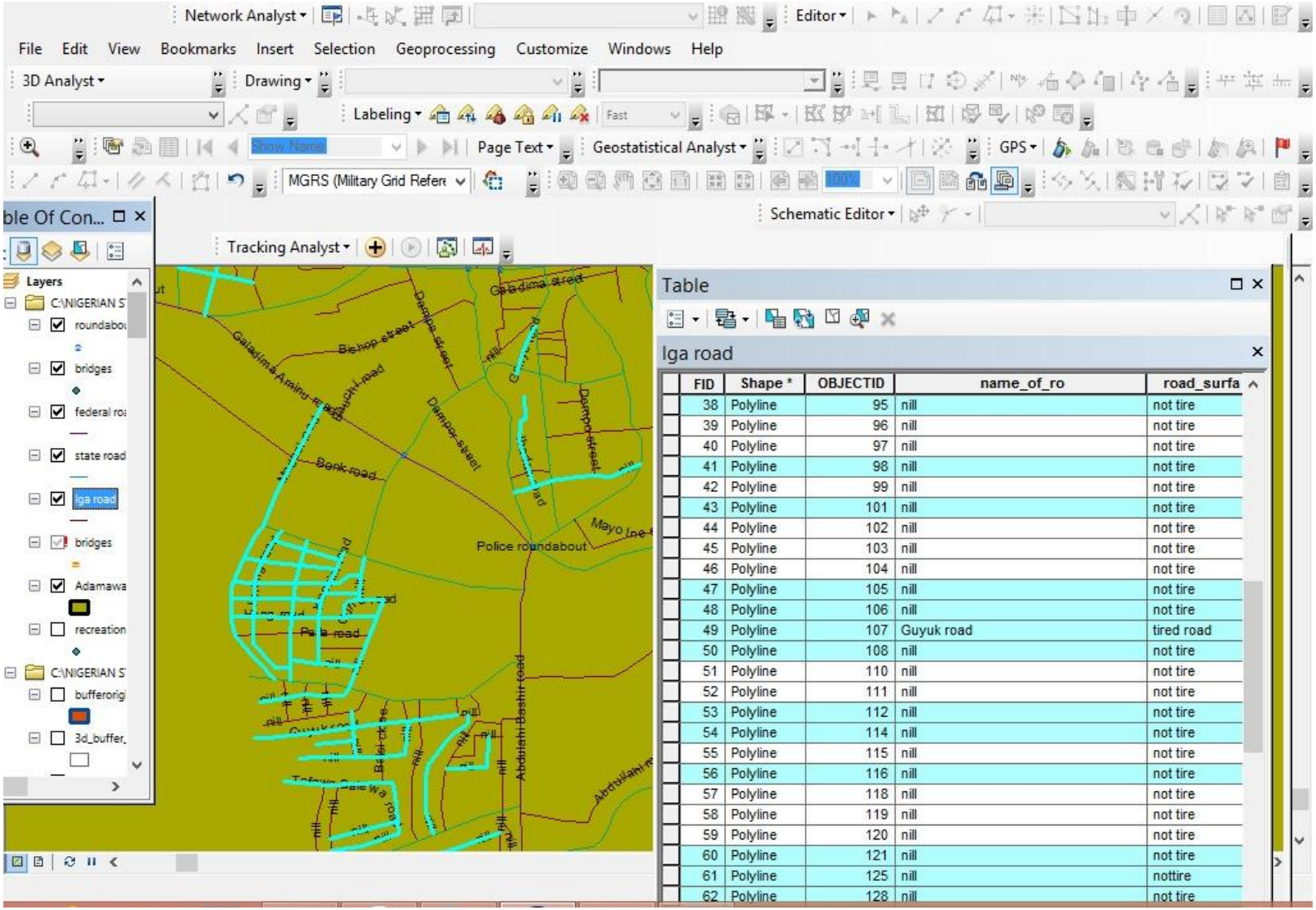


Figure 4.20 The Roads with Bituminous Surfaces.
Source: Author's Analysis

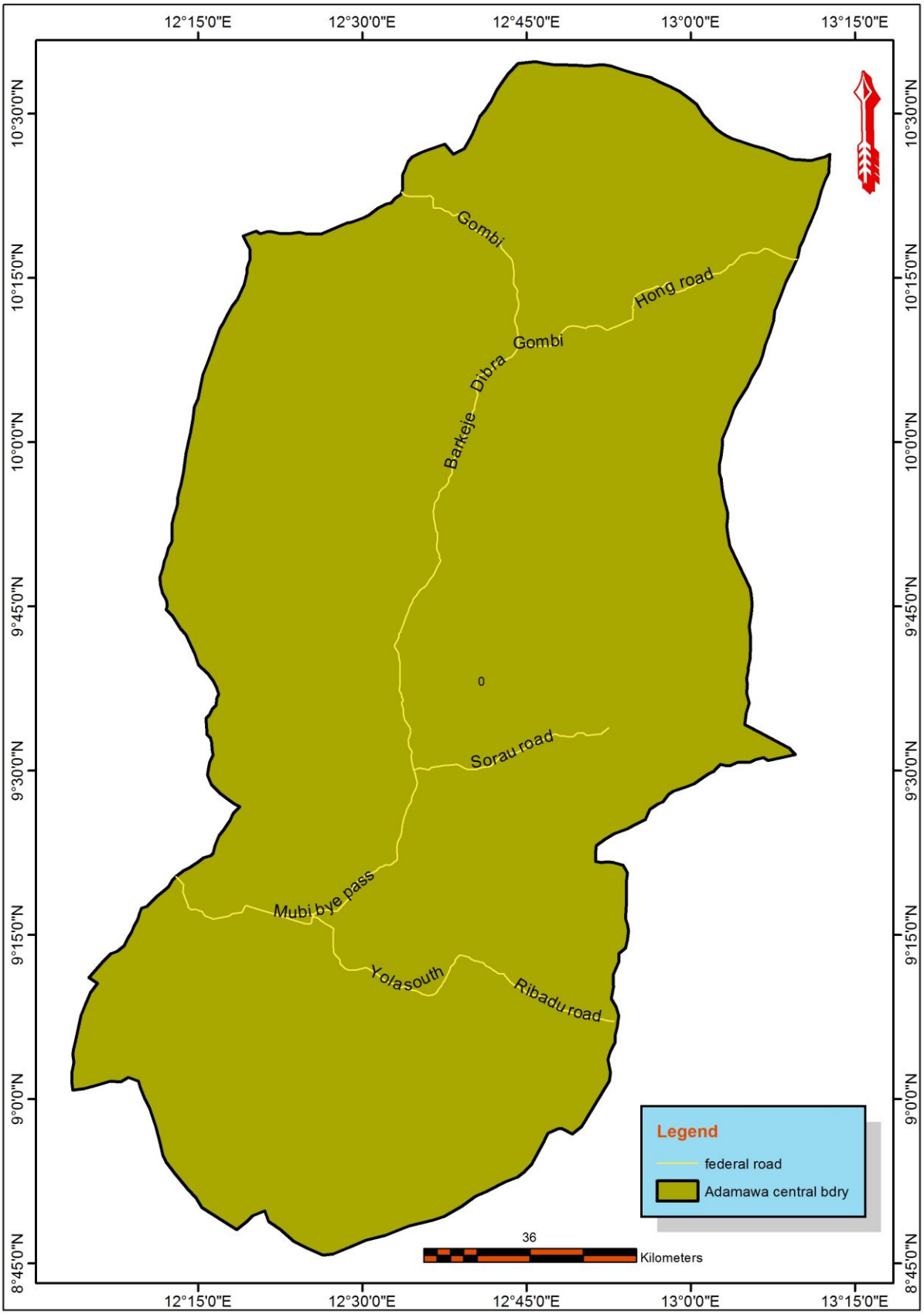


Figure 4.21 The Federal Roads
Source: Author's Analysis

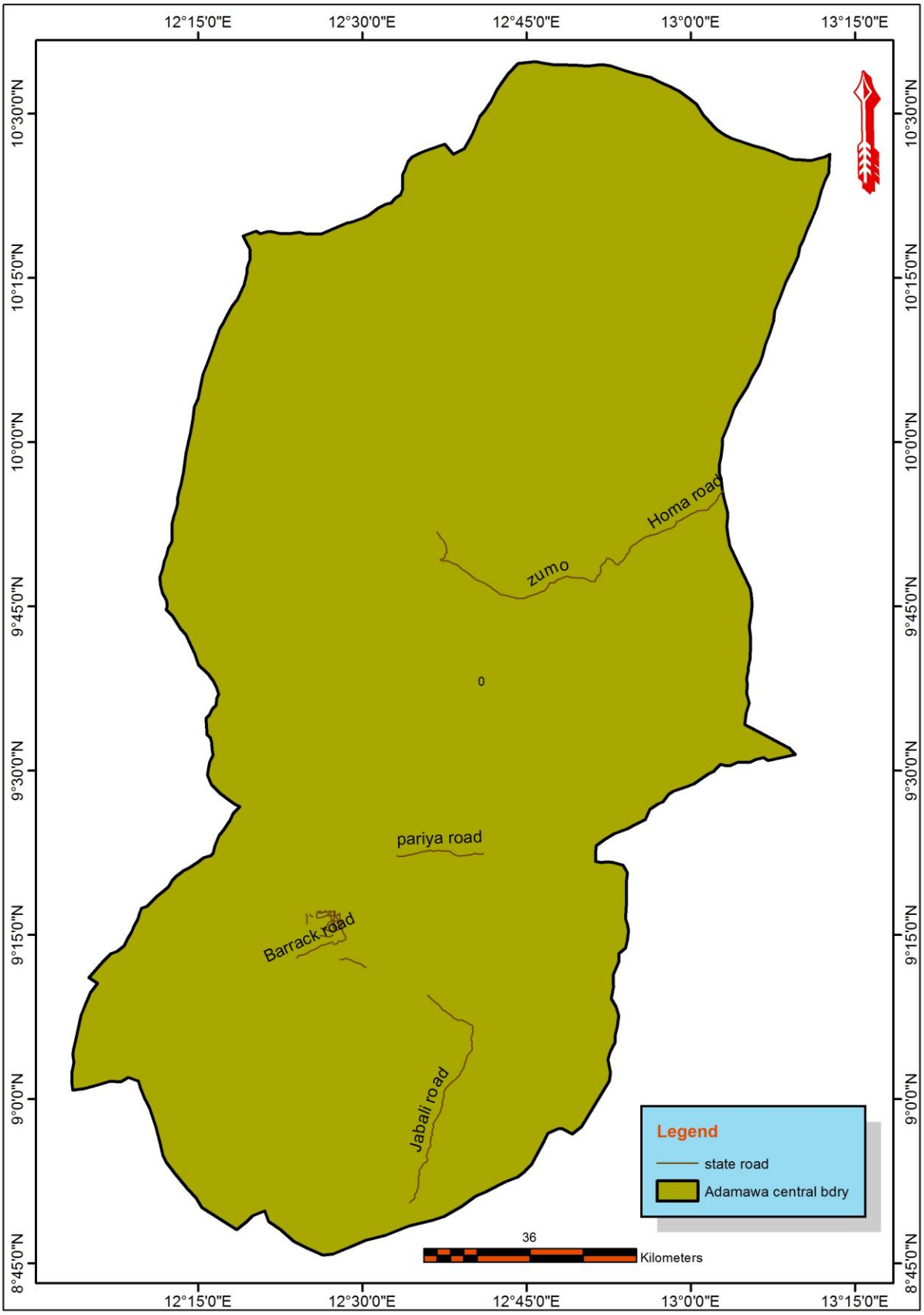


Figure 4.22 The State Roads
Source: Author's Analysis

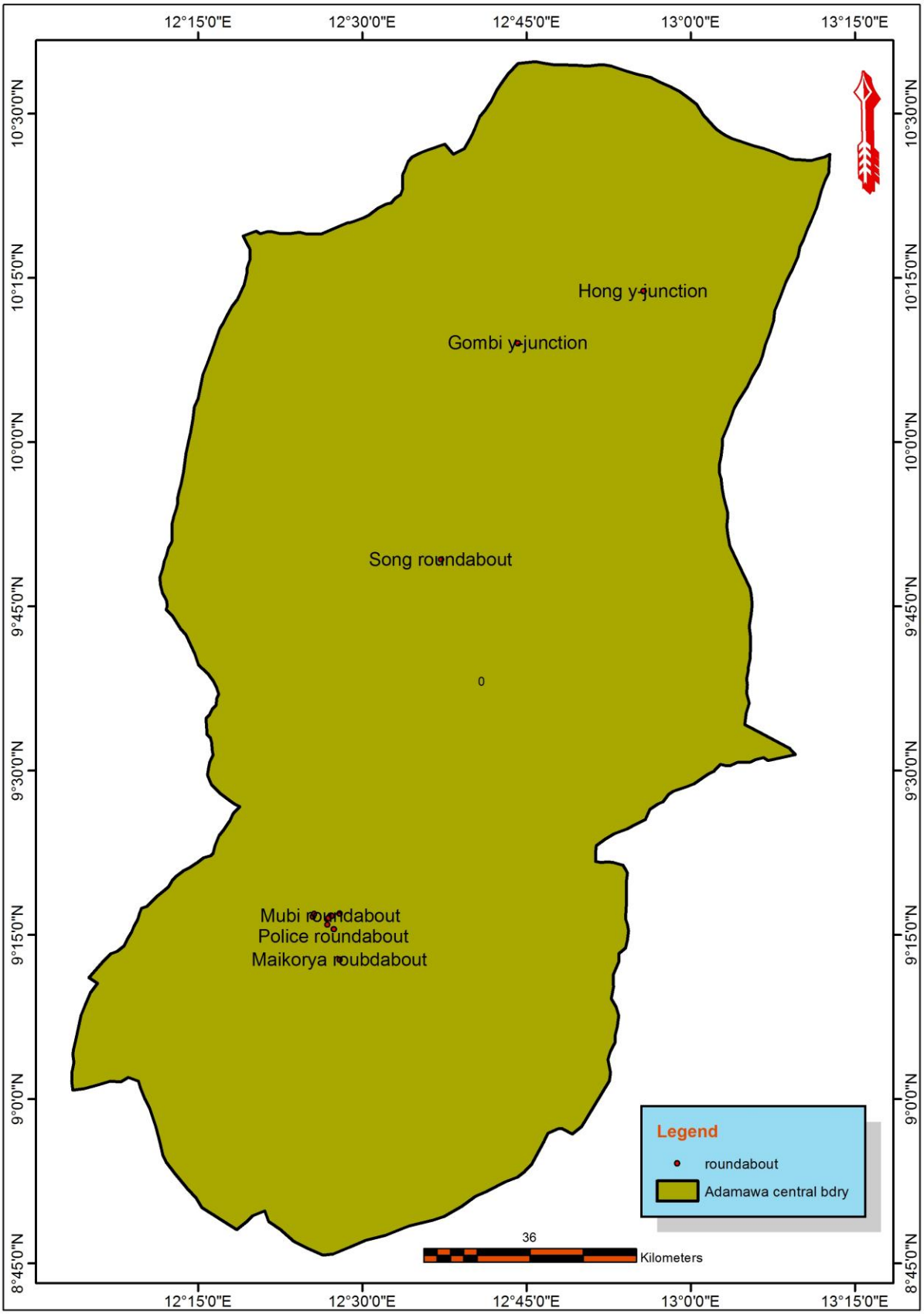


Figure 4.23 The Roundabouts Map
Source: Author's Analysis

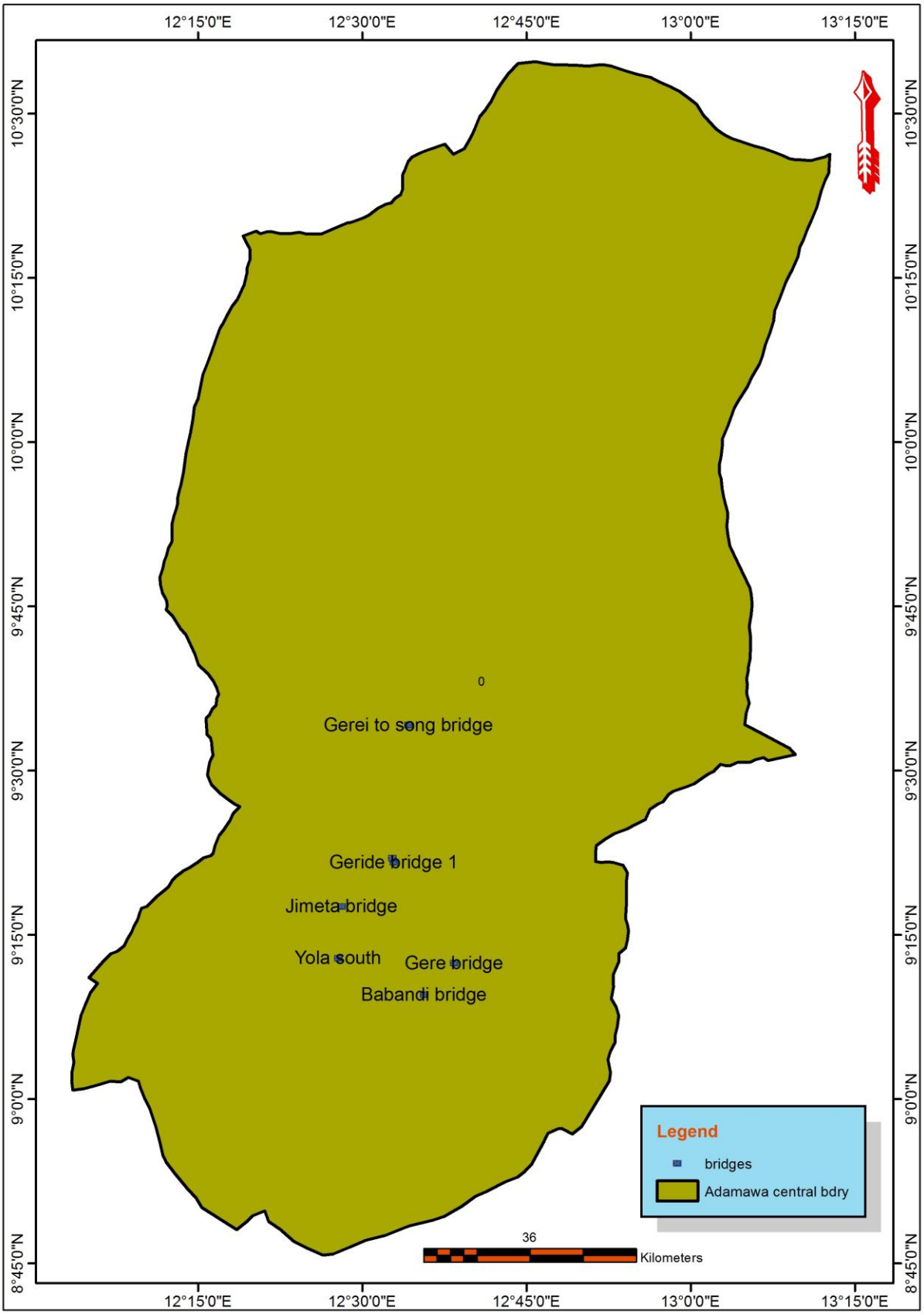


Figure 4.24 The Bridge Map
Source: Author's Analysis

As show from figures above figures, the various uptodated digital map of road transport infrastructure were presented on a different thematic map format base on their characteristics for beta understand and feature representations. These one of the advantage of GIS-based RTIMS, the ability to represent information differently and collectively as show in figure 4.24, figure 4.25, figure 4.26 and figure 4.27 respectively. From table 4.5 above, the report is generated from the geodatabase gave another written document for the Road Transport Information Management.

Data representation is a core research topic of GIS. Before we can use GIS to tackle real world problems, we must properly represent our data in a digital computing environment. One unique characteristic of GIS is the capabilities of integrating spatial and non-spatial data in order to support both display and analysis needs as supported by Lo and yeung (2002).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

3.1 Summary

The purpose of this study focuses on the GIS techniques used in the Development of GIS-based Road Transport Information Management System in Adamawa central with respect of the traditional method of road transport data handling and management using archive in the ministry of works Yola. To develop that road transport infrastructures inventories provided by the ministry of land and survey Yola, Department of works Yola, Spot 5 image of 2012, Google earth image 2013, coordinate of the road infrastructure, picture of road transport etc were used for the analysis. There were analysed using ArcGIS software.

The methods employed include and among others the road map scan, digitised and update using the Spot 5 image of 2012 and Google earth image 2013 in order to produce the uptodate digital road transport infrastructures map in ArcGIS 10.1 environment. Also the roads transport infrastructures information were used as an inventory in building the geodatabase and file geodatabase were built in ArcGIS following the stages of building geodatabase by (Lo and Yeung, 2002) to store the information collected from the ministries and grounthruthing for proper data handling and management. Again, pictures captured and coordinate collected from the field were linked with the map in ArcGIS in order to saw the locations and physical nature of the road transport infrastructures.

The result reveals that GIS could provide a mechanism for data integration, management and output generation in its spatial environment. In this study, federal roads, state roads, local government roads, bridges and roundabout depicting the availability, distribution and extent or abundance of physical features in the Adamawa central were

derived using GIS technology. Various maps and layer designed for the Adamawa central provide valuable records (information) for the assessment, management, monitoring and development of the physical features on the map. A logical query has been translated into a series of what lies here and/or what lies there. The results received descriptive and analytical answers which are for road planners, managers and decision-making because the types of inference, deduction and conclusion made is left entirely with the road transport authorities.

5.2 Conclusion

The Development of GIS-Based Road Information Management system in the study area reveal that must of the federal road are the once that are taking good care of than the state and local government roads and there is a need to properly manage the state and local government roads, especially in Fufure, Yola north, Gombi and Hong LGA. It also reveals that 78% of the LG roads are untarred while only 22% are tarred road, the tarred road are mostly located in the Yola north which is the state capital. It also show that there is there is twelve roundabouts in the study area with Yola north the state capital having the heighest number of 9 and three of it is under construction, one in Yola south, Song and Gombi. On the basis of the analysis, there is a need to expand Gombi LGA roundabout. The result still show that there is seven bridge in the study area with Gerei LGA having two with one under construction, Fufore having two and Yola north LG having two and Yola south having one. Generally, most of these infrastructures are not properly taking care of simply because there is no any single system that is developed to manage it to the best of researcher knowledge and personal observatios.

It also that ArcGIS software have a unique characteristic and capabilities of mapping, geodatabase store, integrating spatial and non-spatial data in order to support both display and analysis needs as supported by (Lo and yeung, 2002). Also it could be viewed as integrated

computer software and hardware package, in spatial context, using Geographical Information System (GIS) and Road Transport Information System (RTIMS), its functionality on geodatabase development and management, its analytical modelling, mapping and spatial tabular display, characterising road transport infrastructure map together with a framework for the decision-makers and experts. The findings "demonstrate that the methodology provided reliable results" and that the methodology "could indeed be used by state transportation agencies for Road Transport Infrastructure Management practice.

From the evidence provided by the ministry of land and survey Yola, Department of works Yola, Spot 5 image of 2012, Google earth image 2013, coordinate of the road infrastructure, picture of road transport, grounthruthing used for the research, and literature review, and also the result obtained, and personal observation of the researcher whom has live in area on which this research was carried out. It shows that there is a problem of lack of GIS-based Road Transport Information Management System and even the traditional method of Road Transport Information using archive is not properly handled and managed. This evidence is from the various activities and research carried out for the research thesis. From the literature available and personal observation shows that ministry of land and survey and works Yola are not putting any effort to develop a system for road transport infrastructure management and there is a need to for the integration of GIS and Road Transport Information Management System (Curtin, 2003), and also Loughlin (1999) stated that planning offices everywhere are using GIS to handle development of road transport information management system, this evidence justify my thesis research on the development of GIS-based Road Transport Information Management System for Adamawa Central, Nigeria. Because the integration of GIS and Road Transport Information System have received a lot of attention in the resent years (Rodrigue *et al,* 2006).

All the evidence given from the results obtained from the research and personal observation of the researcher has justify the need which said one unique characteristics of GIS is the capability of integrating spatial and non-spatial data in order to display and analyse need for proper maintenance, management and decision making (Lo and Yeung, 2002)

5.3 Recommendations

Based on the findings of the study, the following recommendations are made.

i. It is recommended that government should tarred the untarred roads and create more roads in the study area and also be properly managing the road transport infrastructure.

ii. It is recommended that government should establish GIS unit in the federal and state ministry of transports board and also encourage the local government areas to do the same for proper planning and development of road transport infrastructure and management for easy management and control of its facilities and also the Federal Roads Maintenance Agency (FERMA) should design a plan for road transport managements whether on periodic, cyclic or development in order to manage RTIMS as the case may be

iii. There is a need for the research like this to be conducted in the Adamawa north and south.

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