Developing WebGIS Based Road Pavement Management System: A case Study of Addis Ababa, Nifas Silk Sub City Woreda 8

Tewodros Zegeye

A Thesis Submitted to the Department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirements for the Degree of Master's in Geo-Informatics Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

January, 2021

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Co-advisor: Daniel Alemayehu (PhD, Asst. Prof.)

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APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Tewodros Zegeye have read and evaluated his thesis entitled "Developing Web GIS based Road Pavement Management System: A case study of Addis Ababa, Nifas Silk Sub City Woreda 8" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master's in Geo-Informatics Engineering.

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CANDIDATE'S DECLARATION

I, Tewodros Zegeye declared that, this MSc Thesis is my original work and that it has not been submitted partially; or in full, by any other person for an award of a degree in any other universities, and all sources of material used for this thesis have been duly acknowledged.

Tewodros Zegeye	________________	_______________
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ADVISOR’S APPROVAL SHEET

To: Geomatics Engineering Department

Subject: Thesis Submission

This is to certify that the thesis entitled “*Developing Web GIS based Road Pavement Management System: A case study of Addis Ababa, Nifas Silk Sub City Woreda 8*” submitted in partial fulfillment of the requirements for the degree of Master’s Geo-informatics Engineering, the Graduate program of the department of Geomatics Engineering, and has been carried out by Tewodros Zegeye, ID. PGR/18040/11 was under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence he can submit the thesis to the department.

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LIST OF ACRONYMS AND ABBREVIATIONS

AACRA	Addis Ababa City Roads Authority
AASHTO	America Association of State Highway and Transport Official
AM	Asset Management
ARAN	Automated Road Analyzer
API	Application Programming Interface
ERA	Ethiopian Roads Authority
FIIDCA	Federal Integrated Infrastructure Development Coordinating Agency
GIS	Geographic Information System
GUI	Graphical User Interface
GPR	Ground Penetrating Radar
GPS	Global Positioning System
HTML	Hyper Text Markup Language
IRI	International Roughness Index
JICA	Japan international Cooperation Agency
MMS	Maintenance Management System
PMS	Pavement management System
PST	Project Selection tool
PCI	Pavement Condition Index
RAM	Road Asset Management
TAM	Transport Asset Management
TIMS	Transportation Infrastructure Management System
VOC	Vehicle Operating Cost
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service

ABSTRACT

WebGIS-Based Road Pavement Management is a systematic process that aims to preserve, expand, and operate road assets in the most cost-effective manner. It is an analytical tool that facilitates organized, logical, and integrated decision-making in road asset management practice. However, in AACRA there is no well-designed geodatabase for pavement management System (PMS) that enables to manage road network in time, efficient and cost effective manners. Due to this, the road Authority faced a problem that had led to fail in properly managing those road infrastructures such as: maintenance issue, controlling and upgrading of such a large road network. As result, the Addis Ababa roads networks are facing structural deficient due to lack of prioritizing road network and timely maintenance, rehabilitation and upgrading. This has adversely affected the traffic movement, resulting to higher operating costs and delays. Nowadays, webGIS-base PMS had led to overcome such problems by designing geodatabase mode which is the most important tool for managing road network more efficiently in a scientific manner. Therefore, the objective of this study were to design the effective WebGIS-Based PMS geodatabase model for Addis Ababa City, Nifas Silk Sub City, which is base for prioritizing road network and making sound and timely decisions used for maintenance. In order to achieve this objective, the study were used both primary and secondary data. The study starts with identifying requirement analysis and collecting primary data such as spatial locations of road network using GPS, road inventory and road condition survey by using ESRI Survey123 Mobil app and secondary data such as CAD files and Traffic AADT data. The need of the Enterprise was identified through requirement analysis, and geodatabase design was done through conceptual, logical, physical design phase by using enterprise architecture UML diagram software. The designed UML was exported to XML schema and the geodatabase model was developed using ESRI ArcGIS 10.5 based on the requirement of the PMS. Primary and secondary data is populated in developed geodatabase for test the model. MCDA was adopted for the road pavement prioritization. The developed road network in the pilot study area was about 29.275km total length. The study identified, about 60% were paved with bituminous and about 40% were cobble stone. The finding of the study showed that, out of 355 segments around 40 segment need urgent maintenance. Finally the developed PMS Geodatabase was uploaded to ArcGIS online as a hosted feature layer. This study recommends that, the developed model can be utilized by the enterprise for effective pavement management and decision making for pavement maintenance in the City.

Keywords: WebGIS, PMS, Geodatabase Design

CHAPTER 1: INTRODUCTION

1.1. Background of the Study

Road pavement management is a relatively new term in the transportation world. In the past and even today, transportation entities have used traditional methods of managing their assets (AASHTO, 1990). These methods are based either on a yearly rotation for maintenance and rehabilitation or on the "fix it when it's broke" principle (Attih-Okine and Adarkwa O, 2013).

WebGIS based road pavement management System is a systematic process of maintaining, upgrading and operating transportation assets cost-effectively (Zietlow, G., 2004). Road pavement management in transportation involves creating an asset inventory, assessing current conditions and performance, determining and evaluating future system needs, evaluating and selecting appropriate strategies to address those needs and evaluating the effectiveness of each strategy (Agarwal P.K., 2006).

Most recently, transportation agencies throughout the world are increasingly adopting a strategic approach, referred to as road pavement management, to make investment decisions for system preservation, expansion, and operation, based on comprehensive information and in a holistic and proactive way (OECD, 2000).

Australia and New Zealand have national legislation requiring government agencies to utilize road pavement management systems. The strategies identified a programmed set of management actions that directed physical treatments to that asset (AUSTROADS, 1997).

The English Highways Agency (EHA) was mandated by legislation emanating from the United Kingdom to adopt road pavement management-oriented approach to infrastructure development and maintenance. The agency is currently making efforts to develop a geographically referenced database to support an online pavement management system. This system will serve as the basis of a comprehensive pavement management system to be developed in the future (Sodikov and Jamshid, 2015).

The American Public Works Association (APWA) also commissioned a task force for road pavement management. In August 1998, the task force delivered a report titled "PMS for the public works manager: challenges and strategies" to the APWA board of directors (Danylo and Lemer, 1998).

Generally, pavement management system is still a growing discipline throughout the world; some state transportation agencies have taken a proactive approach to road pavement management as an overall departmental initiative. For instance, the New York Department of Transportation (DOT) has had an active asset management program focusing on system preservation since 1998. Michigan has pursued several business process and information technology advances for PMS since the mid-1990s. Arizona, Indiana (INDOT), and Pennsylvania are currently developing PMS (Neumann, 1997).

In Africa, however, such systems have not been put in place thus hampering integrated and efficient inter-modal infrastructure provision. Advanced technologies are increasingly playing a major role in the planning, development and management of road transport infrastructure to enhance efficiency and safety in transportation worldwide (GoK and Basheka, 2004).

Currently, the Road construction industry is one of the biggest industries in Ethiopia contributing 10% to Gross domestic product (GDP) (RSDP, 2014). This industry is an enormously important part of economic growth of the country. The economic growth of the country depends on availability and utilization of physical infrastructures. Reports indicate that about 58% of the federal capital budget of Ethiopia is consumed by the construction industry mainly by the road subsector that generates significant employment opportunities (Alemayew.A. and Abiyu.B., 2019). According to RSDP (2014) assessment report states Ethiopia has more than 99,522 km in 2014 (an increase of 275 percent). As a result, the road density per 1000 sq. km has increased to 90.5km.

Ethiopia spends high costs for maintenance due to lack of well-organized road pavement management system (PMS) which leads to wrong decision as result of un controlled road pavement conditions. The current maintenance practice also depends more on visual observation and functional evaluations such as surface roughness and visual survey at network level rather than detail pavement evaluation at project level (Federal HighwayAdministration , 1999).

Road maintenance management system is not a new concept for AACRA. In 2004 AACRA attempted to introduce a Snowy Mountain Engineering Corporation (SMEC) RMMS based on HDM-4, but this attempt was failed due to: considerable number data was required, no trained staff in AACRA (resign, turnover) and system cannot be customized. Since 2010, after SMEC was failed road maintenance management system of AACRA has become very poor and prone to many problems. In order to improve this poor road maintenance management system collaboration agreement was signed between AACRA and JICA in July 2015 for development of road maintenance capacity of Addis Ababa. The purpose of the project is to enhance the management capacity of AACRA for road maintenance. The expected outputs of the project are to: development of road data base which involves setup target road (start point and end point), formulate inventory and condition survey information, preparation of survey schedule and staff assignment. However, this attempt was also failed due to different reason between to the enterprise. Therefore, currently in AACRA there is no well-designed geodatabase model for pavement management system (PMS) that enables to manage road network.

Therefore, the transportation entities in our country, are feeling the pressure to maintain their transportation infrastructure at a high level of service. This along with an increasingly restricted transportation budget makes the reality of reaching higher levels of service seem impossible. Using traditional methods may cause transportation entities to perform deferred maintenance rather than preventative maintenance (Porter, T, 2014). In most cases, preventative maintenance is much more cost-effective than deferred maintenance. Transportation entities that use a yearly rotation for maintenance or rehabilitation may cause transportation entities to spend money on projects that may not be a priority (Flintsch and McGhee F., 2009).

Now a day different countries in the world were applied proper road pavement management system to over-come wrong decisions and to enhance cost efficiency through managements of road conditions by integrating with GIS (Miller, 1991; Kamal *et al*., 1994). The breadth of the field of integration of GIS and pavement management system provides large opportunities for the development of new and innovative applications in transportation system of different transportation organizations (Curtin *et al.* 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 (Good child *et al.* 2004), they have become one of the most powerful tools to support pavement managements studies and applications.

The relationship between GIS and PMS 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 (Fotheringham, 2000). Capitalizing on this relationship both academics and practitioners have focused their attention on research/work that makes use of GIS in asset management applications (Shaw, 2002). However, besides some early contributions, which aimed at explaining the role of GIS in transportation planning, no major efforts were made with respect to pavement management. Surprisingly, methods of prioritizing the road network or road segments that support the road authority in decision making and timely maintenance were lacking.

The road networks are capacity constraint and structurally deficient due to lack of timely maintenance, rehabilitation and upgrading (Haas, R., 1998). This has adversely affected the traffic movement, resulting into higher operating costs and delays. Maintenance and upgrading of such a large network is a challenging task because of the logistics and constraints of resources. There is a need to manage the network more efficiently in a scientific manner; the most important aspect lacking is the application of information system.

Therefore, there is a need to establish a centralized facility where information on road and road transportation can be utilized for the development of effective and efficient maintenance and rehabilitation measures and for planning strategies. (Good child, 2000).

Therefore the purpose of this study is to provide a webGIS-based PMS geodatabase model that will be used as a framework for implementing cost-effective reconstruction, rehabilitation, and preventive maintenance programs and results in pavement design to accommodate current and future pavement deteriorations, in a safe, durable, and a cost-effective manner.

This study is important and timely because Addis Ababa City road 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 different technology transfer priorities in problem resolution.

The study will be used as a basic tool for decisions makers with a system which could be used for road pavement inventory, physical road maintenance, road traffic management as well as any other road-related management issues. The study will develop a webGIS based road pavement management system geodatabase in Addis Ababa City, as support to the traditional pattern matching (majorly based on human judgment), that has been used over time.

1.2. Statement of the Problem

WebGIS based Pavement managements system is one the most important asset management system, which is crucial for the economic growth of the country (Hussein M., 2009). Now a day's our country spends huge costs for road pavement maintenance and reconstruction. This is because of less follow up the pavement conditions, poor pavement management awareness and absence of prior setting and planning for timing maintenance.

According to Addis Ababa City Road Authority 1996 EC., report the Authority had annual expenditure of around 300million birr for road construction and maintenance out of which more than 30million birr was expended for routine maintenances. However, with proper maintenance the life of the road can be extended. The cost to maintain a road in good condition is approximately 42birr/m^2. The cost to replace a road is approximately 3,163.00 birr/m^2 (S.P.A., 1994). There is a significant difference between maintenance and reconstruction costs. Such expenditure for construction and maintenance of the Addis Ababa roads is obviously too big and require special attention. This has resulted in the maintenance operation not to be efficient and effective.

The Road User Cost Study in Addis Ababa has established that due to improper maintenance and poor surface condition of road pavements, there is a considerable economic loss to the country due to increase in vehicle operation costs. If the road pavements are maintained to the desired level at an appropriate time, it is possible to save the losses in road user cost. In view of the budgetary constraints and the need for judicious spending of available resources, the maintenance planning and budgeting are required to be done based on scientific methods. The whole life cycle cost analysis based on the road user cost relationships enables the decision makers to examine financial and economic implications of various options for formulating appropriate strategies for cost effective use of resources.

As stated by Robinson (2000), lack proper managements of pavement condition, the importance of sufficient investment for the maintenance and management of the road infrastructure lead to its chronic under- financing and deterioration. This chronic underfunding and lack of maintenance can very quickly jeopardize this huge asset which has been built at great expense and effort in the last decades (Ferreira, A. *et al*., 2002). As a consequence it can no more serve the required level of service. As a matter of fact shortfall in investment for maintenance of the road infrastructure and its dramatic consequences huge deterioration of the network results in, higher risks of accidents, problems of congestion, increased noise and a reduced service to society (Marathe P.D., 1995).

In Ethiopia, however, such systems have not been put in place thus hampering integrated and efficient inter-modal infrastructure provision. Similarly, there is lack of appropriate road pavement management systems and spatial database design for road pavement management system. Due to this reasons AACRA follow traditional way to prepare a short and long term maintenance plan, to administer the road, to know condition of road and make decision in scientific way, to share the data, to make analysis, to select praiotize the most deteriorated road. They followed traditional way “fix it when it’s broke”.

Today in developed country, all transportation facilities can pull their information together in a single, common database to evaluate the total transportation infrastructure of a municipality or state, not just a single mode. The webGIS based pavement management system provides preventive, periodic and routine maintenance activities in addition to an emergency maintenance, which requires urgent need of maintenance.

In order to overcome this problems, the study also come up with rational solution for AACRA and recommend a better way of road ownership and management for sustainable social and economic development of our country.

1.3. Objective

1.3.1. General objective

The general objective of this study is to develop webGIS-based road pavement management system geodatabase model for Addis Ababa City road Authority in Addis Ababa, Nifas Silk Sub City Woreda 8.

1.3.2. Specific objective

The specific objectives of this study are to:

1. Design the physical PMS Geodatabase model.

2. Test the model by prioritizing the road network for maintenance.

3. Couple the PMS Geodatabase to WebGIS online.

1.4. Research question

1. What are the requirements for developing pavement management system geodatabase model?
2. Is the developed geodatabase model is efficient for prioritizing road network and road pavement management system?
3. How to integrate the developed PMS Geodatabase with WebGIS online?

1.5. Significance of the Study

Currently in the world most of the developed country use geospatial technology like WebGIS, GNSS, satellite image etc. as tool to plan, design, construct, manage and administer the rood pavement and related asset.

WebGIS based road pavement management system is vital for developing country like Ethiopia for planning and managing the constructed road properly. The system also provides a significant social and economic benefit to communities.

The main beneficiary is AACRA. In AACRA structure of organization, there is a lot of department concerned by this study. The department of road asset management is one of the beneficiaries by managing the road pavement data easily by storing; analyzing, sorting, displaying and sharing the collected and analyzed data in modernize way. The other department that will be benefited from this study is road maintenance department, this department also can make decision in scientific and reasonable way to select the urgent need of the road pavement maintenance by set priority using the developed model.it has shortage of budget to maintain the road once a time, to utilize the budget this study has answer by ranking and identifying the need of urgent maintenance.

The stakeholder like Ethio-telecom, Ethiopian electric power, Addis Ababa water supply and sanitation etc. were the another beneficiary of this study; through accessing the data easily from the office using the internet connection. The study also supports the stake holder to prepare the integrated plan each other through web.

The other beneficiaries at the end of this study were, the road user like driver, passenger will be benefited by visualizing and accessing information about the pavement condition before traveling. Such kinds of information are important to travel on the road safely.

In general not only the above one but also the other stakeholder or user can use this study. Road manager, engineers, planer, policy makers, and others are beneficiary to give and make decision easily and modernized way about the road pavement.

1.6. Scope of the Study

The spatial scope of study was limited to the federal state Addis Ababa, Nifas Silk Sub City Woreda 8, because of the availability of data such as the existence of all five primary road categories, i.e. Ring Road (RR), Principal Arterial Street (PAS), Secondary Arterial Street (SAS), Collector Street (CS) and Local Street (LS) required for the study. The study will be focused on the possible spatial database design and testing the model for road pavement management system. The study also develops webGIS based user interfaces for querying and analyzing the database.

1.7. Limitation of the study

In this study, certain limitations have been encountered. One of these limitations was during data collection presence of high rise buildings, cloudy/rainy weather, and presence of high tension electrical line obstructs the signals from satellite and radio signal between base station and rovers. This result in delay in acquiring accurate location information which may need more time to collect road center line by GNSS.

Other limitation was the challenge to collect design information of structures such as foundation soil info, hydraulic data, design data, etc. Therefore, to overcome this challenge, the study was used secondary data such as; pavement composition data including information of the material type and thickness of asphalt layer from AACRA.

The other limitation was in during data collections due to absence of VOTERS survey vehicle and sensors to monitor and collect road conditions survey, the study was used manual data collections method by visualizing and measure the defect area, this is difficult to know severity of the segment this may be go to wrong PCI value.

1.8. Thesis Organizations

This thesis is presented in to five chapters. The first chapter introduction part, it includes the problem statements, research questions, significances of the study, objectives, delimitations and limitations of the study. The second chapter describes the related literature reviewed, and it also includes the theoretical framework, such as definition, methods; empirical framework which includes previous studies related to this study and finally, the conceptual framework developed from the existing theories and previous works to achieve the objective of the study. The third chapter presents materials and methods. In this chapter, the study area were described, materials used and data analysis methods are discussed. In forth chapter results obtained from the data analysis to achieve the objectives of the study follows together with interpretation of results and discussion. Fifth chapter were the conclusion and recommendations for future studies based on the result of the study.

CHAPTER 2: REVIEW LITERATURE

This chapter presents the related literature and studies after a thorough and in-depth search done by the researchers. This also presents as the theoretical, empirical and conceptual framework was developed based on the objectives and statement of the problems of the study.

2.1. Theoretical Framework

2.1.1 Pavement Management Systems

Pavement management is a set of activities associated with the process of maintaining, rehabilitating and reconstructing road pavement in a cost effective way (Robert G., 2017). It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized approach to decision making. The system should be easy to use and learn, requiring only minimal training. Customized input menus should be developed to make the system easier to use (Gongera K. *et al*., 2016).

According to American Society of Civil Engineers (2013), pavement management and pavement management systems (PMS) have been recognized as a legitimate part of highway engineering and as a viable tool for the decision-makers in managing the rather considerable resources entrusted to them in the form of pavements. For example, the Illinois Pavement Information and Management System (ILLIPIMS) developed for the state of Illinois in the USA is equipped with engineering and economic methods and models that predict future traffic, rehabilitation and pavement condition (Khadaroo and Seetanah , 2008). PMS should be considered as a tool for decision making, not a decision maker itself. The system should be flexible enough to incorporate user input in the decision making process (Khadaroo and Seetanah , 2008). As a minimum, a pavement management information system should contain roadway section location description and identification (master file); pavement condition history; pavement materials & construction data; traffic conditions; and maintenance items expenditures (AASHTO, 1990).

Since the 1970s, highway administration has provided guidelines for developing a set of decision making tools known as pavement management systems. These guidelines were created to assist agencies in minimizing the overall costs of maintaining their transportation systems while maximizing the benefits of having a sound road infrastructure. (Hudson and

Pedigo., 1999) Describe a pavement management system (PMS) as “a coordinated set of activities, all directed toward achieving the best value possible for the available public funds in providing and operating smooth, safe, and economical pavements”. PMS systems were developed based on the concept that resources for road maintenance can be efficiently managed by determining the current condition of the pavements and their deterioration rates (Greenwood, I. *et al,* 2012). In fact, a successful PMS deploys a combination of engineering algorithms and business trade-off analysis techniques to suggest the right repairs, in the right place, and at the right time. Figure 2.1 shows the impact of timely maintenance on the money spent and life extension of roads (Federal HighwayAdministration , 1999).

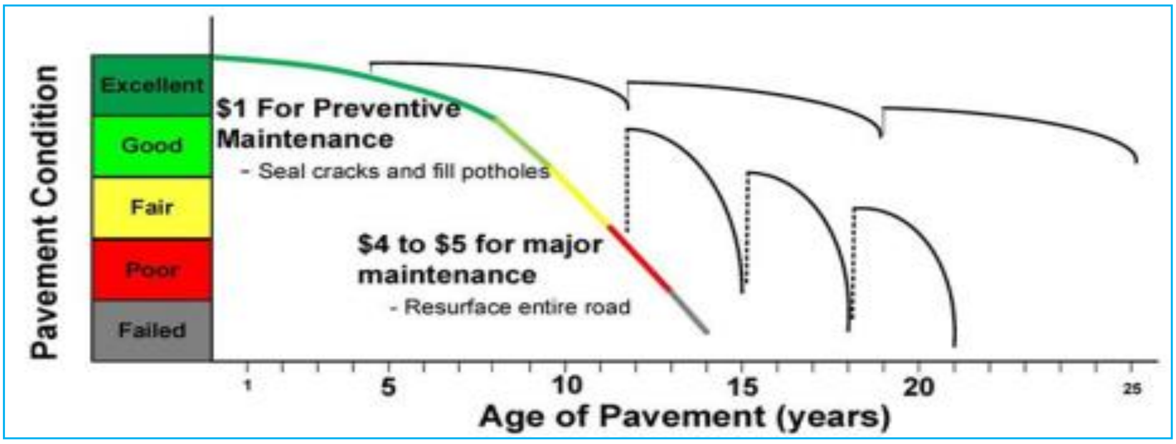
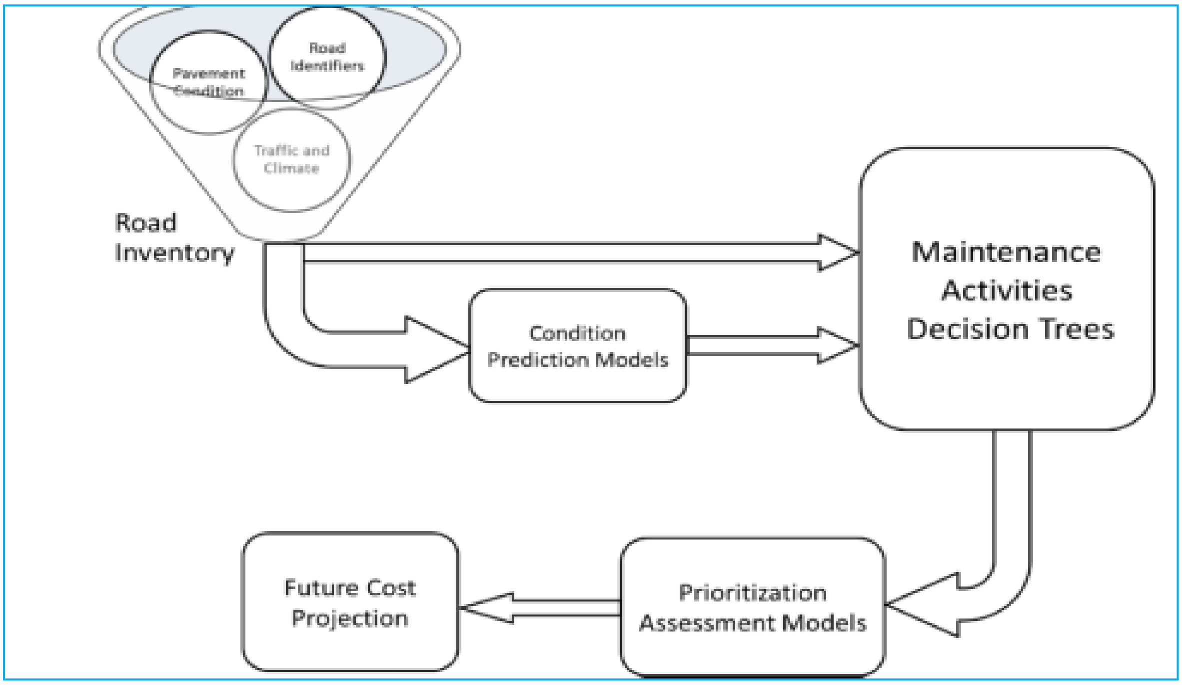


Figure: 2. 1. Maintenance activities effect on lifecycle of pavements and money spent.

2.1.2. Components of a Pavement Management System

Generally, pavement management systems consist of the following parts. A comprehensive database which stores the data required for the PMS analyses, mathematical methods which develop useful decision making products and calibration processes which fine-tune system’s parameters by using the latest field observations (Finn.F, 1974).

A PMS process starts with collecting the data required for the PMS’s analyses and assigns maintenance and repair activities with respect to the life-cycle costing and priorities as compared to other pavement requirements in the network (Meng L, and Wenial C, 2012). Every time new data is collected, this process reproduces the cost and condition predictions to recalibrate the system’s prediction models. Figure 2.2 summarizes a PMS process.



[Source: Zofka A., 2014]

Figure: 2. 2. Maintenance activities effect on lifecycle of pavements and money spent.

Two key differences in PMSs are their method of evaluating pavement conditions and develop webGIS based management system to present the results and run the PMS models (AASHTO, 1990). Here in, first an overview of the state of the art pavement condition surveys is provided. Then, a review of webGIS based management system is presented.

2.1.3. Pavement Evaluation Methods

A review of some of the most common pavement evaluation methods is followed. These methodologies are: pavement condition index (PCI), pavement surface evaluation and rating system (PASER), condition rating survey (CRS) and localized pavement condition metrics.

Pavement Condition Index (PCI): A widely-used method of road assessment in the United States is to calculate ASTM's Pavement Condition Index (PCI). Developed in 1976 by the US Army of Corps, PCI is a numerical ASTM standard between 0-100 to indicate the general condition of pavements, with 100 being the best possible condition and 0 being the worst possible condition (AASHTO, 1990). PCI inspections are either on-foot surveys (experts walk on each road and make measurements) or wind-shield surveys (experts ride in a car that is moving slowly and see through the windshield to record pavement distresses).

PCI methodology is well-documented in ASTM D6433, Standard Test Method for Roads and Parking Lots Pavement Condition Index Surveys (American Society for Testing and Materials, 2009). As described in this document, to calculate PCI experts visually inspect and assess the severity of 39 pavement distresses in three severity levels of low, medium or high. From these distresses, twenty are specific to flexible pavements, and 19 are specific to concrete pavements. PCI is then calculated in respect to severity of each of those reported distresses by using the measurements of the experts to deduct points out of 100 (Cation and Shahin, 1987). To calculate PCI experts should first divide the road network to three categories: individual roads or "branches", pieces with similar work history or "sections", and "samples". Figure 2.3 shows a graphic illustration of PCI methodology.

Figure: 2. 3. The graphic illustrations of PCI

Consequently, the pavement distresses stated earlier are inspected in these samples and their severity levels are determined. In flexible pavements, which are the focus of this thesis, the samples' sizes are 2,500 f ± 1,000 (Finn.F, 1974). After the existing distresses and their severities are determined in the samples, the numbers are entered into a sheet from which the deduct values stated earlier are calculated. These calculations are based on available graphs in the ASTM specifications (AASHTO, 1990). Consequently, the total deduct values are subtracted from 100 and a weighted PCI average of inspected samples are calculated as the pavement condition index of each section1 (Flintsch and McGhee F., 2009). PCI scores are typically translated into the maintenance categories shown in table 2.1 below.

Table: 2. 1. PCI Ratings Related to Maintenance and Repair Strategies.

PCI	Maintenance Action Required
90 < PCI	Do Nothing
70 < PCI < 90	Preventive Repair
70 < PCI < 90	Rehabilitation
PCI < 40	Reconstruction

[Source: (Flintsch and McGhee F., 2009)**]**

Pavement Surface Evaluation and Rating System (PASER) is another popular measure of pavement conditions. PASER is a classification metric between 1-10 which indicates the general condition of pavements, with 10 being the best possible condition and 0 being the worst possible condition. The PASER rating system uses four major surface distresses based on visual inspections of the experts on the field: surface defects (raveling, flushing, polishing), surface deformation (rutting, distortion)**,** cracks (transverse, longitudinal, alligator, block, reflection, slippage) and patches & potholes (Cologrande, S. *et al.,* 2011).

Surveyors first assess the general condition of the pavement to calculate PASER, i.e. if the pavement is in a generally good, fair or poor condition. Then, they evaluate the four pavement distresses mentioned above by referring to the snapshots of each rating (Walker and Kummer S, 2010). The PASER rating scale can generally be translated into the maintenance categories shown in table 2.2. PASER is an estimated measure of road conditions which is subjective to the surveyor's judgment.

Table: 2. 2. PASER Ratings Related to Maintenance and Repair Strategies

PASER	Maintenance Action Required
PASER = 9, 10	Do Nothing
PASER = 8	Little Maintenance
PASER = 7	Routine Maintenance
PASER = 5, 6	Preventive Repair
PASER = 3, 4	Rehabilitation
PASER = 1, 2	Reconstruction

Condition Rating Survey (CRS) The Condition Rating Survey (CRS) is another popular metric to rate the overall condition of pavements. CRS is a numerical metric between 1-9 to indicate the general condition of pavements, with 9 being the best possible condition and one (1) being the worst possible condition (Attih-Okine and Adarkwa O, 2013). The CRS rating scale can generally be translated into the maintenance categories shown in table 2.3.

Table: 2. 3. CRS Ratings Related to Maintenance and Repair Strategies.

CRS	Maintenance Action Required
$7.6 \leq CRS \leq 9.0$	Do Nothing
$6.1 \leq CRS \leq 7.5$	Preventive Repair
$4.6 \leq CRS \leq 6.0$	Rehabilitation
$1.0 \leq CRS \leq 4.5$	Reconstruction

[Source: (Attih-Okine and Adarkwa O, 2013)]

CRS values differ in 0.1 increments, where a road with CRS of 5.9 has been compared to a road with CRS of 5.8. While the surveyors may use the images provided as examples of pavement conditions in terms of CRS, CRS can also be derived from several algorithms which relate other measurements such as Roughness and Rutting to CRS (AASHTO, 1990). These algorithms, however, are generally dependent on the local agency which developed them for its own purposes.

Localized Pavement Condition Metrics: In addition to the well-documented methods outlined above, many agencies have created a customized rating system that specifically meets their needs. Some of these rating systems simply classify the roads in three categories of good, fair, and poor, while the others are more sophisticated (Wolters A,2011; Zimmerman 2013; and Schattler, 2015).

2.1.2 Data Collection Methods

Data collection, data management, and data integration are essential parts of the Asset Management framework that are critical to its success. Timely and accurate data lead to information and form the basis for effective and efficient decision making (Nemmers, 1997).

The pavement condition data is an important component in developing effective maintenance and rehabilitation strategies for many reasons (Esri, 2015). First, identifying appropriate maintenance and rehabilitation alternatives rely on pavement information such as thickness, current condition, traffic, climate conditions, etc. The pavement data includes many factors, for example, pavement current condition, historical performance, materials, thicknesses, traffic information, pavement geometry, and environmental data (American Society of Civil Engineers, 2013). The various methods and technologies used for infrastructure data collection have shown a trend toward automation and computerization. Methods used for the collection of Asset Management data include (1) manual, (2) automated, (3) semi-automated, and (4) remote collection. Regardless of the method used, the existence of an effective quality control and quality assurance (QC/QA) program is vital for the success and reliability of the collection. A brief description of each method follows (Detwiler, 2009)

(i) Manual Collection: This method employs two or more data collectors and a distance-measuring device. The collected data are documented either with pen and paper, or in more recent cases, with handheld computers equipped with GPS (Peggar2000; Larson *et al.*2004). At a particular location, the data collectors walk from one site to the other and inspect and record the condition of the considered assets. A variation of this method, the windshield survey, uses a vehicle to perform the inspection while driving; the recording is still done manually. Manual surveys allow for very detailed data collection but are very labor intensive and require more time per asset than automated or semi-automated methods.

(ii) Automated collection: The method involves the use of a multipurpose vehicle which is equipped with a distance measuring device, digital video cameras (downward and/or forward looking), a gyroscope, laser sensors, computer hardware and potentially GPS antennas in order to capture, store, and process the collected data. The gyroscope and GPS are used to capture location data. The laser sensors are used to acquire pavement surface properties and the downward looking cameras are used to assess pavement surface properties (usually distresses). The forward looking cameras are used to determine the location of roadside assets and assess performance measures. Specifically developed software is generally used in order to visualize in three dimensions the location of the transportation assets from the digital two dimension frames. The newest data collection equipment's have achieved high automation and accuracy and are capable of very fast and comprehensive data collection (Peggar and Rada, 2004). In most cases, however, even with the use of automated methods, some post-processing of the data is required.

(iii) Semi-automated collection: This method involves similar equipment as the completely automated method but with a lesser degree of automation. It is very popular within transportation agencies and yields comprehensive and accurate data collection when properly implemented.

(iv) Remote collection*:* This last method pertains to the use of satellite imagery and remote sensing applications. These methods involve high resolution images acquired through satellites or other types of images and scans obtained by remote sensing technologies (lasers, aerial photos, aerial GPR, etc.). The images are used in conjunction with ground information in order to reference the location of the road assets and to assess asset condition and characteristics (Finn, 1974; NCRST 2001).

2.1.3. Application of GIS in Pavement Management

Geographic Information System, commonly called a GIS, is an information system that deals with digital geographic data (Peterson D, 1987). A useful GIS has the ability to manage specific tasks such as: preprocessing of data into a form that can be analyzed (e.g., projection or projection of coordinates and reclassification of data), analysis of data and modeling of physical and social processes and post processing of results, including production of map displays and data reports (Esri., (2008).

These capabilities of GIS reveal its potential as a tool for modeling processes involved in pavement management. The urgency that accompanies road management problems and the spatial nature of road data analysis also promote the use of GIS. GIS is therefore clearly a technology that needs to capture the attention of highway and other civil engineers a lot more than is the case at present, especially in developing countries where awareness of the technology and the benefits it can bring to their work is still quite low (Zofka A., 2014).

One of the major problems in preparing the road network improvement strategy is the lack of large volume of data needed for it. And even if it is available, the problem is how to manage and access the data. As the different data sets and information is scattered at different agencies, it is a severe problem for the respective organizations to make any decision on the road network problem. Every time it is mandatory for those organizations to start from scratch in planning and executing their work. Considering the complexities in developing, updating and processing of transport related data there is an urgent need to adopt new concepts on information technology in design and development of information system for the road network.

The application of GIS in particular has relevance to road network due to the spatially distributed nature of road related data. Thus, GIS technology provides core framework for an integrated information system on transportation (Esri, 2015). GIS is an effective tool for integrating, managing, querying, and spatially analyzing transportation data. Moreover, it provides an efficient means for interpreting and displaying empirical trends and patterns in transportation data. The ILLIPIMS system contains unique mapping and graphing capabilities, allowing Illinois Department of Transportation (IDOT) to display, analyze, and update data for the entire Illinois Interstate highway network more efficiently (Khadaroo and Seetanah , 2008). GIS-based road information and management system and the framework on which it has been developed for the state of Maharashtra in India can serve as an effective workable model for governing bodies of other organizations and can go a long way in not only enabling policy makers, but also solving the problems of spatial data (Nemmers, 1997).

2.1.3.1 Geodatabase Model

According to ESRI modeling our world, (2003) the CAD data model, the very first computerized mapping systems drew vector maps with lines displayed on cathode ray tubes and raster maps using overprinted characters on line printers. The CAD data model stored geographic data in binary file formats with representations for points, lines, and areas. Scant information about attributes was kept in these files; map layers and annotation labels were the primary representation of attributes.

The coverage data model, in 1981, Environmental Systems Research Institute, Inc. (ESRI), introduced its first commercial GIS software, Arc-Info, which implemented a second generation geographic data model, the coverage data model (Zeiler, M. , 2007). Arc Info 8 introduces a new object-oriented data model called the geodatabase model. The defining purpose of this new model is to let you make the features in your GIS datasets smarter by endowing them with natural behaviors, and to allow any sort of relationship to be defined among features.

The purpose of a geographic information system (GIS) is to provide a spatial framework to support decisions for the intelligent use of earth's resources and to manage the man-made environment (Zeiler, M. , 2007). According to Abdul-Rahman and M. Pilouk (2008), spatial data were stored in GIS by three components: geometric data, thematic data and link identification (ID) for the geometric and the thematic component. GIS technology that offers the combined power of both geography and information systems is an ideal solution for effective management of water industry infrastructure (Shamsi, U., 2005). Identify the enterprise needs, evaluate the system for feasibility, perform economic and technical analysis, allocate functions to system elements, and establish schedules and constraints create system definitions (Girma, A. B. , 2019).

Geodatabase used to organize geographic data into a hierarchy of data objects; those data objects are stored in feature classes, object classes, and feature datasets. A feature class is a collection of features with the same type of geometry and the same attribute. An object class is a table in the Geodatabase that stores non-spatial information and a feature dataset is a collection of feature classes that share the same spatial reference. Feature classes that store simple features can be organized either inside or outside a feature dataset. Simple feature classes that are outside a feature dataset are called standalone feature classes. Feature classes that store topological features must be contained within a feature dataset to ensure a common spatial reference (Sherbrooke, 2008).

Geodatabase model is a new data model allowing smarter features to be made in the GIS dataset by endowing them with natural behaviors and allowing relationships to be defined among features. There are three type of geodatabase; which are personal geodatabase, file geodatabase and enterprise geodatabase see below comparison of geodatabase source Esri documentation.

i. File Geodatabase in ArcGIS: is single-user and small workgroups, many readers or one writer per feature dataset, stand-alone feature class, or table. Concurrent use of any specific file eventually degrades for large numbers of readers. A collection of various types of GIS datasets held in a file system folder. This is the recommended native data format for ArcGIS stored and managed in a file system folder. It has cross-platform and file system management database administration tools.

Each dataset is a separate file on disk. A file geodatabase is a file folder that holds its dataset files. One TB for each dataset; each file geodatabase can hold many datasets. The 1 TB limit can be raised to 256 TB for extremely large image datasets. Each feature class can scale up to hundreds of millions of vector features per dataset. Only supported as a geodatabase for clients who post updates using checkout and check-in and as a client to which updates can be sent using one-way replication.

ii. Enterprise geodatabase: *A* collection of various types of GIS datasets held as tables in a relational database (This is the recommended native data format for ArcGIS stored and managed in a relational database). This database is a multiuser or many readers and many writers. The Enterprise geodatabase were stored in the form of Oracle, Microsoft SQL Server, IBM DB2, IBM Informix and Postgre SQL formats. It is fully supported across all DBMSs; includes cross-database replication, updates using checkout and check-in, and historical archiving. Database administration tools is full DBMS functions for backup, recovery, replication, SQL support, security, and so on.

iii. Personal geodatabase: Original data format for ArcGIS geodatabase stored and managed in Microsoft Access data files. (This is limited in size and tied to the Windows operating system). Single user and small workgroups with smaller datasets: some readers and one writer. Concurrent use eventually degrades for large numbers of readers.

All the contents in each personal geodatabase are held in a single Microsoft Access file (.mdb). Two GB per Access database; the effective limit before performance degrades is typically between 250MB and 500MB per access database file. Only supported as a geodatabase for clients who post updates using checkout and check-in and as a client to which updates can be sent using one-way replication.

2.1.3.2. Geodatabase design Process

Geodatabase design and creation is one of the fundamental process in every GIS work executed. It is the process by which real world entities and their relationships are analyzed and modeled in order to solve specific problems and find solution to questions of interest. A database is designed to service the need of a group of users (Zofka A., 2014). Such needs are called the information needs of the users or the user requirements. The heart of a geographic information system is a well-structured database i.e. spatial database. The process of designing a database is called data modeling. The design phase consists of three levels, i) Conceptual Design, ii) Logical Design, and iii) Physical design (Kufoniyi, O, 1998). It gives a breakdown of the design phase to include conceptual, logical and the physical designs, while the construction phase is as a collector of the logical and physical designs data stored in the spatial database.

This is the presentation of human conceptualization of reality in a simplified manner to meet the information requirement of the application (Kufoniyi, O, 1998). The objective is to determine the basic entities, the spatial relationships among the entities and the attribute of each entity that support the process and application for which the database is designed. Conceptual design is a modeling of the projected system that is independent of implementation of the data method that is to be used for the conceptual modeling and it must enable analyst to express the structure of information in the system (data type and relationship). It is an arrangement of human conception of reality and is decided by the human on how to present it in a simpler manner but still will satisfy information required of the GIS concerned.

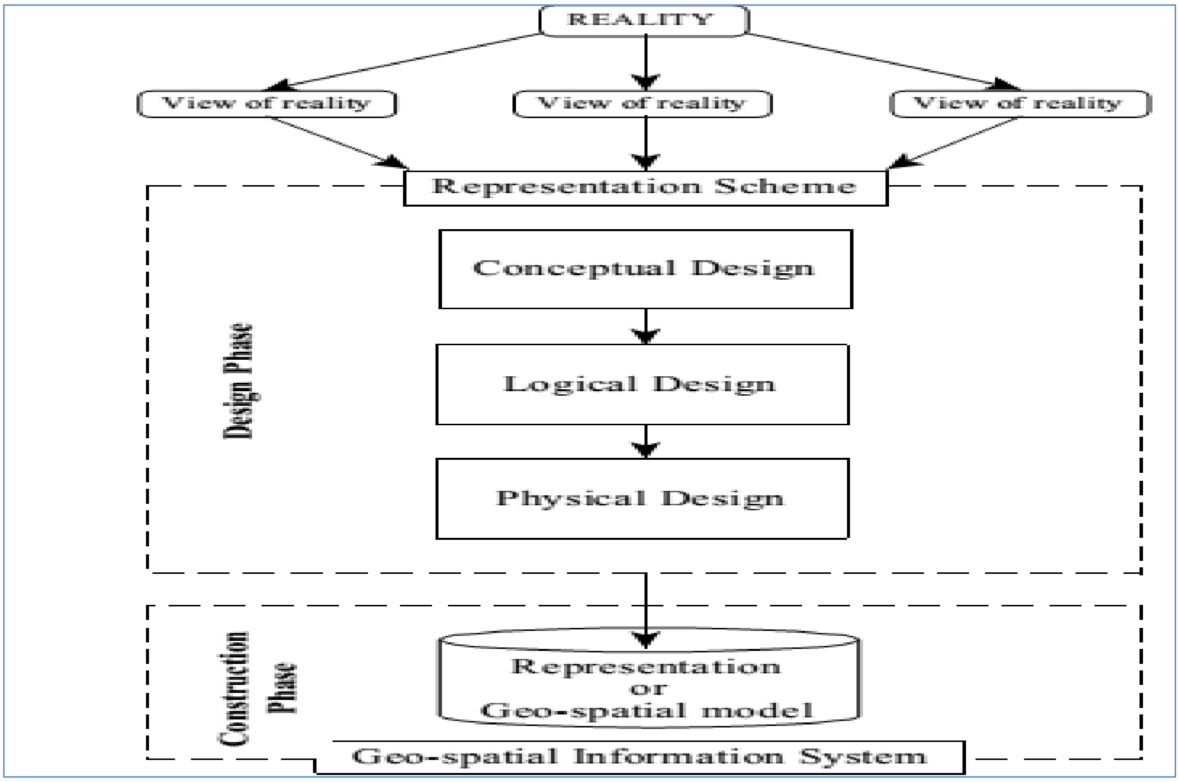


Figure: 2. 4. Data design phase sourced (Abdul-Rahman and M. Pilouk, 2008)

2.1.4. Road Network Prioritization

2.1.4.1 Multi-Criteria Decision\ Analysis (MCDA) method

Multi-Criteria Decision\ analysis (MCDA) method affords decision makers the opportunity to analyses possible alternatives based on multiple factors (Eastman, 2009). MCDA was therefore adopted for the network section prioritization. The criteria is to select sections of roads that need maintenance based on the severity and the extent of surface distresses, the class of the road section and the traffic volume. Weights were then assigned to the three major criteria identified to be the major contributing factors in the network prioritization.

The road sectional condition was rated higher than the other two criteria, traffic condition and the road classification factor. The road four road classes in the city, major arterial, minor arterial, collectors and local roads were rated according to the its importance. Similar ratings were done for the road surface condition and road traffic volume.

The other criteria are PCI value, after pavement condition evaluation, next step of a PMS process is identifying the maintenance activities required to restore pavements' serviceability. In general terms, PCI based systems can easily identify network-level maintenance categories. Typically, pavements below a PCI of 40 require reconstruction due to the significant structural damage (AASHTO,1990).

Pavements with a PCI of 40 to 70 can benefit from rehabilitation activities like overlay. If the pavement has a PCI score of above 70 and has not been damaged from load related distress, it can be recovered by performing preventive maintenance like crack sealing (Federal HighwayAdministration,1999). These numbers might be slightly different for arterial, residential and rural roads. Weights were assigned to the individual ratings for each criterion used. The weights were then aggregated and the results used in the prioritization process. PAS and RR in fair condition with a high volume of traffic has higher priority than SAS, CS and LS road section in the metropolis with a high volume of traffic but in fair condition. The road network was categorized into three for management purposes with different colors for visual analysis and display. Policy makers use the results of the prioritization process to schedule maintenance activities. The system is user friendly, cheap and one need not to be a database expert or an expert in GIS before he/she can operate it. If implemented, it will help decision-makers in making decisions interactively with the aid of visualization of data in GIS without requiring any specialized technical skills.

2.1.5. WebGIS

WebGIS is the process of designing, implementing, generating and delivering maps on the World Wide Web by combining both the advantage of GIS and the internet (Wikipedia, 2010). GIS integrates and relates data with spatial component and supports users to view in proper format which supports in making complex spatial decisions through visualization, interactive modeling and analysis environments. GIS is thus far utilized to help with perception and understanding of spatially distributed phenomena in many areas of decision making and evaluating problems (Finn *et al*., 2004; Zofka, 2014). Generally, GIS systems were considered as monolithic and platform-dependent applications (Wong *et al*., 2002). The development and rapid growth of web and web based application created a new platform for traditional GIS to grow and spread. Unfortunately, not everyone has access to GIS, nor would be able to spend time necessary to use it effectively. WebGIS became a cheap and easy way of disseminating geospatial data and processing tools (Khadaroo *et al*., 2002).

WebGIS have the highest number of users, although typically internet users focus on simple display and query tasks (Goodchild *et al*., 2005). The capability of webGIS for interacting dynamically in distributed environment from cross platform to client/ server computing system made it more interesting to develop and use for accessing spatial information. The major development of cartography is using web as a distribution. By the means of web, now it has opened the possibility of the availability of real-time maps, cheaper maps sharing, more frequently updated database sources and cheaper software and hardware requirement. There are some problem and difficulties for fully development of web mapping. Some technical difficulties such as bandwidth, lower resolution of image are common. Reliability issues and security issues are limited the expansion of web mapping.

The development of web cartography and GIS is steady as compare to web technologies. Web 2.0, a new generation of internet services and technology (Deshpad, 2012), support user interaction significantly. This evolution leads GIS away from data browsing, analyzing and managing for individual decisions, and more towards group participating and communicating on social decision issues. As (Zofka *et al*., 2004) describe the public participation GIS principles as accessibility, understandability, and accountability, webGIS continues to draw attention as a public participation tool. Nowadays, Google Maps, Google Earth, Open Street Map, Yahoo Maps, Microsoft's live search maps and other many commercial as well as noncommercial applications provide many kinds of geographical related information such as detailed maps, satellite images and terrain maps covering all over the world and allow users to use their APIs (Dang, 2000).

2.1.5.1 WebGIS Architecture

The basic approach for deploying webGIS application depends on the user requirements that have to concern with which webGIS packages are suitable to accomplish their objectives

(Phisan, 2001). Developments of webGIS are changing as fast as internet and Web technologies. According to Dang, (2000) there are basically two types of architectures for developing web based GIS applications client side, and server-side.

2.1.5.2. Server-Side Strategy

In a server-side webGIS application, a Web browser is used to generate server requests and display the results on client-side browser. As it is shown in figure 2.5 users interact with the client machine and type the address they are looking for (the request), which is transferred to the webserver. The webserver passes the request to the GIS application server, which runs an address matching routine, generates a map graphic, convert the graphic to web format, wraps the image in HTML and sends it back to the webserver, which then returns the response to the client as a standard webpage.

Map data transmitted to a Web client are in standard HTML formats that can be accessible through any web-browser, creating significant positive implications for performance, reliability and size of user base. Because of the entire complex and proprietary software, as well as the GIS databases resides on a server, it is easier for simplified application development in server-side applications for deployment and maintenance of data. But server-side solutions are primarily associated with poor performance and limited user interface and interaction years to use their APIs (G. Zhou, 2011).

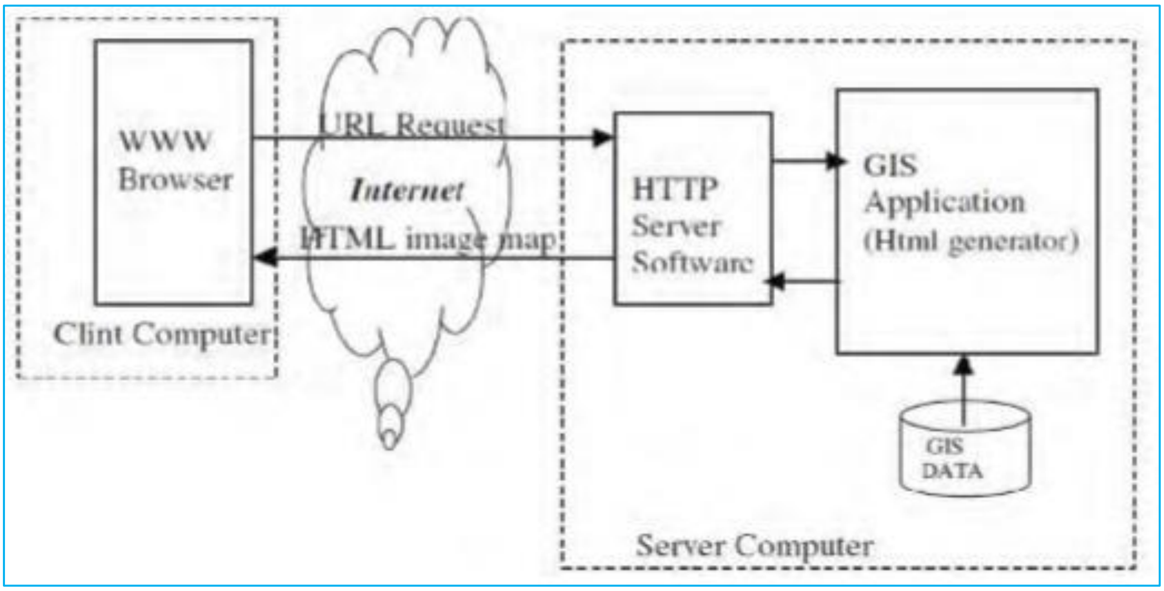


Figure: 2. 5. Server Side Architecture

2.1.5.3. Client-Side Strategy

Client-side webGIS applications can provide full GIS analysis and management support to specific users within business, government or public sectors. In a client-side webGIS application, users are required to install a complete client application. In such systems, either a substantial amount of GIS functionality is moved to the client, or only the user interface is enhanced slightly to enable specific user interaction. In either case client-side application require software of some kind (other than browser) to be transferred to the ser. In client-side webGIS, the client system should be enhanced to support GIS operations. That is, to implement client-side solutions, software must be transferred to the client (Dang, 2000). As it is shown in figure 2.6 in client-side webGIS, the main tasks will be processed in the server, which is basically delivering files. The server receives request from the client and starts to communicate to the database and retrieves attributes of the map stored in the database. The GIS application server has also direct access to the map file. The map file could be SHP, DXF, etc. and used to create map files like lines, point, area and labels. The server provides the client with raw data map and HTML image. The primary advantages of client-side solutions are improved performance.

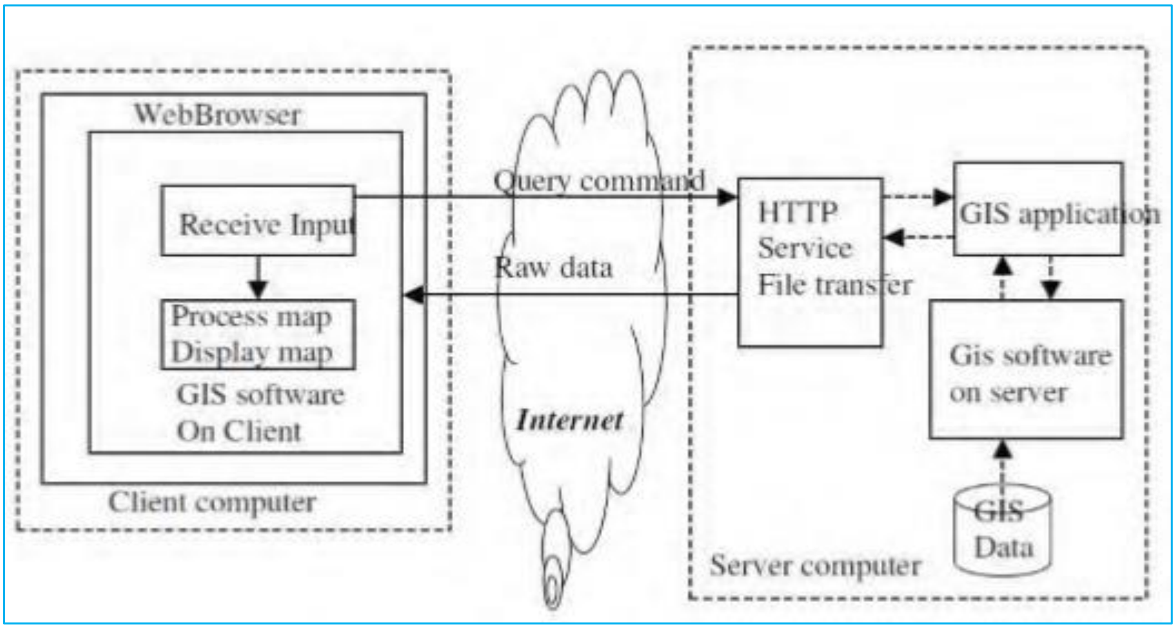


Figure: 2. 6. Client-Side Web GIS

2.1.5.4. Available Technologies for WebGIS

Web based GIS being one of the newest fields in Geographic Information systems. Different software and technologies are being developed in both commercial as well as open source. For commercial purposes commercial companies develop well documented software that contain advance features but the price for that technology is high while open source system is developed by communities and can be used free of charge by having poor documentation. Open source system is developing rapidly with the involvement of large number of people. The major technologies involved in the realm of webGIS today are (Detwiler, 2009).

Commercial: ArcGIS Server by Environmental Research Institute (ESRI), Geo Media Web Map by Intergraph, Map Xtreme by MapInfo and Map Guide by Autodesk.

Open source: Geo Server, Map Server, chameleon, Open Layers, Scalable Vector Graphics.

Public APIs: Google Maps, Yahoo Maps, Microsoft Virtual Earth (2D).

2.1.5.5 Open source software for web-based GIS

Open source software are programs whose licenses give users the freedom to run the program for any purpose, to modify the program, and to freely redistribute either the original or modified program without further limitations or royalty payments (http://www.opensource.org). There are many open source software available to develop the web based GIS. The descriptions on software below are some of them selected to be used in this paper.

Map Server: is an open source development environment for building spatially enabled internet applications. It can run as a CGI program or via map script which supports several programming languages. Map server was developed by the University of Minnesota so, it is often and more specifically referred as "UMN map server", to distinguish it from commercial "map server" (David Fawcett *et al*., 2010).

Anatomy of a map server application: A simple map server application consists of:
Map file*:* it is a structured text configuration file for map server application. It defines the area of the map, tells the map server program where the data is and where to output images. It also defines the map layers, including their data source, projections, and symbology.

Geographic Data*:* Map server can utilize many geographic data source types. The default format is the ESRI shape file.

HTML-Pages: the interface between the user and map server. They normally sit in Web root. In its simplest form, map server can be called to place a static map image on a html page. To make the map interactive, the image is placed in an html form on a page.
CGI programs are ‘stateless’, every request they get is new and they don’t remember anything about the last time that they were hit by the application. For this reason, every time your application sends a request to map server, it needs to pass context information (what layers are on, where you are on the map, application mode, etc.) in hidden form variables or URL variables. A simple map server CGI application may include two html pages: initialization file uses a form with hidden variables to send an initial query to the http server and map server. This form could be placed on another page or be replaced by passing the initialization information as variables in a URL; template file controls how the maps and legends output by map server will appear in the browser.

By referencing map server CGI variables in the template html, you allow map server to populate them with values related to the current state of your application (e.g. map image name, reference image name, map extent, etc.) as it creates the html page for the browser to read. The template also determines how the user can interact with the map server application (browse, zoom, pan, and query). Figure 2.7 shows basic architecture of map server applications.

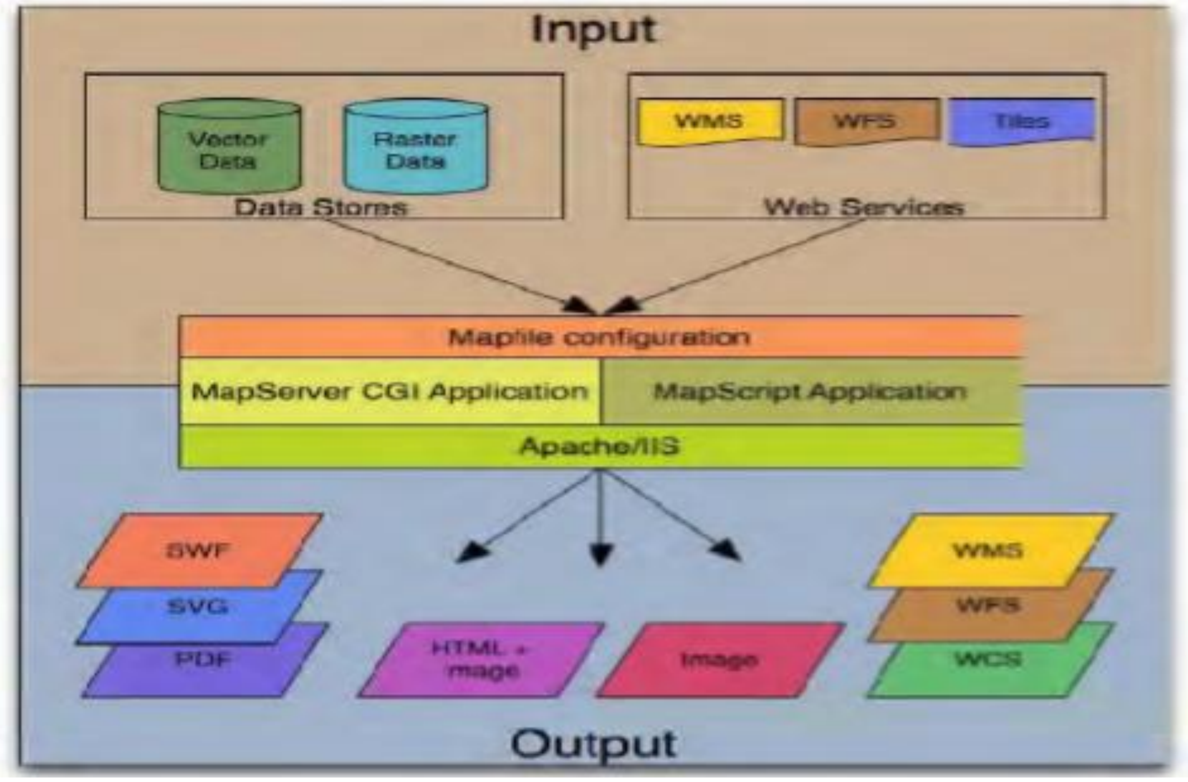


Figure: 2. 7. Basic Architecture of Map server Applications

Map Server CGI*:* The binary or executable file that receives requests and returns images, data, etc. It sits in the cgi-bin or scripts directory of the http server. The web server user must have execute rights for the directory that it sits in, and for security reasons, it should not be in the web root. By default, this program is called map server.

HTTP Server: serves up the html pages when hit by the user's browser. You need a working HTTP (web) server, such as apache or Microsoft internet information server, on the machine on which you are installing map server.

2.1.5.6. Chameleon

Chameleon is an open source, distributed, highly configurable, environment for developing web mapping applications (http://www.mapcruzin.com). It is built on map server as the core mapping engine and works with all map server supported data formats. It also works well with open GIS consortium standards for web map server WMS and web map context documents (WMC) through map server support for these standards.

Chameleon has a plug-in architecture. A large number of plug-ins, or widgets as they are called by the chameleon developers, are available. A Chameleon widget can implement a mapping task such as zooming, panning, showing legends, or displaying map coordinates. Over a hundred widgets are distributed with the application and developers can easily create their own widget for any specific task.

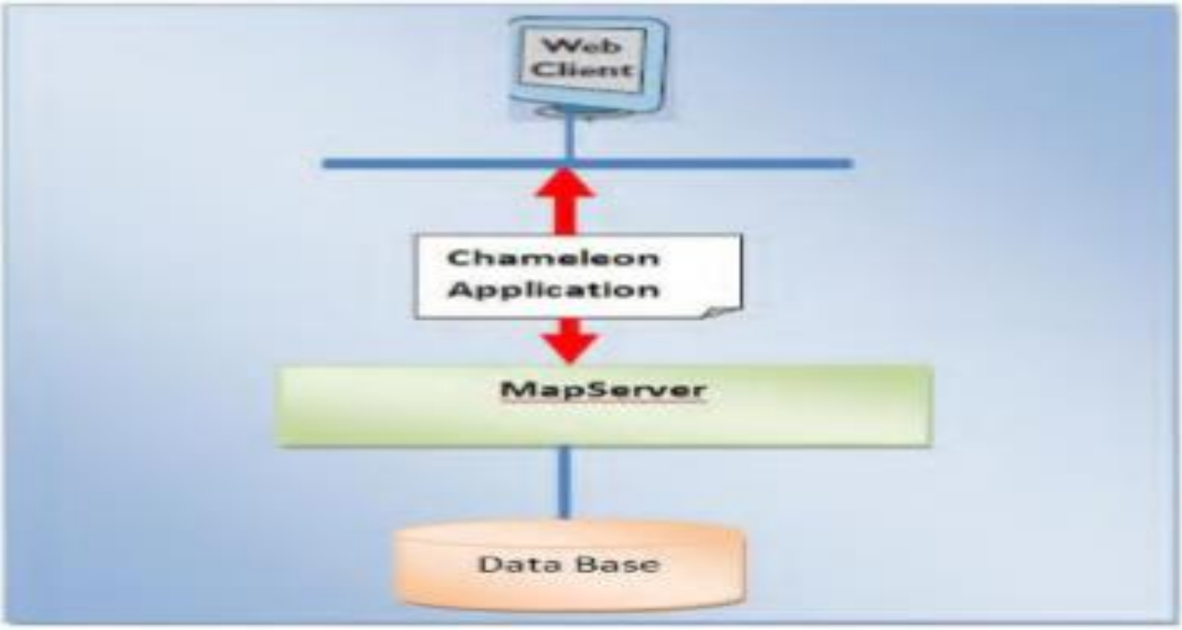


Figure: 2. 8. Shows a typical Configuration of a Chameleon using Map server

2.1.6. PMS/GIS Integration

Since geographical information systems with their spatial analysis capabilities, match the geographical nature of the road networks, are considered to be the most appropriate tools to enhance pavement management operations, with features such as graphical display of pavement condition. Nowadays, as GIS is increasingly used in public authorities, there is a growing trend toward integrating PMS data into the GIS. With the technological advances in computer hardware and software, this integration is becoming more realistic. Advantages of such integration include flexible database editing and the ability to visually display the results of database queries, statistics and charting, pavement management analyses on a map of the highway network, view network conditions through dynamic color-coding of highway sections, and access sectional data through the graphical map interface (Deshpad, 2012).

2.2 Pavement Management System in Addis Ababa City Road Authority

2.2.1 Overview of Addis Ababa City Road Authority

Addis Ababa, the capital city of Federal Democratic of Ethiopia, is located at the center of the country .The city was founded by Emperor Minellik II and Empress Tartu in 1987.Minellik II constructed the first ever two roads in the city as well as in the country that stretch from Addis Ababa to Addis Alem and from his place to British embassy in 1902.

The country's modern road construction is highly interlinked with Emperor Haile Sellase's ruling period. During the regime of Haile Sellase a number of contractors were organized to carry out road construction. When it was decided for Addis Ababa to have a mayor and a council in 1942, the city roads construction and maintenance was organized under the municipality. To fulfill the road construction activities together with building works the "Road and Building Works" department was established. This department stayed till the replacement of the Haile Sellase regime by the derge regime performing its duties. But no fundamental organizational change of the department was observed in the Derge regime.

In 1993 the EPRDF has established regional governments and gave them power to administer their regions with autonomy. During this time Addis Ababa was also established as one of the regions. The Addis Ababa Administration during this period established the "bureau of works and urban development" and the bureau organized a department under it to carry out the road construction and. maintenance works. The newly established road department constructed and maintained the city roads till the establishment of the Addis Ababa city Road Authority in March 15, 1998 by regulation No. 7/1998 to be administrated by board of directors to construct maintain and administer the road work in Addis Ababa by the city Administration.

Addis Ababa lies at altitude of 7,546 feet (2,300m) and is a grassland biome, located at coordinates: 9°1´44´´N, 38°44´24´´E 9.03°N, 38.74° E9.03; 38.74 the lowest point, around Bole International Airport, at 2,326 meters (7,631ft) above sea level in southern periphery, the city rises to over 3,000 meters (9,800ft) in the Entoto mountains to the north.

According to the 2007 national census, the population of Ethiopia has reached73, 909,355 of which urban population was 11,956,170 accounting for 16.1% of the total population. Having a growth rate of 2.1%, the population of Addis Ababa was 2,738,248 which accounted for 32.27% of the total urban population of the country (Central Statistics Agency, 2010). The expansion of the city, increasing population size coupled with the economic growth has required respective transport service supply for the increasing mobility needs of the People.

According to (Alebachew 2005), the road construction and maintenance works in Addis Ababa until1996 were not organized with proper human power, equipment and material resources. Such inadequate resources coupled with organizational shortcomings within the municipality such as lack of formal policy and standards for road Construction and maintenance has resulted in substandard maintenance services which directly or indirectly affect the pavement performance as follows.

- Materials and construction quality control & tests were not performed at all. As a result, it was not uncommon to encounter pavement failures distresses within short time after the new roads are opened to traffic.

- Different administrative bodies of the city government such as Higher, Woreda, Kebele and other agencies constructed most of the Road network without following the master plan and appropriate standards.

- Lack of integrated infrastructure development is the other problem affecting the road network. There is no proper coordination with local Agencies, which carry out utility constructions such as water works, telephone lines, power lines, sewer lines and etc. Due to this, there is repetitive destruction of the existing road pavement and drainage structures, which consequently cause bumps, sags, patch deterioration another damages on the asphalt due to water infiltrating in to the cracks. In addition to the above shortcomings related with the network, the road construction and maintenance has the following problems:

- No proper pavement evaluation,
- No proper quality control during construction and maintenance
- No coordination between different bodies involved in the road construction and maintenance.
- Do not comply with the city master plan, appropriate design standards and construction practice,

2.2.2. Pavement Management System in AACRA

AACRA has Road Asset Management Department which is responsible for the management of pavement. Although, they were started using Pavement Management System software before six years ago, unfortunately the system collapsed before it becomes well practiced by the Authority.

From the basic pavement management processes components discussed in chapter 2. They have road network inventory data for rods being managed by the Authority and condition survey data in spreadsheet in hard and soft copy. However, there was no method to predict the future condition of the road segment to estimate the average rate of deterioration. And which in turn has significant role for scheduling short term and long term plans. Moreover there was no efficient and effective system for prioritizing and selection the appropriate treatments for the roadway network and its networks. However; AACRA is currently attempting to use matrix method of prioritizing maintenance. Concerning the road treatment; the only treatment they were used includes; patching and overlay irrespective of cost benefit analysis, pavement age and traffic condition and so forth.

The asset management department defines the segment of the roadway to be maintained either by patching or overlay with the respective unit cost which will be given to the maintenance department to be maintained. There was no detail and well defined working methodology, material specification and maintenance design etc. Maintenance activities are not yet been exercised to be outsourced to other companies, AACRA perform the activities by their own forces. From the above facts during the study period Addis Ababa city was not benefited from the merits of well-established pavement management system.

2.2.3 Road Maintenance Management System (RMMS) in AACRA

Road maintenance management system is not a new concept for AACRA.in 2004 AACRA attempted to introduce a Snowy Mountain Engineering Corporation (SMEC) RMMS based on HDM-4, but this attempt was failed due to: considerable number data was required, no trained staff in AACRA (resign, turnover) and system cannot be customized. Since 2010, after SMEC was failed road maintenance management system of AACRA has become very poor and prone to many problems .in order to improve these poor road maintenance management system collaboration agreement was signed between AACRA and JICA in July 2015 for development of road maintenance capacity of Addis Ababa. The purpose of the project is to enhance the management capacity of AACRA for road maintenance. The expected outputs of the project are to: development of road data base which involves setup target road (start point and end point), formulate inventory and condition survey information, preparation of survey schedule and staff assignment. Establishment of road maintenance management system: procedures in RMMS are given in figure below.

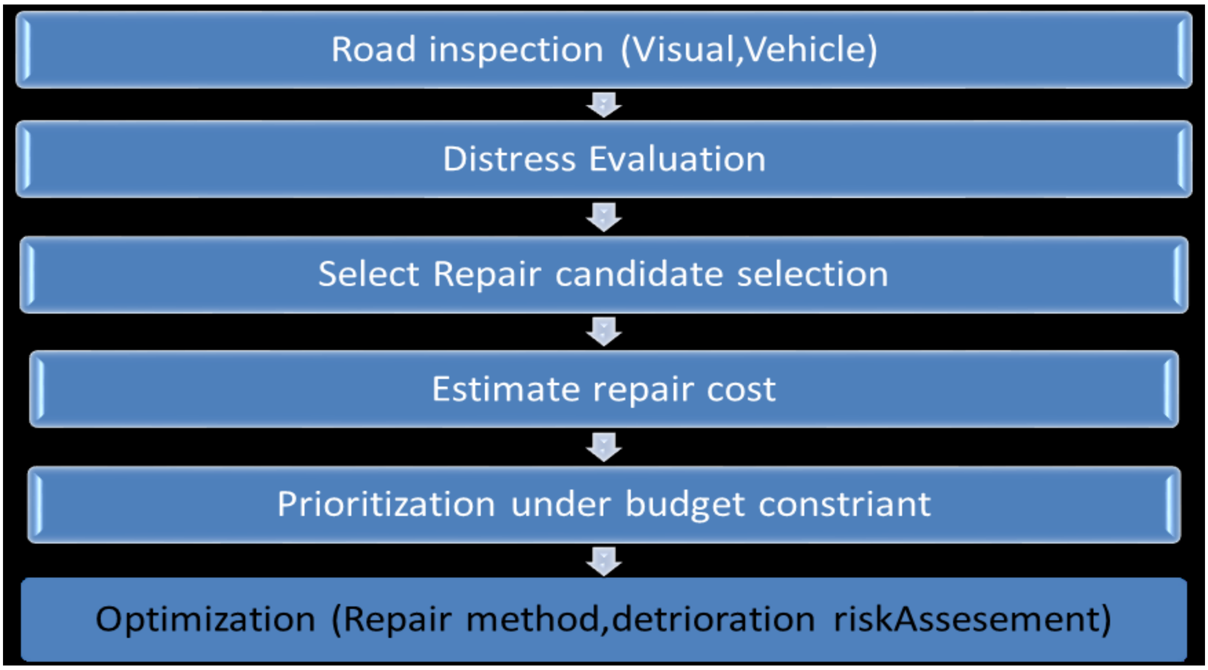


Figure: 2. 9. Procedures in RMMS [Source: (AACRA Seminar Report, 2014)]

In AACRA there is a lot of department from this department of Road Maintenance responsible for performing routine and periodic maintenance works throughout the city. The department develop schedule for the maintenance activities to be done either pouching or overlay which is already specified by road asset management department. The maintenance activates are usually done on night time. The available resources at the department in terms of technical skills, other supportive and administrative human resources, the quantity and existing condition of equipment are the backbone for its capability to carry out the road maintenance and rehabilitation programs. Currently, AACRA road maintenance department held 3 engineer 2 technician 5 Forman and 35 machine operator, totally in this department above 45 permanent employs are participate in the overall asphalt pavement maintenance work.

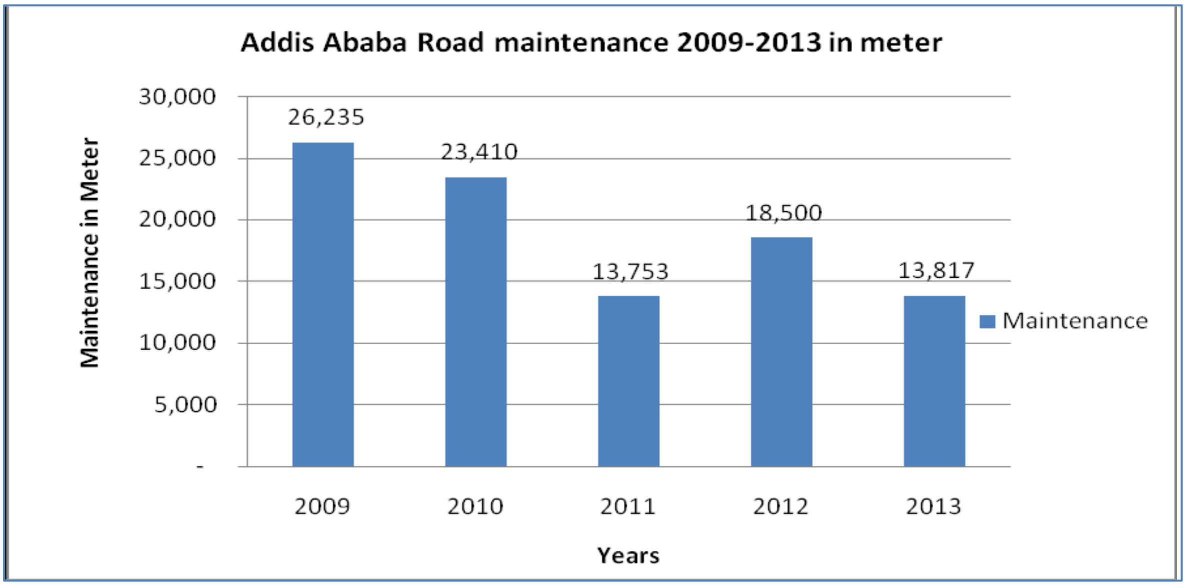


Figure: 2. 10. Asphalt maintenance per year in meter

2.2.3. Pavement Evaluation in AACRA

In order to carry out pavement rehabilitation and maintenance, firstly the existing pavement condition must be evaluated. Such an evaluation usually involves the assessment of the existing pavement structural, functional, surface condition and safety concerns using visual assessment, none destructive testing, destructive testing and so forth. Pavement evaluation techniques differ between different countries and highway agencies, they are more focused on establishing the root causes of existing distress in order to determine the best rehabilitation strategies.

At the time of this study, ACCRA Road Management Team is responsible for pavement evaluation and it is done on yearly bases using condition survey by visual method and encoding in spread sheet which comprise; street number, street name, total length, road type, defect type, defected area detail (i.e., specific area, length width, and condition).

They perform condition survey for all types of roads, walkways, drainages, and bridge with a team composed of three data collectors (technicians) and two engineers. This condition survey crew covers 2-2.5km per day. After visual condition survey the pavement condition become summarized and reported as very good, good, fair, poor, very poor and also by types of distress. The maintenance type required, unit rate and maintenance priority will be defined and reported to the maintenance department.

There is no destructive and none destructive test procedures for structural, functional and safety evaluation other than visual surface condition evaluation method which plays significant role in identifying major causes of distress for recommending the best option for maintenance and rehabilitation decisions.

2.3. Empirical Review

Mutai H. and Dr. Johnmark O. (2018) conducted with the title of "*The effect of road assets management on performance of road agencies in Kenya"*. The study was guided by stakeholder theory and it posited a conceptual framework in which road assets management was the independent variable, road agency performance the dependent variable. A correlation survey design was employed to find out the relationships between the studies variables. A purposive sampling technique was used to select the respondents for the study and data was collected using structured questionnaire. Results showed that RAM was a positive and significant predictor of road agency performance in Kenya and it accounted for 81.7% of variance in performance of the road agencies in Kenya. The study concluded that RAM contribute significantly to road agency performance and recommends that RAM should be integrated in the policies of road agencies in Kenya in order to realize better condition of roads in Kenya in the long run.

According to Organization for Economic Co-operation and Development (OECD , 2001) road network constitutes one of the largest community assets and is predominately government owned. Road agencies must maintain, operate, improve, replace and preserve this asset while, at the same time, carefully managing the scarce financial and human resources needed to achieve these objectives. All of these are accomplished under the scrutiny of the public who pay for and are regular users of the road network, and who increasingly demand improved levels of service in terms of safety, reliability, environmental impact and comfort. Governments are therefore placing greater pressures on road administrations to improve the efficiency of, and accountability for, the management of the road network (OECD , 2001).

Queiroz, C., & Kerali, H, (2010), carried out a comprehensive review on "*Institutional arrangements for road asset management providing lessons for the developing world"*. This paper reviewed such arrangements for selected countries including China, Brazil, Slovenia, New Zealand, United Kingdom, and the Slovak Republic. These countries had adopted different approaches of road asset management in several dimensions, such as decentralization, sources of financing, management structure, and modal responsibility. The paper reviewed main factors affecting the efficiency of road agencies and described the steps taken in creating a new institution, or transforming an existing one, and assessed the efforts required to achieve such results. The main aspects of institutional reforms that contributed to increased efficiency of road and transport agencies included improved institutional structures, separation of the client and supplier functions, separation of client and supplier organizations, privatization of the supplier organizations, establishment of an executive agency or a commercialized (client) organization, user participation through oversight boards, improving management information systems, and seeking additional sources of financing.

Banyenzaki, M., (2016), examined the use of "*contract management practices and performance of the road construction projects in Wakiso district-Uganda"*. The main aim of the study was to examine the role of monitoring intensity in enhancing performance of the road construction projects in Wakiso district and to analyze the relationship between risk management and performance of the road construction projects in Wakiso district. The findings indicated that there was a significant positive relationship between monitoring intensity, risk management, evaluation and performance of road construction projects in the study context. The study recommended that there should the intensity of monitoring should be enhanced for construction projects to attain the expected performance standards.

Byaruhanga, A., & Basheka, B. C., (2017), conducted a study on "*Contractor monitoring and performance of road infrastructure projects in Uganda and developed a management model*". The objectives of the study were to assess the relationship between contractors monitoring and performance of national road infrastructure projects and the relationship between contractor monitoring components and performance of national road infrastructure projects in Uganda. Purposive sampling was employed in selecting the procurement professionals, engineers and simple random sampling was adopted in selecting private consultants, members of parliament and respondents from the civil society organizations. The findings revealed that weak procurement rules which lead to awarding road projects to incompetent contractors; contractor monitoring being handled by unqualified, incompetent and inexperienced professionals; lack of contractors and contract supervisors appraisal system; delay of contractors payments which affects timelines in services delivery; lack of a strong internal project monitoring and evaluation mechanism at the Uganda National Roads Agency (UNRA).

Kamau, C. G., & Mohamed, H. B, (2015), did a study on "*The efficacy of monitoring and evaluation function in achieving project success in Kenya*". This paper was set out to review literature on the efficacy of monitoring and evaluation in achieving project success in Kenya. The researcher used literature review approach to analyze the factors related to M&E influencing project success. All the factors identified were grouped into four main categories which included strength of M&E team, monitoring approach adopted, political influence and project lifecycle stage. The study revealed that management support is a mediating factor between M&E and the Project Success and emphasized that a good performance monitoring and evaluation without management support is likely not to succeed.

Wairimu (2016) conducted a study on factors influencing completion of road construction projects in Embanks, Nairobi county Kenya. The study aimed to highlight factors that influence completion of road projects. The study focused on how resources, competency of staff, stakeholder participation and procurement procedures influence completion of road construction projects. The research design used was descriptive research design. The findings revealed that competency of staff positively influences completion of road construction projects since if the staff have the required skills, experience and knowledge in the area this would help them undertake the task placed on them. It also found out that stakeholder participation positively and significantly influences completion of road construction projects and that stakeholders should be encouraged to participate in road projects.

Geddes, *et al*., (2016) reviewed economic growth through effective road asset management. The main purpose of the project was to review literature and report on existing and recent road management and maintenance programs and identify 'what works' and 'what doesn't work' in the type of environment likely to be encountered in the project area. The approach to the project was intended to foster self-reliance in road agencies in the project areas and encourage greater accountability to road users and other sector stakeholders.

Sodikov & Jamshid (2015) conducted a study on "*Road asset management systems in developing countries with specific reference to Uzbekistan*". The study explored the key issues on how to manage existing assets in way that it delivers maximum benefit to public taking into account limited financial resources. Road asset management system was reviewed from perspective of four major components such as goals, budget, asset and performance. The study established that there are several issues at policy level of analysis such as set up long term goals, expansion of road network, traffic safety action plans, environmental impact analysis, economic development and other; at budget level to plan year and multiyear financing plan, budget breakdown and cost estimation; at data management level inventory and condition data collection, database management, traffic data and other; at performance modeling level to predict future condition, network level analysis and other; at programmed optimization level to perform economic, environmental and risk analysis, multi-criteria analysis and other; implementation programs to carry out construction, maintenance and operation of road assets.

Arif & Bayraktar (2012) did a theoretical framework for "*Transportation infrastructure asset management based on review of best practices*". The study provided a review of the best practices adopted by different transportation infrastructure agencies internationally and in the United States. The review showed that the front-runners in the asset management system internationally are Australia while Michigan takes the lead in US. Finally, based on the review of best practices, a theoretical framework for transportation infrastructure asset management was proposed. The framework focused on six important aspects of an asset management system i.e. asset management organization and concept, planning, contractual arrangement and mechanisms, monitoring and performance measurement, information systems and decision making.

Zanule, P. G. (2015) carried out a study on "*Road management system and road safety in Uganda*". The purpose of the study was to describe the strategies and processes needed to implement a road management system that would significantly reduce the fatalities and accidents in Uganda. The study was anchored on management theory, strategic management theory and criminology theory. The action requirements that emerged from data analysis were that there is need to improve transport operations and transport services profitability, reduce traffic jams and fatalities, provide sufficient driving training and maintain road infrastructure.

Yetnayet Bihon (2017) conducted his study on the title *"Investigation of Road Asset Management Practices in Ethiopia the Case of AACRA, 2017"*. The findings of the study revealed that there is lack of: Asset management system components implementation rated as low with a result of 54.5%, 63.6%,64%,82% and 73% respectively except condition assessment rated as medium with a result 45.5%,technologies like individual management system implementation in AACRA is in the planning phase as the response of the seven (7) professional in aggregate revealed, Integration of those management systems also is not there yet, Decision making levels are not explicitly defined in AACRA except programming and budgeting level rated as 54.5%. 91% of respondents revealed that there is lack of professional associations, conferences, short courses and 73% of the respondents disclosed that there is lack of organized asset management department. Some of the specific recommendations forwarded are decision making levels should be explicitly defined, applying different individual management systems and integration of those management systems is necessary and etc. Finally framework and organizational structure were developed for effective and efficient Road Asset Management.

Emad A. (2016) conducted the study on title "*GIS-based pavement maintenance Management model for local roads in the UK*". The study were used, multi-criteria Decision Making (MCDM) approach is used to handle the trade-off between conflicting factors. It is processed in the Analytical Hierarchy Process (AHP) using Excel software, and the database developed in excel is then imported into GIS in order to allow ease of query, analysis and visualization of results. The main key output of this research will be the development of a GIS-based pavement maintenance management model to support decision making in pavement maintenance management. The most important factors influencing decision making in pavement maintenance management are established through a nationwide questionnaire survey, which is undertaken among the UK local authorities' pavement maintenance experts. 14 factors were identified, which are: remaining service life, road condition indicator (RCI), type of deterioration, observed deterioration rate, traffic diversion, importance of road/classification, annual average daily traffic (AADT), possible conflict or overlap with other road works, risk of failure, safety concern, accident rate (related to surface condition), scheme cost, available budget/funding and whole life- cycle cost. Interviews were also conducted with experts in pavement maintenance within different local road authorities to justify the rated factors affecting pavement maintenance prioritization.

Lucia R., Dan Andrei Sitar T., Sergiu J. (2015) conducted the study on title "*An Integrated Solution for Pavement Management and Monitoring System".* The aim of this paper is to present a holistic platform for pavement monitoring and maintenance management (PMMP). Our solution tries to exploit new technologies in order to design, integrate and implement an automated and portable visual road inspection system for traffic-speed pavement distress monitoring and analysis that can be installed on non-specialized vehicles. PAV3M developed based on solution based on PMMS requirements and recommendation made in EU programs as a modular decomposition based on business process analysis. For road monitoring and maintenance we opted for LCCA methods. Our solution includes Risk management module.

George C W., George T. (2014), the paper describes "*PMSView, a customizable, web-based, pavement management system, and its early implementation for the Washington State Department of Transportation (WSDOT)*". *PMSView* is an Internet application that allows pavement related data to be accessed and analyzed from any geographic location through a straightforward navigation and display scheme on a web browser. *PMSView* extends beyond the typical pavement management boundary by providing the ability to incorporate pavement design, construction, and usage data into the interface. *PMSView* can be populated through a wide variety of electronic data sources, including spreadsheets, existing databases and mainframes, map-based spatial data, among others. *PMSView* also supports the use of multimedia, such as digital roadway images or video and can be integrated into legacy systems.

Temesgen Girmay (2016) conducted a research titled with "*Asphalt Road Pavement Rehabilitation and Maintenance Case Study in Addis Ababa City Roads Authority*". In conclusion, the finding of this study implies that Addis Ababa City Roads Authority doesn't conduct adequate pavement condition evaluation that can be sound input for recommending maintenance options and the maintenance work is limited to overlay and pouching and performing maintenance without adequately defining the root cause of distress, moreover this study identifies the greatest challenge for road rehabilitation and maintenance in

AACRA is the absence of well-established pavement management system. The study recommended that AACRA shall asses and apply alternative pavement evaluation and maintenance methods. Moreover, AACRA has to establish pavement management system to manage maintenance activities for better and optimum utilization of resource. Further research is also recommended which includes development of pavement management system and pavement treatment selection alternatives for Addis Ababa City Roads Authority.

2.4 Conceptual Frameworks

As mention under theoretical and empirical framework different researchers, books, reports used different methods and different results to solve the problems of for pavement management system. Under conceptual framework this study brief explain how the gap that the study identified and solved, which materials and method was used. WebGIS based pavement management system is more effective and efficient in time managements, data storage, up to dating daily activities. GIS used to organize the data for usage in pavement management system s geodatabase design, and analysis. In addition, GIS is used as a tool for number of created applications for road network management; such prioritizing road network for maintenance using MCDA.

AACRA was responsible on road pavement management and providing timely maintenance for the road pavements in the City, but the enterprise have problems on handling and management data of manageable road infrastructures. But, they can’t automate their daily activities in geodatabase for handling spatial and non-spatial data of road pavement infrastructures. So, to full-fill the gap of data management of the enterprise the study selected material and develop method to achieve the objectives. Assessing primary and secondary data including literature reviews. Based on the problems and needs of the Enterprise requirement analysis was made.

Geodatabase design was developed through three phase; conceptual, logical and physical design phase. For validation of geodatabase prototype site was selected depend upon the availability all road infrastructures types or road classes. Primary data and secondary data was collected from the site/ field and populated to geodatabase. The develop model is tested through different scenarios. The developed a model to perform road network prioritization by using MCDA. Finally, in this study the model is uploaded to Arc GIS online. The conceptual frame work developed from the literature was shown by figure 2.11 below.

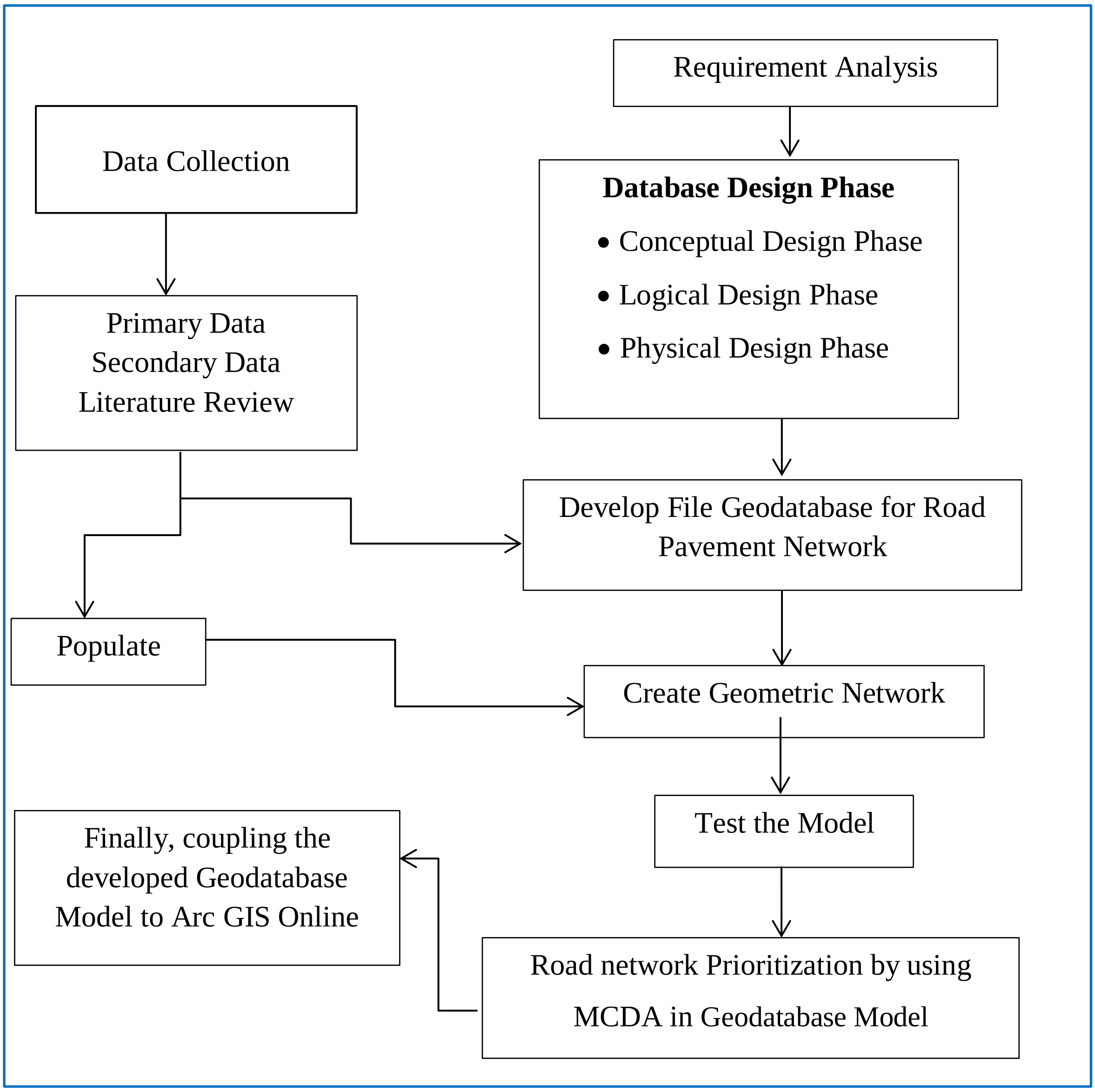


Figure: 2.11. Conceptual Framework Diagram

CHAPTER 3: MATERIAL AND METHODS

3.1. Descriptions of Study Area

Addis Ababa is the capital and largest city of Ethiopia established in the year of 1887. It is a self-governing City of the Federal Government of Ethiopia and The City dominates political, economic, cultural, historical and other concerns of the country. The capital hosts the headquarters of the African Union and the United Nations Economic Commission for Africa (ECA), as well as various other continental and international organizations. The city, which gains the status of a state also, has an administrative area about 550sq.km. The City is divided into 10 sub-cities, which are: Addis Ketema, Akaki Kaliti, Arada, Bole, Guele, Kirkos, Kolfe Keraniyo, Lideta, Nefas Silk and Yeka. From these sub-cities the study will be conducted in Nefas Silk.

3.1.1. Location Descriptions

When considering data collections of such a large and complex transport infrastructure system, pilot studies area selection were very useful in assessment of the appropriate data collection methodologies. Woreda-08 of Nefas Silk Lafto sub-city was selected for conducting the pilot survey.

Nefas Silk Lafto is one of the 10 sub-cities of Addis Ababa located in the south-western suburb of the city. This sub-city borders shares borders with Kolfe Keranio, Lideta, Kirkos and Bole and Akaki Kaliti sub-city.

The woreda consists of all five primary road categories, i.e. Ring Road (RR), Principal Arterial Street (PAS), Secondary Arterial Street (SAS), Collector Street (CS) and Local Street (LS). Addis Ababa Light Railway Transit (AALRT) line of about 1 km also passes through this woreda. The boundary of the woreda spreads from Gotera bridge structure in North to Nefas Silk LRT station in the south and Bole-Bulbula River in the east.

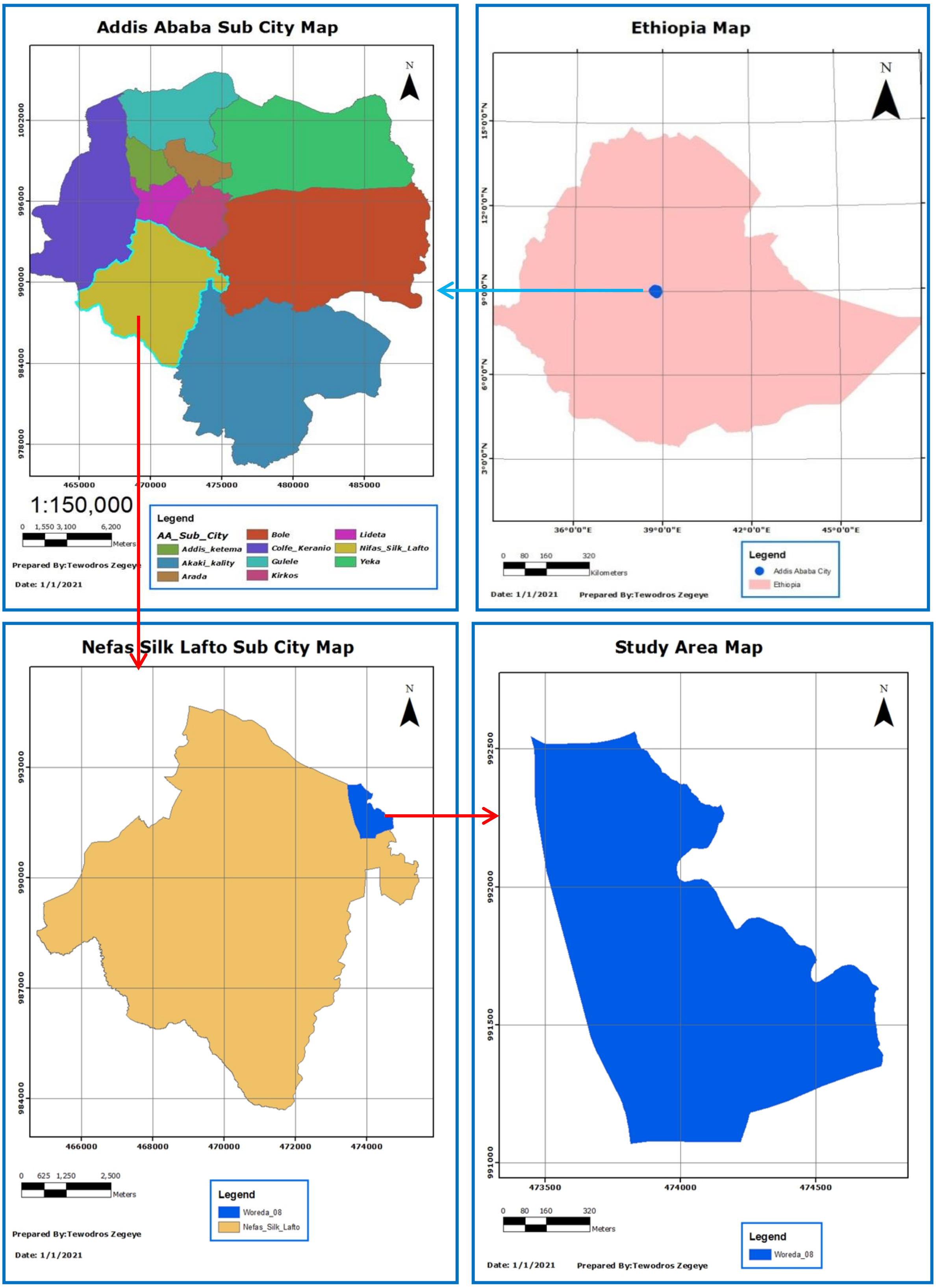


Figure: 3. 1. Location of Study Area

3.1.2 Population

As of the latest 2017 population census conducted by the Ethiopian national statistics authorities, Addis Ababa has a total population of 3,739,551 urban and rural inhabitants. For the capital city 662,728 households were counted living in 628,984 housing units, which results in an average of 5.3 persons to a household.

In the previous census, conducted in 1994, the city's population was reported to be 2,112,737, of whom 1,023,452 were men and 1,089,285 were women. At that time not all of the population was urban inhabitants; only 2,084,588 or 98.7% were. For the entire administrative council there were 404,783 households in 376,568 housing units with an average of 5.2 persons per household.

Table: 3. 1. Population of Addis Ababa

Year	1984	1994	2007	2015
Population	1,412,575	2,112,773	2,739,551	3,273,000
±%	---	+49.6%	+29.7%	+19.5%

[Source: (https://en.wikipedia.org/wiki/Addis_Ababa, Geography, 2020)]

3.1.3 Climate

Addis Ababa has a subtropical highland climate (Köppen: *2020*) with precipitation varying considerably by the month. The city has a complex mix of alpine climate zones, with temperature differences of up to 10 °C (18 °F), depending on elevation and prevailing wind patterns. The high elevation moderates temperatures year-round, and the city's position near the equator means that temperatures are very constant from month to month. As such the climate would be mari-time if its elevation was not taken into account, as no month is above 22 °C (72 °F) in mean temperatures.

Mid-November to January is a season for occasional rain. The highland climate regions are characterized by dry winters, and this is the dry season in Addis Ababa. During this season the daily maximum temperatures are usually not more than 23 °C (73 °F), and the night-time minimum temperatures can drop to freezing. The short rainy season is from February to May. During this period, the difference between the daytime maximum temperatures and the night-time minimum temperatures is not as great as during other times of the year, with minimum temperatures in the range of 10–15 °C (50–59 °F). At this time of the year, the city experiences warm temperatures and a pleasant rainfall. The long wet season is from June to mid-September; it is the major winter season of the country.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Daily mean Temp (°C)	16.0	16.8	17.8	17.8	18.2	16.8	15.5	15.6	16.1	16.1	15.4	15.2	16.4
(°F)	60.8	62.2	64	64	64.8	62.2	59.9	60.1	61	61	59.7	59.4	61.5
Average Rainfall (mm)	13	30	58	82	84	138			149	27	7	7	1,165
(inches)	0.5	1.2	2.3	3.2	3.3	5.4			5.9	1.1	0.3	0.3	45.9
Mean daily *Sun shine* (hr.)	8.6	7.3	7.8	7.0	7.7	5.8	3.6	4.3	5.4	8.0	8.9	9.3	7.0
[Source 1: World Meteorological Organization (average high and low, and rainfall)]													
[Source 2: Deutscher Wetterdienst (mean temperatures 1961–1990, humidity 1951–1990, and sun 1985–1998) Mateo Climate (record highs and lows)]													

Figure: 3. 2. Climate data for Addis Ababa (1981–2010, extremes 1898 and up to present)

3.1.4. Addis Ababa City Road Asset Description

This section investigates the road maintenance, rehabilitation and road management process in the City. It explicate the detail procedure how AACRA conducts the above listed tasks currently. The information has been gathered from AACRA official website, from archive, interview with Engineers working in asset management, road construction and maintenance of AACRA and consultants who engaged in consulting AACRS maintenance, construction and design activities.

ACCRA were planned to increase the road coverage to 20% in 2020 of the total coverage of the built up area. The road asset is growing noticeably; the city road in 1998 was 1360km which is around 5.1%. In 2005 the coverage increase to 15.64%, from this 960 km is asphalt pavement road. Table 3.2 below shows the road asset of Addis Ababa city asphalt road pavement rehabilitation and administered by AACRA. Total area of Addis Ababa is 550,000 hectare, total road length of road network with 7 meter width is 4671km total built up area 16,902 hectare or 169,02km2 and road density is about 22,07km/ km2 of the built up area, therefore the road coverage of Addis Ababa city is 17.50% of the total coverage of the built up area.

Table: 3. 2. AACRA Road Asset in 2017

Types of Road	Road length/ KM
Arterial	1130
Sub Arterial	425
Collector	342
Local	267
Cobble stone	1330
Gravel Road	1176
Road Average	17.50%

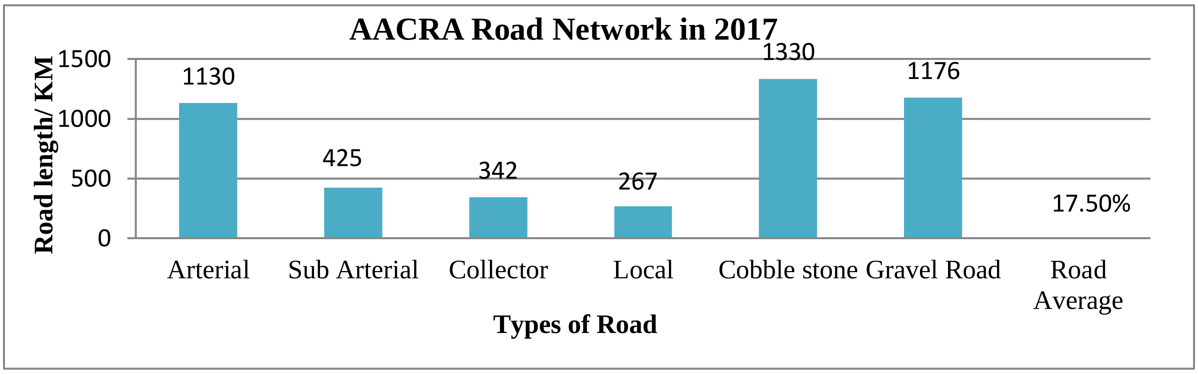


Figure: 3. 3. AACRA Road Network in 2017

3.1.5. Pilot Study Area Descriptions

When considering data collection about such a large and complex transport infrastructure system; pilot studies are very useful in assessment of the appropriate data collection techniques. Woreda-08 of Nefas Silk Lafto sub-city was selected for conducting the pilot survey. Nefas Silk Lafto, is one of the 10 sub-cities of Addis Ababa that located in the south-western of the city. This sub-city shares borders with Kolfe Keranio, Lideta, Kirkos and Bole and Akaki Kaliti sub-city.

The woreda consists of all five primary road categories, i.e. express way, Principal Arterial Street (PAS), Secondary Arterial Street (SAS), Collector Street (CS) and Local Street (LS). Addis Ababa Light Railway Transit (AALRT) line of about 1 km also passes through this woreda. The boundary of the woreda spreads from Gotera interchange structure in North to Nefas Silk LRT station in the south and Bul-Bula River in the east.

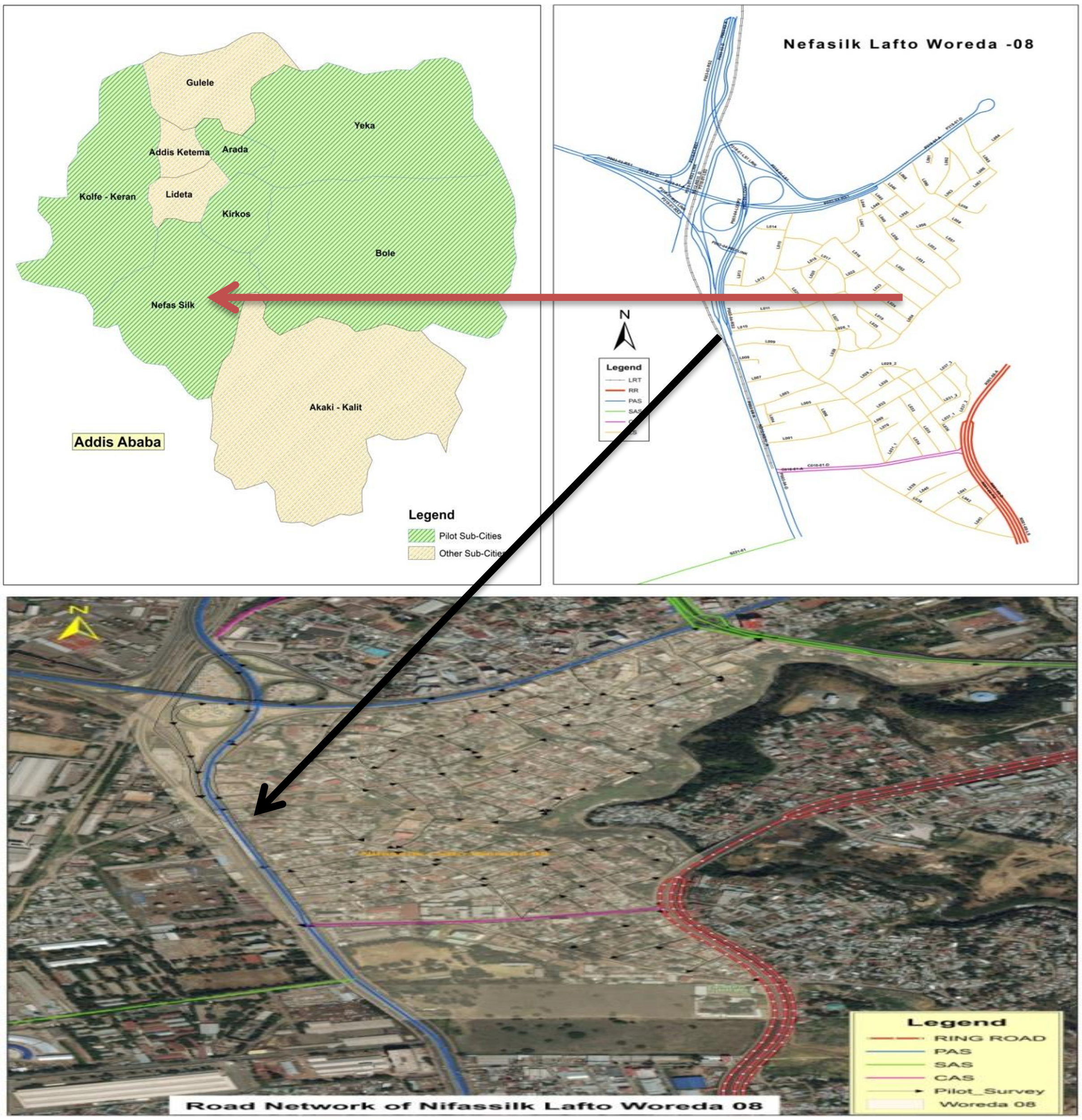


Figure: 3. 4. Map of Pilot Study Area

3.2. Materials used for the Study

Table: 3. 3. Table shows Hardware and Software

Software	Version	Usage
ESRI ArcGIS 10.5	10.5	Used for mapping, designing and creation of geo-Database, analysis, querying, and production of road transport maps, charts and tables
Survey123 Mobil app.	2019	Used for road inventory and condition survey
Survey Master	2019	Used for track the road center line and collect road asset
Py. Charm community edition 2017.3.1	2017.3.1	To develop and debug Payton script
Post processing software	Compass solution 3.2	Used for processing the collected GCP
MS accesses	2016	Used for database design and creation
Microsoft Word 2016	2016	Used for compiling and documentation of the research document ESRI
Architectural Enterprise	15	To design UML Model,

Hardware	Model/Version	Accuracy	Usage
DGPS /RTK	Comnav GNSS/ T300	H:± .005m V:± .001	Used for establishing GCP's and capture of center of the road and the condition of pavement.
Tablet	Samsung		Used for data collection and capture picture of some pavement condition
Measuring wheel	Topcon	ISO©	Used to measure the road segment distance
A digital electronic Laptop computer	CORE TM i7	RAM 8Gb HD 1tera	Used for processing all the information gathered in this study

3.3. Data Requirements and Sources

3.3.1. Data Requirements

A key step in building a GIS is selecting and georeferencing spatial data layers. This step is especially important when those layers, along with their underlying attribute data, provide vital input to modeling tools. There are some data sets that are necessary for almost any analysis of a pavement. These data sets are referred to as base data layers. The data required in this study can be classified broadly into the following subgroups:

a) Road referencing data**:** longitude and latitude of start and end point along with center line or waypoint shall be recorded. this recorded data to be able to have a road referencing system that accurately references sections of road as well as individual points in order to record key asset information in a two dimensional coordinate system.

b) Road inventory: The road inventory data required for the PMS analyses includes: Carriageway width, length, type of pavement shall be measured and noted for every 100m or at change in any features of the pavement in with chainage. All information related to the geometry of the road sections (e.g., pavement width, number of lanes, pavement type, pavement condition etc.) and parameters defining the characteristic of roads (e.g., urban/rural, maintenance group, road hierarchy etc.).

c) Traffic data: The Annual Average Daily Traffic (AADT) and Equivalent single axle loads (ESAL) data collected from count surveys at regular intervals over the years are collected.

d) Pavement condition data: potholes, cracking, failed section, rutting and other distress types (based on the type pavement) shall be recorded and. In general Condition Rating Survey (CRS), International Roughness Index (IRI), rutting, information on pavement rehabilitation, number of lanes, original type of pavement and other relevant detail for every pavement section.

3.3.2. Data Sources

In order to achieve the stated objectives, the spatial data used in this study and their sources are shown in table 3.4 below.

Table: 3. 4. Data type, sources and usage

Data required	**Sources**	**Data Type**	**Usage**
Road referencing data (define the road segment)	Google Earth And AACRA	Shape file	• Serve as road network map and delineate the roads for geospatial database creation. These consisted of digitized road and their properties.
Road hierarchy (Express way or RR, PAS, SAS, CS, LS)	Both from field survey and AACRA	Excel format (Primary Data)	• To show the pilot area Center Line of the road network in ArcGIS. • To show the linear georeferenced Road network of the study area.
Traffic Data (AADT)	From Federal Transport Biro and Traffic Management office	Row Data in Excel format (Secondary Data)	• To know the traffic volume of the different road category of the study area.
Pavement Condition Data	Field condition survey	Excel Format (Primary Data)	• To know the current condition of the pavement with defect. • It provides attribute data and, width of the road, Deterioration type and amount information to be used as an inventory for creation and populating database • It provides attribute data about the road pavement according to the requirement analysis.

3.4. Methods of Data Collection

3.4.1 Data Collection Technique

The data collection techniques used for this study includes; field survey, observation and interviewing AACRA's engineers. Data collection constitutes the largest component of running costs for operating pavement management system. It is also subject to budgetary scrutiny and at risk due to financial constraints. Therefore, data collection techniques and the overall methodology selected were appropriate to the objectives with available resources. Traditional methods used for the collection of asset management data include manual, automated and semi-automated means. For manual collection, the data are documented on the paper. Relevance, reliability, affordability, appropriateness, accessibility are factors determine the selection of technologies and equipment for data collection.

There are generally two methods used to collect data in the field, namely, both manual, and mechanical or automated. Inventory of the road pavement and associated utilities with in the pavement management system were collected conventional measurement methods. This includes inventory and condition survey of major road and local streets. Survey 123 application was developed and configured for this data collection that consists of modules name PMS and can be downloaded from Apple Store or Google's Play store. Survey master was used to collect geo-coordinates of the study area.

3.4.1.1. Recording Data using Mobile Application

For collection of location reference, inventory and condition of pavement, the following two mobile applications were used;

I. Survey Master: Survey Master is an application used to collect the geographic coordinates of any object on field through Topo-survey/Auto-survey, Static and PPK (post-processed kinematic), also enter, edit and stake points/lines. Survey Master can work in off-line mode and data can be synchronized once internet facility available. It also provides a convenient way to import/export surveying data files.

In this study, survey master was used to collect geo-coordinates of all point and linear Transport Infrastructure Assets (TIAs) on the local streets which are in general impassable for Network Survey Vehicle (NSV). This freely available app can be downloaded through application store and can be utilized for field data collection by connecting with base station and rover of DGPS system through Bluetooth. The interfaces of Survey Master are summarized as below:

Project: This interface is to create project, add base maps, select and manage datum, view/import/export surveyed data for setting-up personalized view.

Device: To connect with Base station and Rover through Bluetooth, to include the satellite information, the sky view, to view position info, etc.

Survey: Topo survey feature available to collect geo-coordinates of point asset, Auto survey feature to collect geo-coordinates of linear assets, can do area survey, etc.

Tool: This interface is to calibrate the device, to cross-check surveyed data, to calculate area/distance, to send the surveyed data through mail and other features available here.

The procedure and guide line to collect the geo-coordinates of TIAs using *Survey Master* Application is explained see (Appendix-1).

II. Survey 123: Survey 123 is a mobile based application used to collect the roadway and right-of-way information on the local streets. It is a web-based commercial application which was configured only for use in the pilot data collection. A separate application similar to this application was built that will connect to the PMS database.

Survey 123 application was developed and configured for this data collection that consists of modules name PMS and can be downloaded from Apple Store or Google's Play store. It is downloaded and installed in tablet / mobile using internet in the office and then utilized for field data collection even in offline mode which synchronizes with the cloud server of the service provider as long as internet facility available. It has facility to record geo-coordinates and photographs. The procedure and guide line to download and operate PMS app are explained in (Appendix: 1).

3.4.1.2. Data Collection Procedure

Data collection is an expensive business. Each data item collected requires time, effort, and money to be invested on, to collect, store, retrieve, and use it. However, visual / manual methods were used in routes for proto type investigation.

I. Define the Road Network

Before the field data collection began some desk study were taken, using Arc-GIS digitizing the available road in the study area. In this office study basic information like sub city, Woreda, flow direction, Number of road section, Number of route, road length, road name are filled by adding the above filed name. The requirement analysis were done in this stapes for both database creation and data collection application development, because of the collected road data and the created geodatabase should be synchronized in data type, data length, domain, and so on during data population . In addition to the defining and geocoding of the road segment the web based data collection tool developed.

II. Reconnaissance Survey done on the Study area

Prior to beginning the survey collection, a reconnaissance was done on the study area to check the existence of ground control points and to get mental map about the study area and surrounding areas. Based on the results of the findings, the controls points locations identified in three places, based on their locations, horizontal and vertical orders and their accessibility.

III. Establishment of Ground Control Points (GCP) conducted

In this pilot study, the ground control stations were established in woreda 8 of Nefas silk sub-city utilizing the three Common DGPS receivers, Compact L1/L2 antennas with ground plane. The three GCP points located in three place, the first one on Over fly Bridge, the second one around Rift valley university and the third one in the end corner of Nifas silk poly technique college.

Ground Control Points (GCPs) are defined as points on the surface of the earth of known location used to geo-reference other GPS readings. GCPs are important in situations where precision mapping and true global accuracy are needed. Ground control points orientate the model and improve the accuracy of calculated model.

Commonly established by national mapping/surveying agencies, control points are locations that has known coordinates and is used to transform another dataset spatially coincident but in a different coordinate system into the coordinate system of the control point. The established ground control points can be seen in Appendix-2.

IV. Detail data collection were taken on the selected road

After establishing the GCP the next step were detail data collection preceded, the road location reference, inventory and pavement condition survey assessment were done using a GNSS, measuring wheel and tablet(use as a data collector). In this study, the two applications used for data collections are inventory of the road network and condition survey of the pavement. The Procedure of data collection was summarized as table 3.5 below.

Table: 3. 5. List of Assets and Methods of Data Collection

Assets	Equipment	Method
Asset Location Referencing		
Major Roads - RR, PAS, SAS, CS, LS	DGPS, Camera, Tablet	Manual method
Asset Inventory and Condition		
Pavement condition	DGPS, Camera, tablet, measuring tape, venire calipers	Manual method
Pavement condition of Local Streets,	DGPS,Camera, tablet, measuring tape, venire calipers etc.	Visual/ Manual method
Asset Maintenance and Valuation		
All Assets	–	Secondary Data source

3.4.2. Road Network Referencing Technique

Network Referencing: The Network referencing, is an essential component of any asset management system which is used to assign a unique address to each asset located on the road network. It comprises of rules and parameters to provide unique identity to each segment / section of the route. The use of an easy-to-follow and logical method of network referencing enables road authorities to organize the collection and management of their asset data in an efficient manner. The adoption of standardized road network referencing system will provide a consistent basis for collection and reporting of inventory, condition and maintenance.

Road Network Model: A road network model is a notation that enables the modeling of relevant features of a transport infrastructure. These notations enable the user to identify the features, their characteristics, collect relevant data for its management. Depending on the use context, different aspects of a transport infrastructure are assessed and used as an input for this study.

3.5. Developing the Geodatabase for Pavement Management System

3.5.1. Database Design Process

The following four steps of database design were used.

i) External Modeling: This is the determination of a finite set of potential users of the database, their information needs and data required to satisfy those needs (Agarwal P.K., 2006).

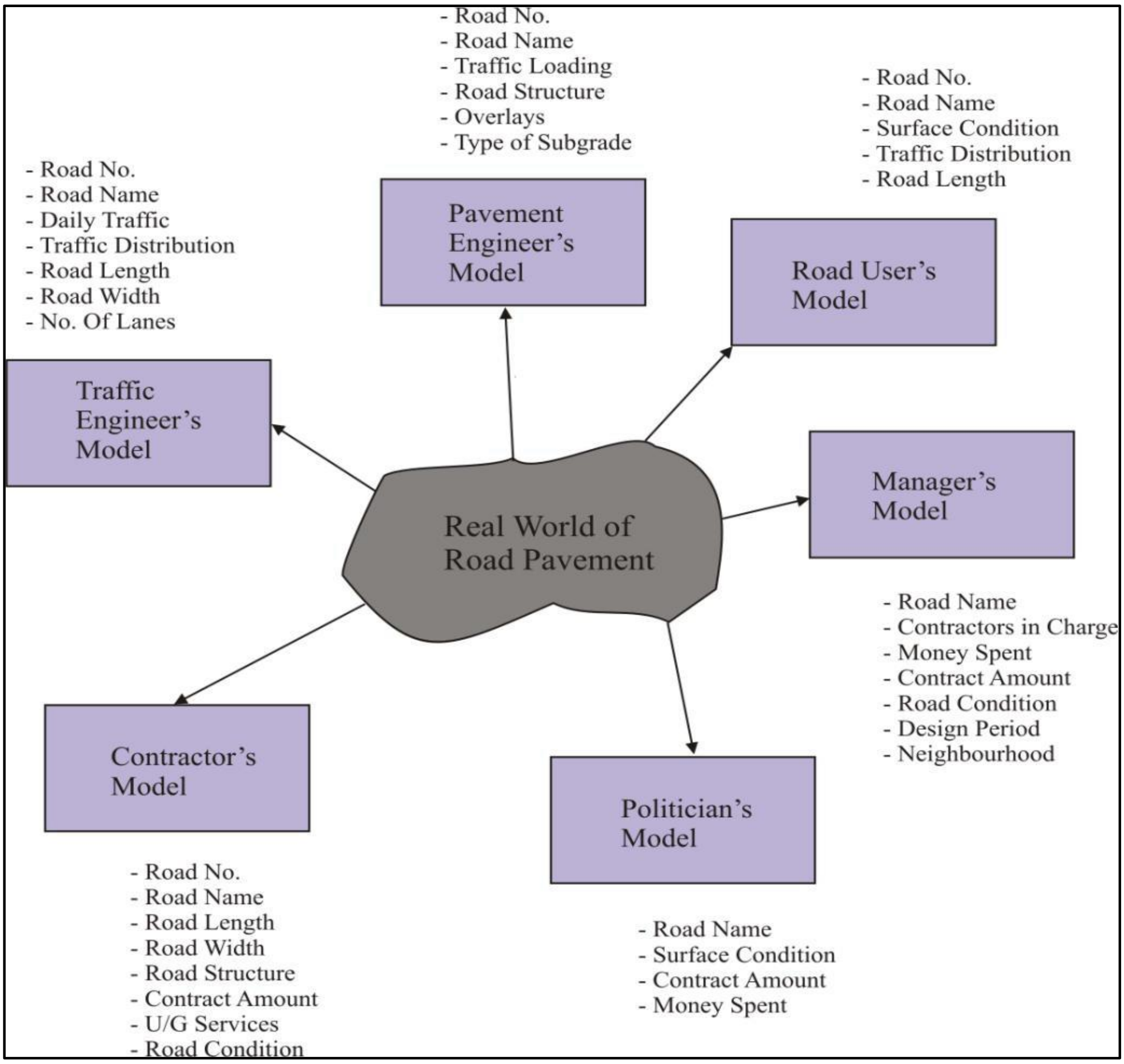


Figure: 3. 5. External Model PMS [source: **(**Agarwal P.K., 2006)]

ii) Conceptual Modeling: Abstraction of an external model into an Entity-Relation diagram showing all the entities (objects of interest) involved their attributes (set of properties) and relationships.

iii) Logical Modeling: This involves mapping the conceptual model into logical model data management system. For a relational database, the logical model is in form of tables or relations which must be normalized before application.

iv) Physical Modeling

This is the actual population of the database. It is hardware and software dependent. The database was created in Microsoft office access.

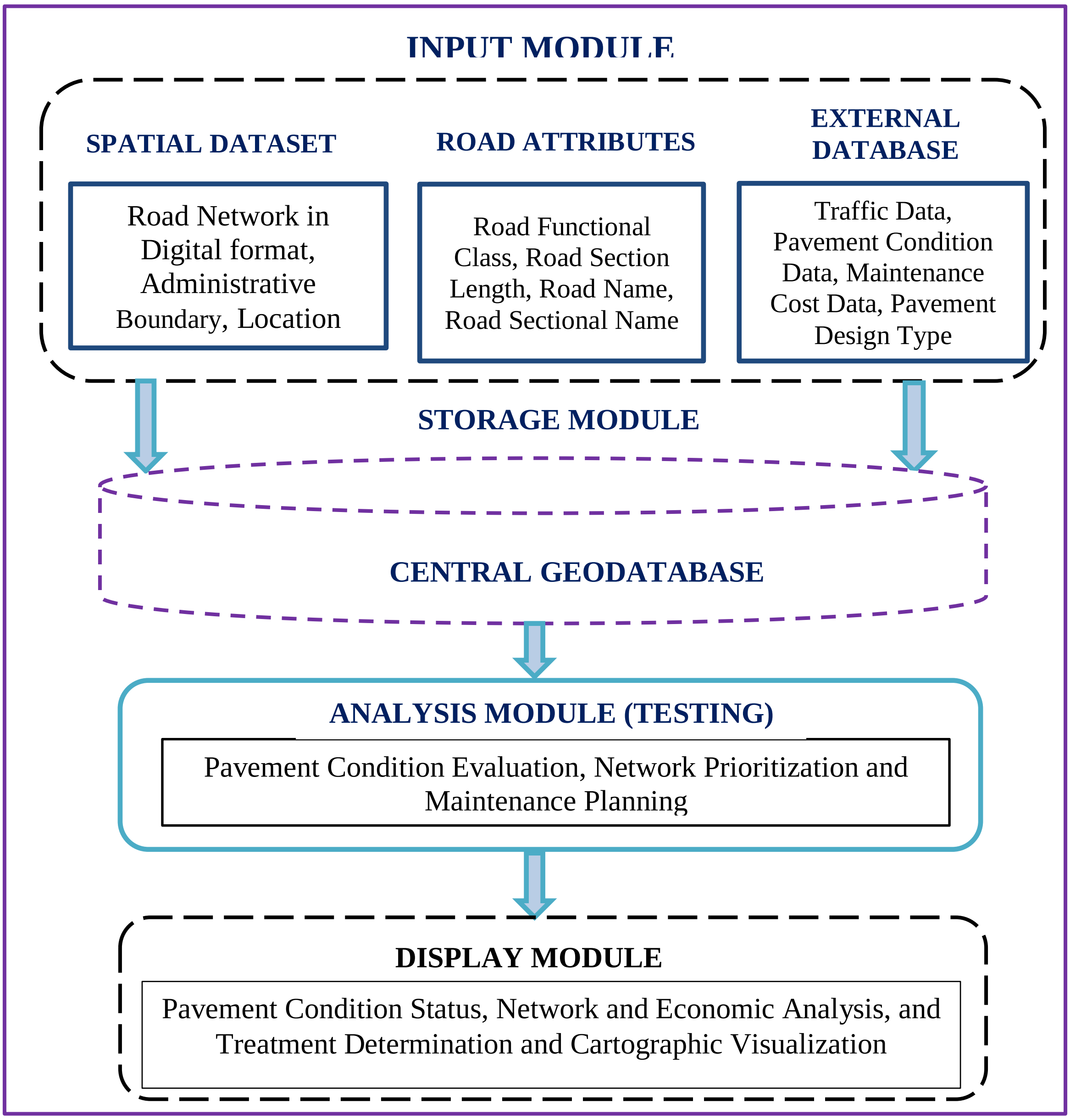


Figure: 3. 6. Conceptual Model of GIS base Pavement Management System

3.5.1.1. Creation of Attribute Tables

The schema identified in the logical model was created and populate in MS access. All the tables were link through relationships. The attribute tables includes: condition rating survey, cracking history, deformation history, degree of cracking, design details, initial pavement structure, international roughness index, pavement maintenance history, pavement maintenance cost history, road inventory, standard pavement structure, sub-grade classes, traffic AADT, traffic AADT summary, traffic classes, transverse deformation under 3m edge. A number of relations were created in order to link all the tables.

3.5.1.2. Developing the User Interface

Web GIS provides the avenue programming language to write add-ons and scripts which can be packaged and installed as extensions. With ArcView it is easy to integrate custom content into the help system to make a customized product which seamlessly integrates with ArcView. If a user knows how to use ArcView they will be able to use an ArcView extension too. Another reason to use Arcview dialog and build this as an extension to Arcview rather than as a standalone product is to take advantage of the data management and display functionality that is designed into any GIS. It also allows for the integration of other tools and datasets inherently. This allows for more design time to be spent on ease of use and functionality rather than designing a new piece of software from scratch.

The dialogs was developed using dialog designer extension in Arcview. In Arc view GIS dialog designer extension, an application that requires input from the user can be developed. This enables an avenue developer to implement the same professional looking dialogs employed by standard Arcview GIS.

3.5.2. Designing a Pavement Management System Process

A pavement management process is comprised of seven steps indicated in figure 3.8.

Step 1: Define Network and Collect Data: The first step is to define the network. In this step the data for inventory were collected based on the need and scope of study and AACRA. The inventories are usually built by breaking down the network into manageable fragments. These fragments are divided based on analogous characteristics and they are of specific significance since they will serve as the foundation for planning, further maintenance and rehabilitation projects.

Step 2: Collecting Condition Data: Asset existing condition data are a substantial factor in any data-driven decision-making processes and asset management procedure. In the asset management process, the existing condition data can be utilized to assist identification of current maintenance and rehabilitation requirements, to predict future needs and to assess the overall effect on the network (Vahid zand, 2018).

Step 3: Predict future Condition: By gathering the condition data, AACRA can use the process to predict future condition. In asset management, future condition will be modeled based on assumptions, which describe the network better.

Step 4: Select Treatments: Treatments are available based on real and practical data collected from the field. Selecting the maintenance is flexible and each treatment has its own pros and corn.

Step 5: Report Results: The results can be released in different ways. The most common method is charts and work orders.

Step 6: Select Asset Management Tool: The requirements of the AACRA and users' needs may influence the selection of pavement management system tool. The tool provides a platform to store the pavement management information and to conduct various kinds of analysis that depends on whether a spreadsheet, GIS tool, and/or an asset management system (public or private) are selected or not. Depending on the requirements of the organization, a local agency can also opt to use a mixture of asset management software and customized spreadsheets and/or GIS software to satisfy their requirements.

Step 7: Keep the Process Current: Asset management requires to be updated since it is a dynamic process. Data management is an important factor to keep the database current.

3.5.3 Pavement Management Model

Pavement management models are categorized in to two levels namely; network level and project level. Network level is deals with the pavement network as a whole. The structure is built to support high-level decisions relating to network wide planning, policy and budget. The project level deals with smaller constituent sections within the network. Structure is based on lower-level decisions relating to condition; maintenance, reconstruction and rehabilitation. Both the network and project level approaches have their advantages and disadvantages. This study adopted the project level approach that uses individual section data (e.g., traffic, safety, inventory, pavement condition) to determine the optimum section maintenance and rehabilitation strategies and priority projects.

3.6. Develop model to prioritize a deteriorated road segment

Three Prioritization criterions were selected in chapter two by review different country experience. In this study Average Annual Daily Traffic (ADDT), pavement condition Index (PCI) and Road category (RR, PAS, SAS, CS, LS) selected as Multi Criterion Decision Analysis to select highly attention need road for maintenance.

3.6.1. Road Network Prioritization

Some sections of roads in the metropolis leading to sensitive installations such as hospital and other security installations have been marked as priority roads. These sections receive special attention for maintenance because of the sensitive role they play in the transportation system. And it requires regular and adequate maintenance. The core mandate of the road managers is to keep the road network in the metropolis including the priority roads in good condition for the benefit of road users. However, due to the limited funding for road development and maintenance in each year, decisions have to be made to prioritized maintenance schedules that provide the highest\ value of return to the road network. Finally, the study used Multi-Criteria Decision\ analysis (MCDA) method to prioritized maintenance schedules. The criterion includes; PCI value, road sectional condition, traffic condition and the road classification factors.

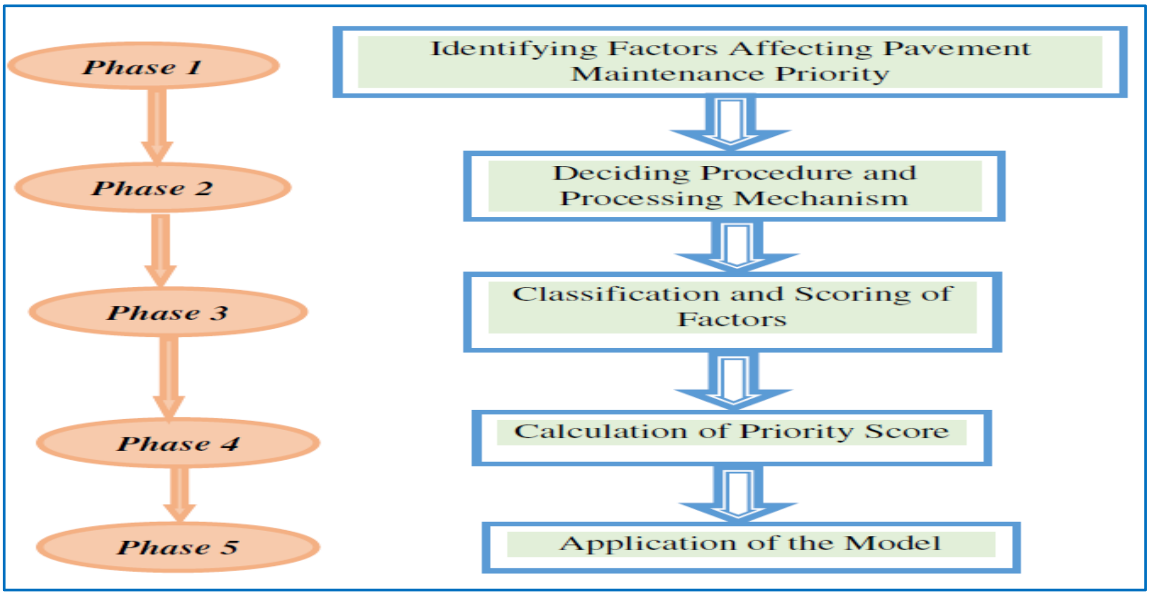


Figure: 3. 7. Phases to prioritize the road network for maintenance schedules.

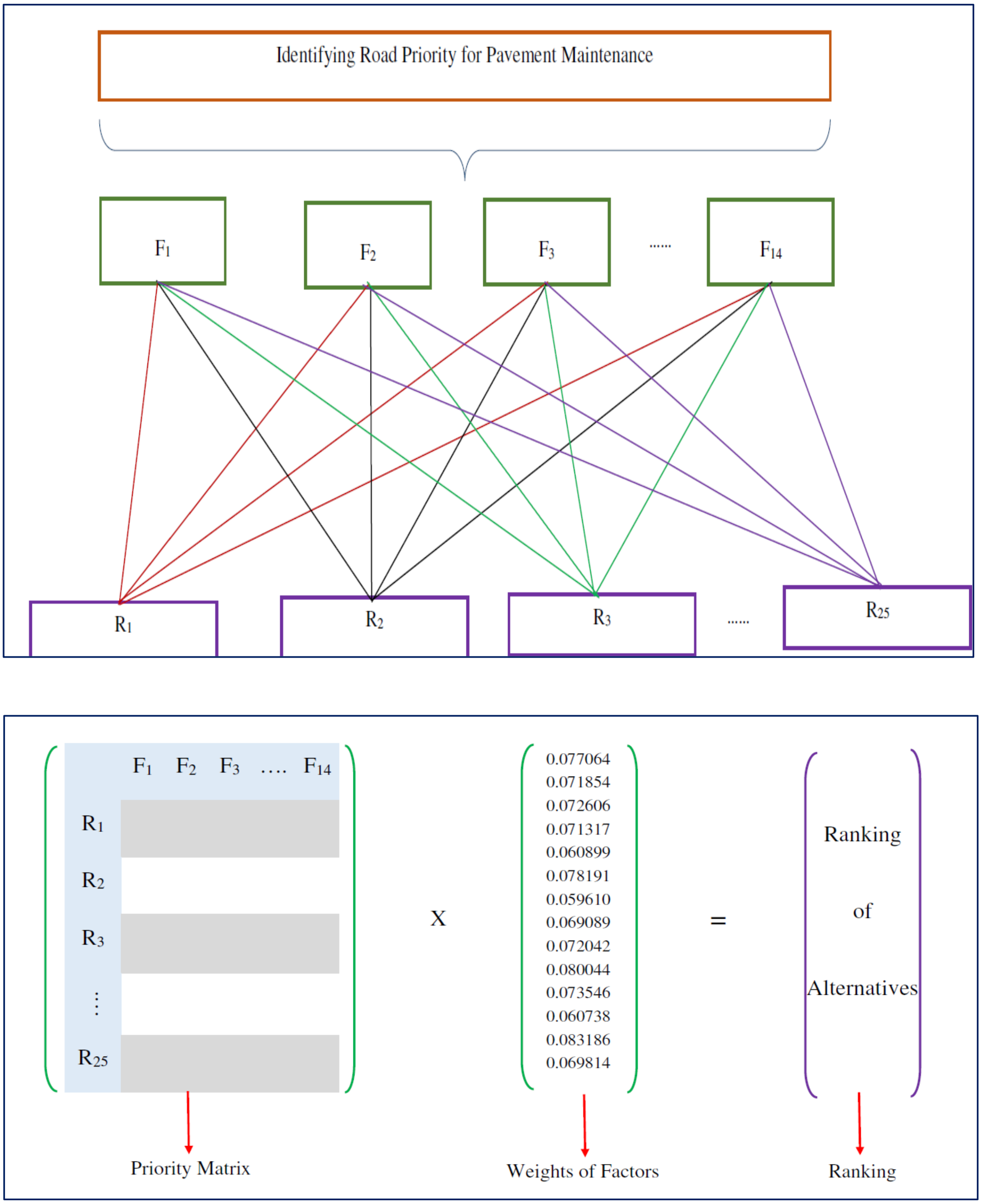


Figure: 3. 8. Method of identifying road priority for pavement maintenance

3.7. Data Processing and Analyses

The collected data which includes the defect type, defect location, defect area and so on were used as an input into the geodatabase and processed using mathematical formula and standard to get PCI, PCR, Maintenance .

3.8. Upload all shape file in to WebGIS

The developed PMS Geodatabase and all shape file were uploaded to ArcGIS online as a hosted feature layer and display the final map.

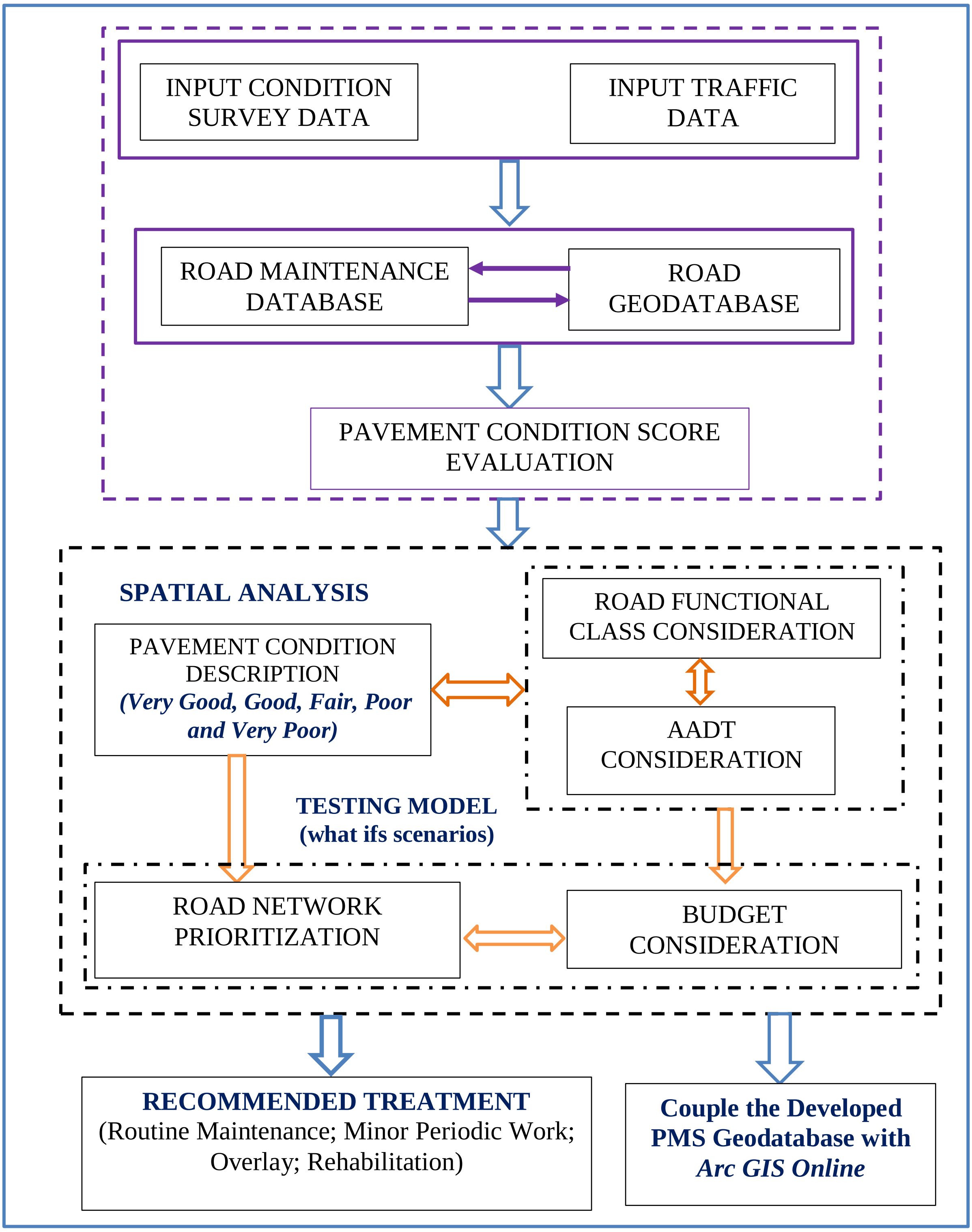


Figure: 3. 9. Technological Scheme of the Study

CHAPTER: 4. DATA ANALYSIS, RESULT AND DISCUSSION

4.1 Introduction

This chapter focused on describing the overall data analysis, results and discussions of the analysis, requirement analysis and designing of the Geodatabase for PMS. The collected primary and secondary data related to road network was analyzed. Based on the requirement analysis the conceptual, logical and physical design of PMS geodatabase was presented. And designed geodatabase were implemented for selected pilot study area and tests its functionality by prioritizing road segments for maintenance. Finally, the developed geodatabase model were coupled with Arc GIS online as hosted feature layer and display the final map.

4.1.1 Road Network

The pilot area survey first started with road center line alignment survey. For each road, geo-coordinates along the center line and inventory data were collected. In case of dual / multiple carriageways, data was collected for each carriageway including service roads separately.

The pilot area mainly consists of about seventy two local streets (11.33km), one collector street (0.971km), one secondary arterial street (0.57km), three principle arterial streets total length were 14.62km from this 3.08km of divided carriageway and 8.47km of fifteen service roads/links and a portion of ring road totally 2.19km from this 0.65km of divided carriageway and 0.88km of two service roads. The road network statistics for the pilot area is graphically shown in figure 4.1 and table 4.1 below:

Table: 4. 1. Road Network in Woreda 08

Road Category	Length (km)
Ring Road (RR)	2.19
Principal Arterial Street (PAS)	14.62
Secondary Arterial Street (SAS)	0.574
Collector Street (CS)	0.971
Local Street (LS)	11.33
Total	29.725

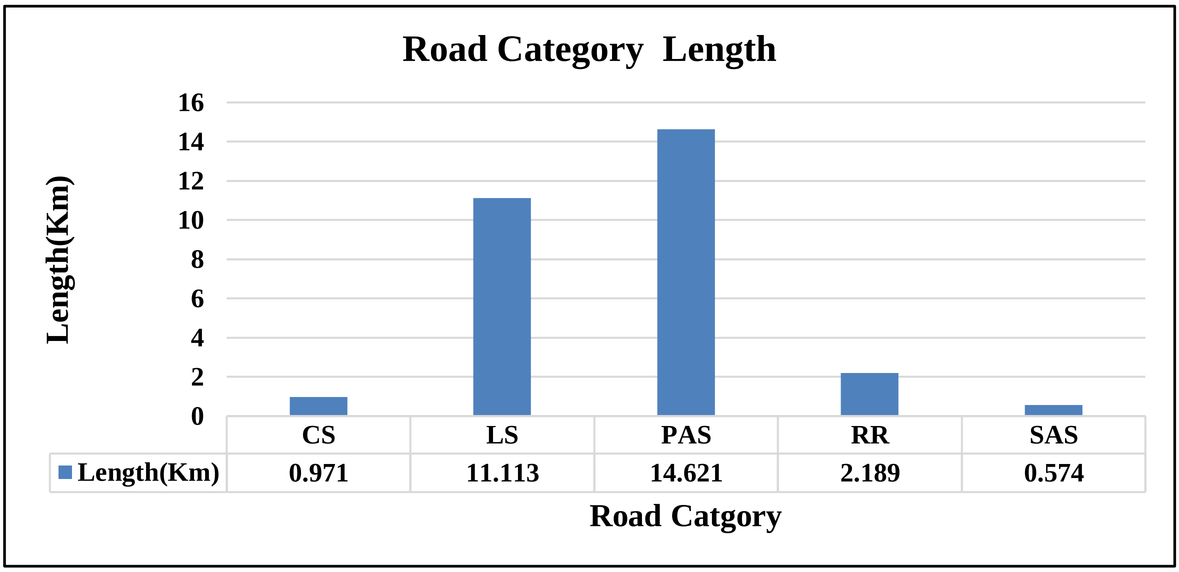


Figure: 4. 1. Road Network Length in the pilot study area

The map displayed below in figure 4.2 below shows tracked center line of the road found in the pilot study. This data were downloaded and added in to ArcGIS, the collected data were converted from point feature to Line feature. This converted feature was used for further analysis. This data were used as reference base map for condition survey and geodatabase design.

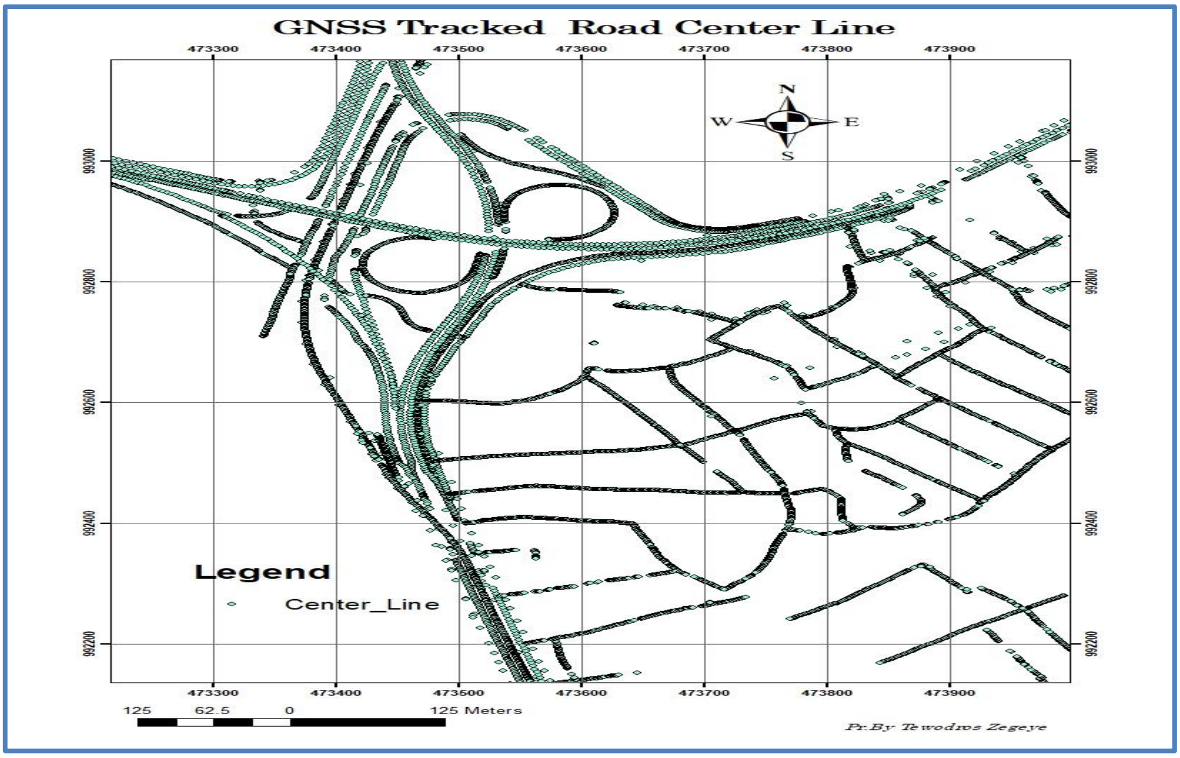


Figure: 4. 2. Road Center line tracked by GNSS

The map displayed below shows in figure 4.3 was converted from point feature to line feature. These steps were very important to study pavement condition and to know the geographical location of each road in the study area and base for further analysis.

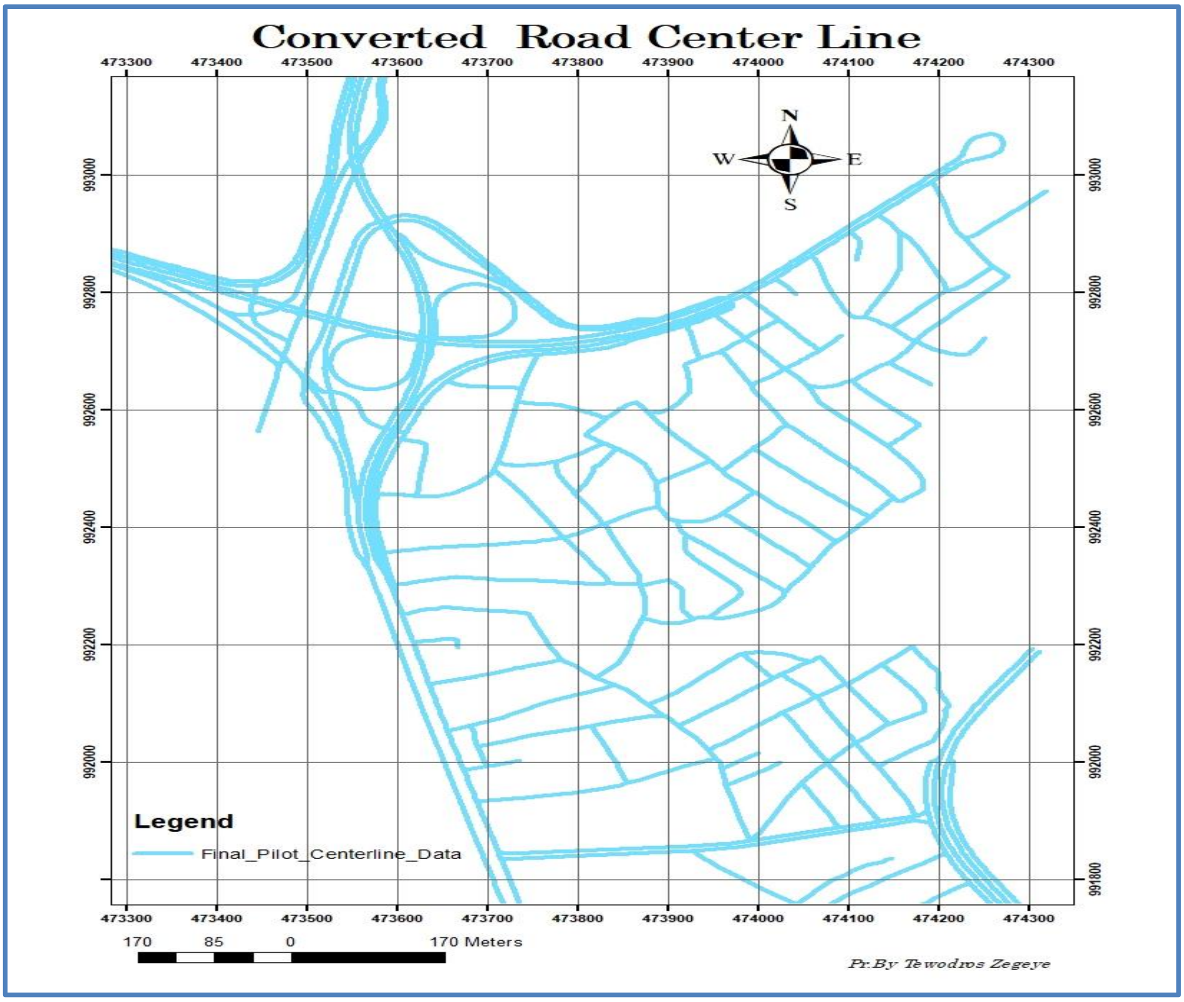


Figure: 4. 3. Converted Road Center line map

The features were edited and the relevant attributes added into the system. The network was then put into sections and linearly referenced. In the GIS environment, the relevant data needed to form the core of the database the road network were created. The following attributes were considered and implemented in the geodatabase; the table 4.2 shows road reference, as in the table shown below in addition to the spatial data some additional and general basic information about the road added.

Table: 4. 2. Road reference attributes and filed name

General Location/ Road Reference						
No	**Attributes**	**Filed Name**	**Filed Description**	**Data Type**	**Domain**	**Data Size**
1	Shape	Geometry	Line feature Class (default)	Line		
2	Auto Generated ID	Auto ID	(Object ID)	integer		
3	Road ID	R_ID	Road number/Geocoding Unique ID	Text		26
4	Sub-city *	Sub-city	Administration boundary (Nifas silk, Bole,Yeka…)	Text		50
5	Woreda	Woreda	The administration boundary of the current woreda	Text		5
6	Align*	Align	NE,NW,SE,SW	Text	Align *	5
7	Road Class*	R_Class	The road Class	Text	R_Class*	50
8	Road number(old)	R_Old_Num	The current road number given by AACRA	integer		20
9	Road number(New)	R_New_Num	A unique Road Identification number of the road	integer		20
10	Number of Lane	N_Lane	Number of lane	integer		5
11	Direction* UP/Down	Direction	The flow direction of the car	Text		10
12	Road/Street name	R_Name	Full Name of the Road	Text		50
13	Road Shape Length	R_Len	The Length of the Road	Double		10
14	Road Category	R_Cat	Road Design Category	Text	Category*	5
15	Road Section	R_Sec	Road section Number	Text		10
16	Survey Date	S_Date	Date/Months/Year	Date		12
17	Remark	Remark	Additional description on the route	Text		100

4.1.2 Pavement Type

In the pilot area 18.355km was bituminous surface and 11.133km cobble stone suface type. Where as, PAS, SAS, CS and RR road category were bituminous and all local street road was cobel stone pavement type. The distrbution of carriageway surface shown on figure 4.4 below. About 60 percent of the road length is paved with bituminous pavement, 40 percent with cobble stone.

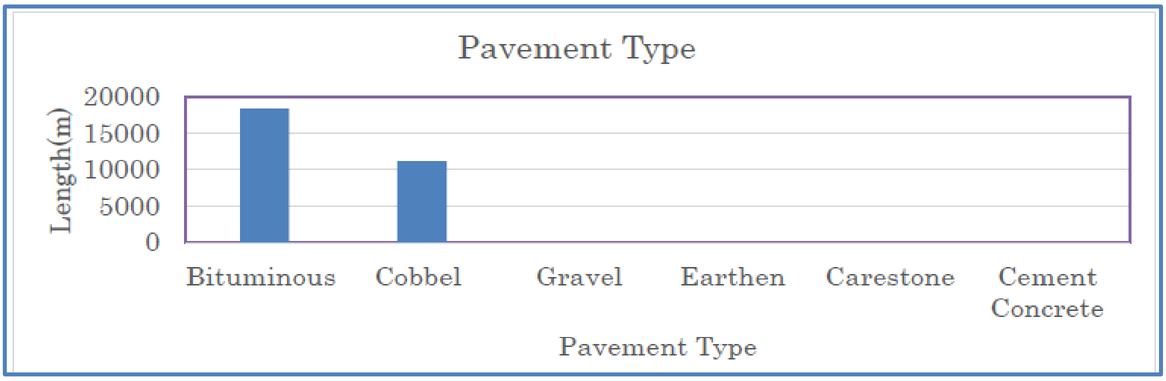


Figure: 4. 4. Distribution of Carriageway Surface

4.2. Requirement Analysis

To achieve the objective this study undergoes requirement analysis. The requirement analysis made in this study involves two folds; organization's need, and GIS needs and data requirements. The Enterprise (AACRA) needs to manage road network infrastructures, to identify and maintain road pavement distress, implement pavement management system via update GIS databases with as-built and CAD data, produce standard and custom map products, integrate with other enterprise systems through Arc GIS online and manage operations activities of road networks. As shown appendices-6 the requirement analysis of the enterprise were done in detail.

The other requirement analysis was for GIS to design the PMS Geodatabase model. To design, database it is the first step to identify the required parameters of spatial and non-spatial geodatabase objects. The process includes, in this study is defining the spatial reference system and identifying data required to GIS Environment.

The data required for GIS to design the PMS Geodatabase model are identified on the basis of the need and requirement to the GIS environment and availability in the organization road network infrastructures. This data road network infrastructures which is line features and they are identified on the basis of AACRA, ERA and ESRI Data model movement network manual infrastructures for road pavement management system.

4.2.1 Spatial Reference and prparetion

4.2.1.1 Establishment and Cheking Geodetic Control Points

In the study area three GCP were established. As shown in table 4.4 and figure 4.5 the GCP established in Gotera adebabay, Rear side of Refit Valley University Gotera branch and corner of Nifas Silk TVET in three places. This three GCP were serving as a base station during the road center line tracked. The monographs were shown in appendics.2.

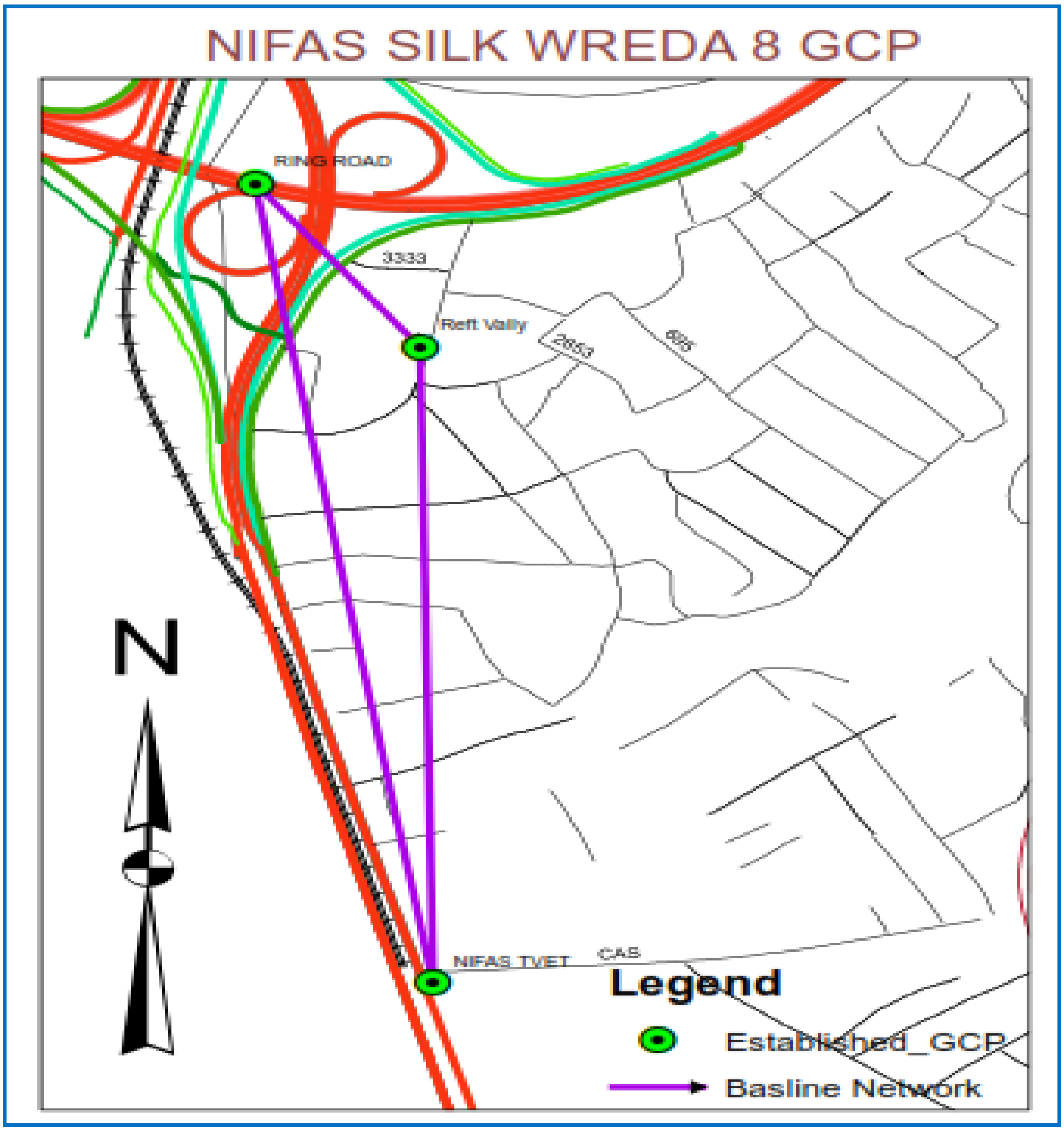


Figure: 4. 5. Established GCP location map

Table: 4. 3. GCP Reports of Pilot Study Area

Station	North (x)/RMS (m)		East (y)/RMS (m)		RMS (m)	Error Ellipse		
						E(m)	F(m)	ET(D: Second)
NIFAS TVET	991623.5769	0.0014	473629.0219	0.0020	0.002	0.0025	0.0020	162:47:31
RING ROAD	992529.7830	*****	473485.8520	*****	EMA GCP (Base)			
RV	992344.3329	0.0018	473618.5741	0.0021	0.002	0.0021	0.0018	111:08:46

4.2.1.2 Define the datum and projection system of spatial data

The coordinate system used Universal Transverse Mercator projection system and the datum was Adindan. Table 4.4 shows the spatial reference used in the study area.

Table: 4. 4. Spatial References used for Pilot Study

Datum and Map Projection System	
Projection	Universal Transverse Mercator
Spheroid/Reference Ellipsoid	Clarke1880 modified
Local Geodetic Datum	Adindan
Unit	Meter
Projection Parameters	
UTM Grid Zone	36, 37, 38 depending up on the geographic location
Central Meridian	33°E for zone 36; 39° E for zone 37 and 45° E for zone 38
False Easting	500,000 m E
False Northing	0 m N
Scale Factor	0.9996

4.2.3 Geocoded the Road Network

The Network referencing, which is an essential component of any asset management system is used to assign a unique address to each asset located on the road network. It comprises of rules and parameters to provide unique identity to each segment / section of the route. The use of an easy-to-follow and logical method of network referencing enables road authorities to organize the collection and management of their asset data in an efficient manner. The adoption of standardized road network referencing system will provide a consistent basis for collection and reporting of inventory, condition and maintenance of pavement.

The pavement road network was divided into a series of sections for easy referencing and identification. The sections are the basic unit of road network used for management purposes. The sections were further divided into subsections for detailed analysis of road condition and prioritization. Each section and segment was given a unique identity and for purpose of identification, the sections were given unique reference number comprising the following According to AACRA Transport Infrastructure Asset Naming and Coding manual the road network is geocoded. Figure 4.6 shows geocoded road network of the study area. In the geocoding process the first two digits shows Region Code- the next two digit describe owner code the next two digit describe route code the next two digit describe section code the final two digit shows the segment code. In general this geocoding is used to visualize the pavement condition evry100m chain-age.

Road Class_ road number – component number – segment number – direction

Example: C 0001 _ LS01 _ 001 _ A

Road Class: C for Collector Street

Road No: 0001 (Originates from RR/PAS/SAS; whichever is of higher order)

Component No.: LS01 (1st service lane on incremental chainage direction (left side)

Segment No. : 001 (First 100m from start of the road)

Direction: ‘A’

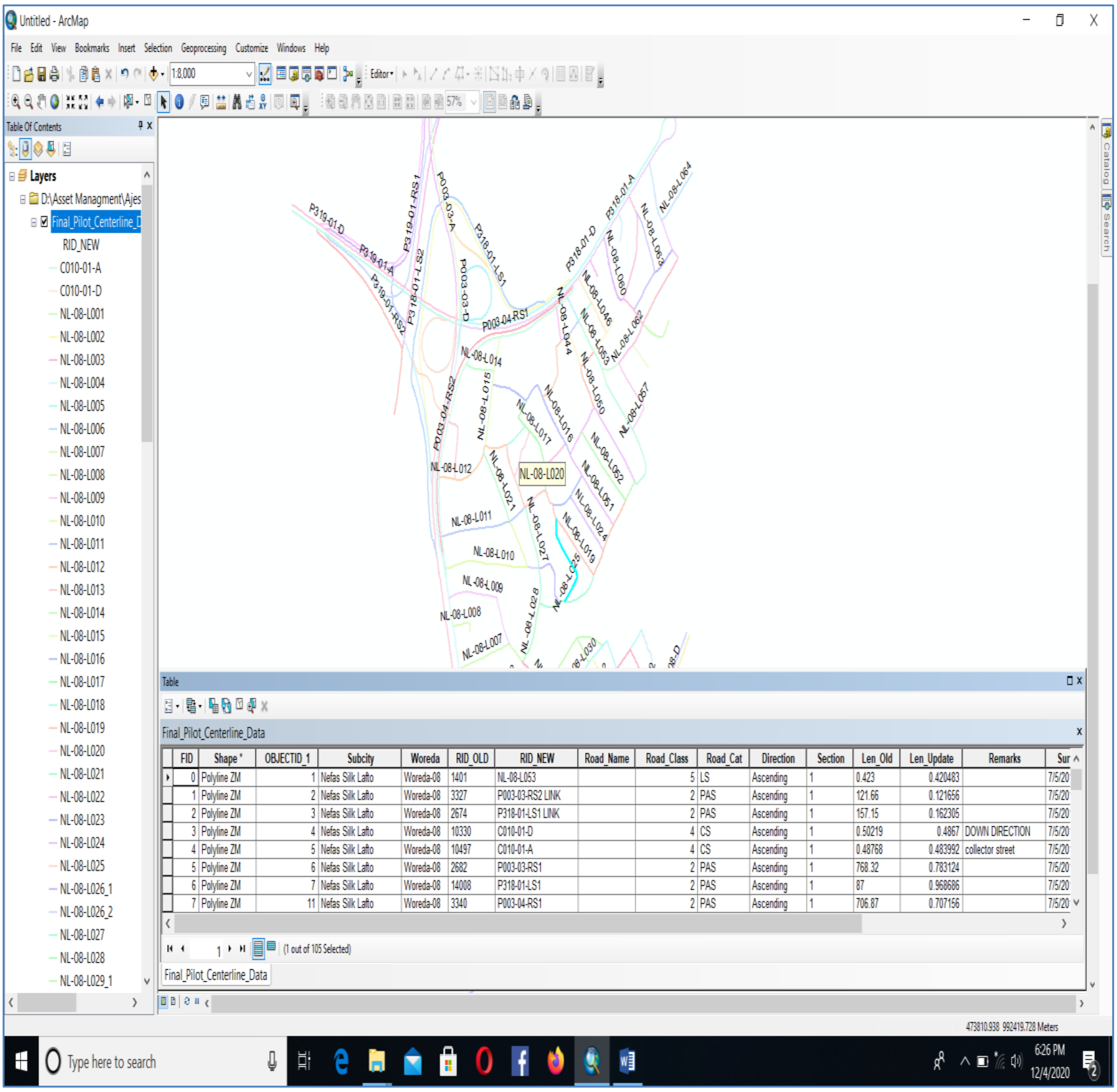


Figure: 4. 6. Geocoded road network of the study area

4.3 Geodatabase Design Phase

A Geodatabase is an integration of spatial and non-spatial information in organized way so that it can be easily accessed, managed and updated. Data is organized into rows, columns and tables, and display in different map format to make it easier to find relevant information. Data gets updated, expanded and dilated as new information added. It processes workloads to create and update them, querying the data they contain and running the applications against. To design the database architecture Enterprise 15.1 was used.

This is achieving through the use of Arc Catalog Tool. Designing and building geodatabase involve three stages; conceptual, logical and physical design.

4.3.1 Conceptual Design

Conceptual design; is the starting point of database design, the purpose of conceptual data modeling is to define in broad and generic terms the scope of a database (Lo, *et al*, 2007).

In this study, all the requirements for conceptual design of PMS are examined and identified. It involves; classifying features based on understanding of the data required to support the organization's functions (i.e. defining geographic data entities) and deciding their spatial representation. This is done for data identified on the basis of organization and GIS needs and requirement identified in the requirement analysis.

4.3.1.1 Define PMS Geographic data Entities and representation

The purpose of this stage of the conceptual phase is to identify a group the key geographic entity required to accomplishes the Addis Ababa PMS. This step define the geographic data entity requires a transformation from the ideas and needs into the creation of concrete feature classes or object class. The geographical entities are bracken down further in this stage to represent by points, lines, polygon, or tables. In this stage the geographic data entity grouped and represented in the geodatabase model. Table 4.5 shows below the geographic entity of pavement management system.

Table: 4. 5. Geographic Data Entity

Layer	Spatial representation	Geographic data entity
Road Network	Line	Feature Class
Road Section and Segment Node	Point	Feature Class

4.3.2 Logical Design Phase

Logical data model bridges the gap between conceptual and physical data model (ESRI, 2008; Girma, 2019). It involves; matching the conceptual model to ArcGIS geographic dataset, determine geometry type of discrete features and implement attribute type for objects. So, in present study these are implemented in logical design phase for the feature classes discussed in conceptual phase.

4.3.2.1 Data structure of the PMS Geodatabase

The spatial data entity and representation of PMS are defined in conceptual phase. In this stage the special attribute known as subtype for the attribute of feature class. In this study the road network category, pavement type, direction, align, sub city and woreda has subtype and code. It avoids additional feature class for each object (ESRI, 2018). The detail of feature and object classes with their subtype in PMS data set were depicted in table 4.6.

Table: 4. 6. Subtype of the pavement management system

S/N	Filed Name	Subtype	Code
1	**Road Network***		
		1.Principal Arterial Street	PAS
		2.Secondary Arterial Street	SAS
		3.Ring Road	RR
		4.Collector Street	CS
		5.Local street	LS
2	**Pavement Type***		
		1.Bituminous	BT
		2.Cobbel	CB
		3.Gravel	GR
		4.Earthen	ER
		5.Carestone	CS
		6.Cement Concrete	CC
3	**Align***		
		North_East	NE
		North_Weast	NW
		South_East	SE
		South_Weast	SW
4	**DIRECTION***		
		Asending	UP
		Down	Down
5	**Subcity ***		
		Addis Ketema	AK
		Akaki Kality	Ka
		Arada	AR
		Bole	BL
		Gullele sub city	GU
		Lideta sub city	LI
		Kirkos sub city	KR
		Kolfe Keanio	KK
		Nifias Silk lafto and	NS
		Yeka subcity .	YK

As shown in the above table, the subtype permit the selection of separated coded value domain behaviors of 5 (five) road class, 6 (six) pavement type, four aligns, two direction and ten sub cities. Figure 4.7 below shows the subtype of the PMS developed in architectural enterprise software.

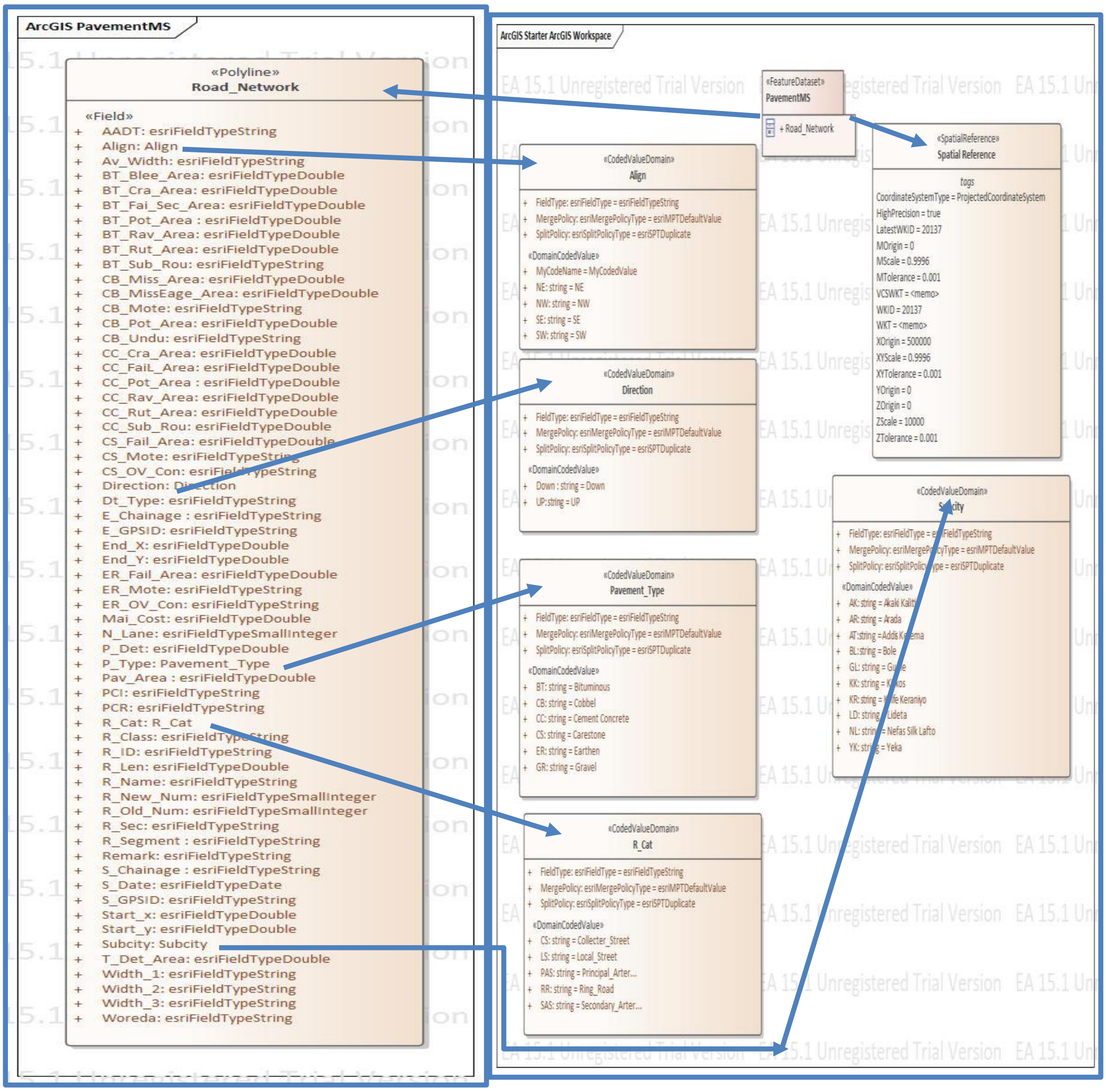


Figure: 4. 7. Logical Design in UML

4.3.2.2 Data Specification of PMS Geodatabase

The result of this logical design phase, which includes the spatial and non-spatial specification of the feature classes and object class in terms of attribute fields /field name/, data types, character size (length), associated domains, and field description are examined and here geometric network with other are identified. These attribute and associated domains identification was made on the basis of existing features in the study area and ESRI infrastructure manual. These domains are coded value domain type. Table 4.7 shows the data specifications of PMS Geodatabase.

Table: 4. 7. General location of the Road Network

General Location/ Road Reference						
No	**Attributes**	**Filed Name**	**Filed Description**	**Data Type**	**Domain**	**Data Size**
1	Shape	Geometry	Line feature Class (default)	Line		
2	Auto Generated ID	Auto ID	(Object ID)	integer		
3	Road ID	R_ID	Road number/Geocoding Unique ID	Text		26
4	Sub-city *	Sub-city	Administration boundary (Nifas silk, Bole, Yeka…)	Text		50
5	Woreda	Woreda	The administration boundary of the current woreda	Text		5
6	Align*	Align	NE,NW,SE,SW	Text	Align *	5
7	Road Class*	R_Class	The road Class	Text	R_Class*	50
8	Road number(old)	R_Old_Num	The current road number given by AACRA	integer		20
9	Road number(New)	R_New_Num	A unique Road Identification number of the road	integer		20
10	Number of Lane	N_Lane	Number of lane	integer		5
11	Direction* UP/Down	Direction	The flow direction of the car	Text		10
12	Road / name	R_Name	Full Name of the Road	Text		50
13	Road Shape Length	R_Len	The Length of the Road	Double		10
14	Road Category	R_Cat	Road Design Category	Text	Category *	5
15	Road Section	R_Sec	Road section Number	Text		10
16	Survey Date	S_Date	Date/Months/Year	Date		12
17	Remark	Remark	Additional description on the route	Text		100

Carriageway Inventory						
14	Segment	R_ Segment	The number of segment (01, 02, 03….)	Text		10
15	Road photo	R _Photo	The Road picture	Raster		<100kb>
16	Pavement Type *	P_ Type	Types of pavement (BT,CB,GR,ER,CS,CC)	Text		25

17	X-Coordinate-start node	Start _x	Coordinate	text		20
18	Y-Coordinate-Start node	Start _y	Coordinate	text		20
19	X-Coordinate-End node	End _X	Coordinate	text		20
20	Y-Coordinate- End node	End _Y	Coordinate	text		20
21	Start GPS ID	S_GPSID	Starting Point of the segment	Numeric		10
22	End GPS ID	E_GPSID	Ending Point of the segment	Numeric		12
23	Start Chainage	Chainage		Text		12
24	End Chainage	E _Chainage		Text		12
25	Carriage Width 1	Width_1	The width of Carriageway in the beginning	Numeric		10
26	Carriage Width 2	Width_2	The width of Carriageway in the middle	Numeric		10
27	Carriage Width 3	Width_3	The width of Carriageway in the end	Numeric		10
28	Average Carriage Width	Av_ Width				

Table: 4. 8. Carriage Way Condition Attributes

Pavement Type * Deterioration type*						
28	Deterioration Type *	Dt_ Type				20
29	Bituminous Pothole Area	BT_ Pot_ Area				10
30	Bituminous Crack	BT_ Cra_ Area				10
31	Bituminous Bleeding	BT_ Blee_ Area				10
32	Bituminous Raveling	BT_Rav_Area				10
33	Bituminous Rutting	BT_Rut_Area				10
34	Bituminous Failed section	BT_Fai_Sec_Area				10
35	Subjective Roughness	BT_Sub_Rou				15
Cobble						
36	loose/Missing Stone area	CB_Miss_ Area	loose/Missing Stone area			10
37	Pothole Area	CB_Pot_Area				10

38	Missing of eage stone	CB_MissEage_Area				10
39	Moterable yes/no	CB_Mote				5
40	Undulation/H/M/L	CB_Undu				10
		Earthen				
41	Failed Section	ER_Fail_Area				10
42	Motorable	ER_Mote				5
43	Overall condition	ER_OV_Con				10
		Care stone				
44	Failed Section	CS_Fail_Area				10
45	Moterable	CS_Mote				5
46	Overall condition	CS_OV_Con				10
		Cement Concrete				
47	Pothole	CC_Pot_Area				10
48	Crack	CC_Cra_Area				10
49	Raveling	CC_Rav_Area				10
50	Rutting	CC_Rut_Area				10
51	Failed Section	CC_FaiL_Area				10
52	Subjective Roughness	CC_Sub_Rou				10

4.3.2.3. Creation of Relationship in the Attribute Tables

The schema identified in the logical model were created and populated in Architectural Enterprise 15.1. All the tables were linked through relationships. The following attribute tables were created: road reference or location, road inventory, pavement deformation, design details international pavement condition index (PCI), traffic AADT, traffic AADT summary, traffic classes. A number of relations were created in order to link all the related tables. Figure 4.8 highlights the attribute tables and relationships established. As shown in figure below, R_ID were used as a key to create relational between the tables.

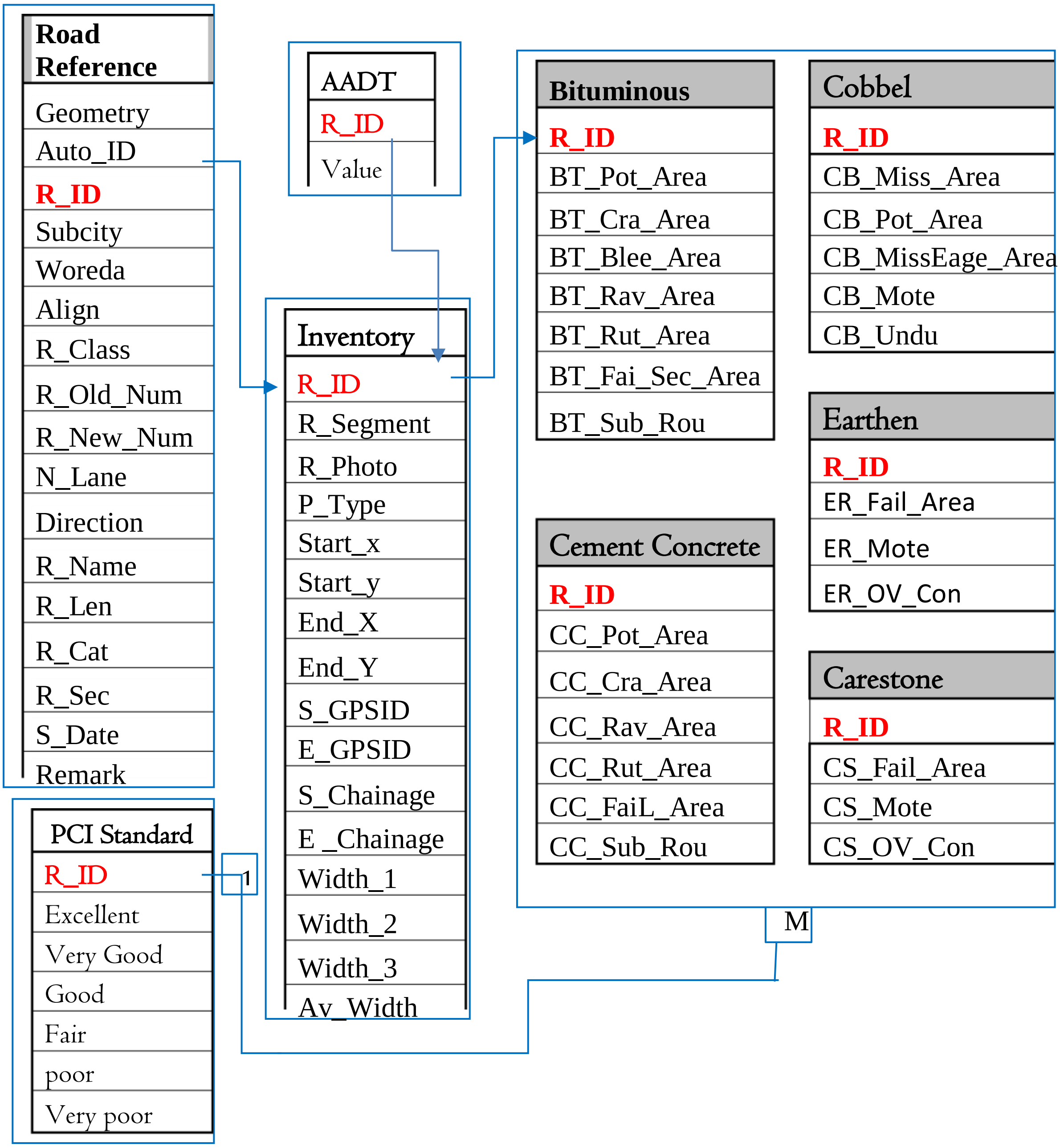


Figure: 4. 8. Relationship Attribute of Road Network

4.3.3 Physical Design Phase

In the physical design phase, the procedure of building the geodatabase will be described in terms of applying the specification identified in conceptual and logical design phase. Using architectural enterprise 15.1 to design the physical model go to specialized unified model language (UML) for Arc GIS specialist and created Arc GIS work space. The spatial reference, feature datasets and domain are coded.in addition, the valid subtype and domain are associated to the features attribute and relationship rule were applied. The UML diagram

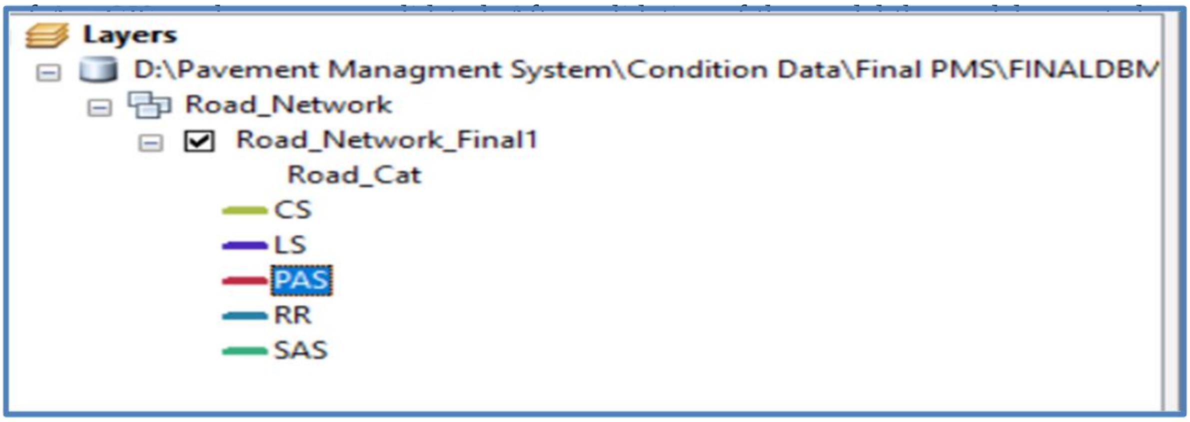


Figure: 4. 9. The Physical design of PMS Geodatabase

Figure 4.9 above shows the designed geodatabase for pavement management system. Before exporting the designed UML model from Architectural Enterprise, the model were validated in terms of spatial reference, domain, workspace package, default subtype codes for feature class. The validated model was exported from UML diagram into XML scheme (see appendix 3) and XML scheme was imported into Arc Catalog and presented in figure 4.10 below. The figure showed the imported road network feature dataset to Arc Catalog.

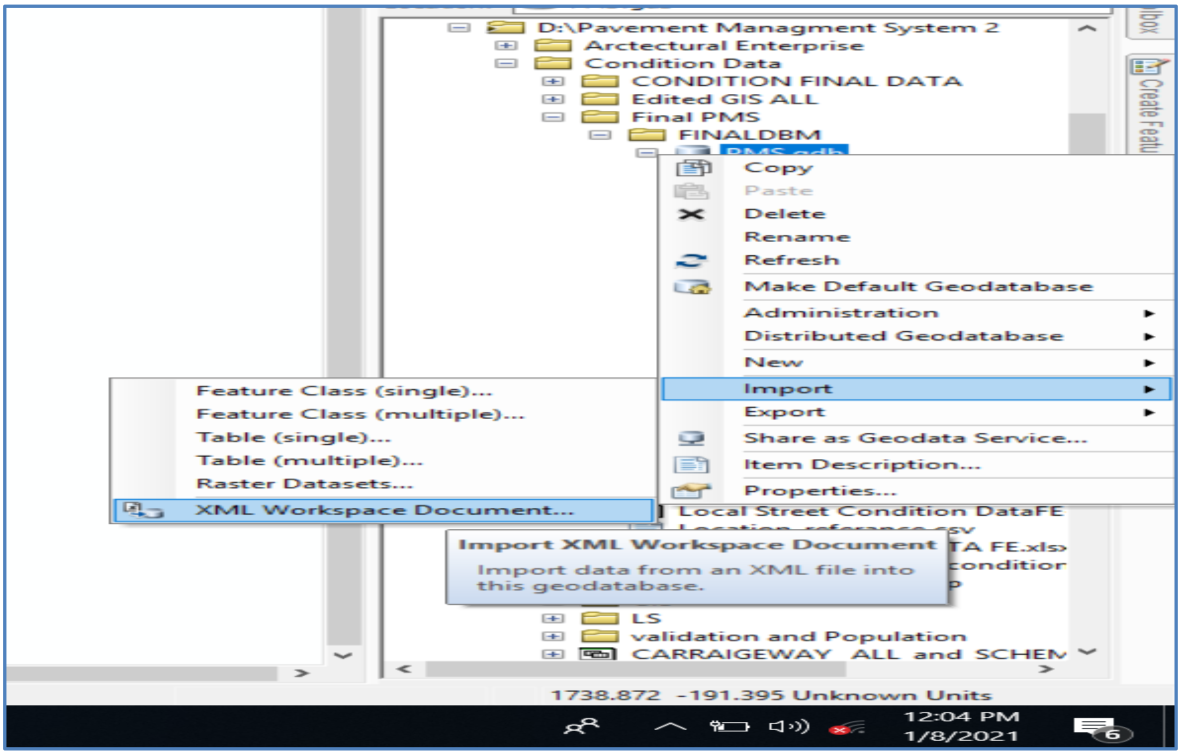


Figure: 4. 10. Importing XML road network feature dataset to Arc Catalog

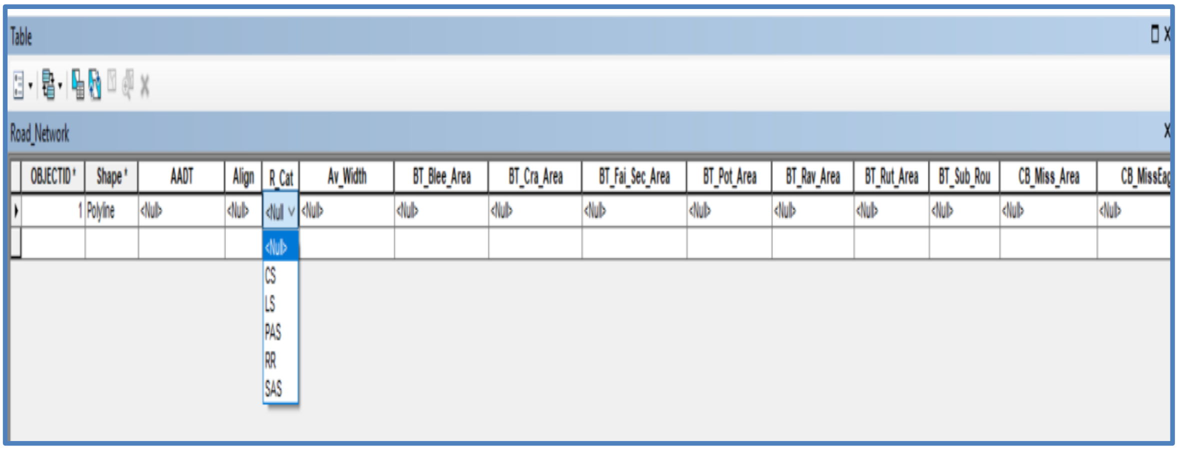


Figure: 4. 11. The Imported XML Schema in arc GIS Environment

The develop XML Schema imported in to previously created PMS Geodatabase on arc Catalog. The newly imported Schema seems like as shown in figure 4.11 in the above figure. The above figure shows developed schema in architectural Enterprise 15.1 for AACRA was successfully imported in ArcGIS 10.5 software. Before going to the collected data the developed Geodatabase the subtype what we give as subtype checked. After the check up all the collected data migrating into physically design geodatabase was discussed the next topic.

4.4 Populate and Implementation

The model was populated by the study area collected inventory, pavement condition data and secondary data for further data analysis. As shown figure 4.11 below, the loadings of constructed Geodatabase feature class and the collected data which is prepared in excel file format from local directory.

The collected data was inventory data, pavement condition and Secondary data (like AADT, Road Class) loaded by relating the filed name. As shown in figure 4.12 all collected data and secondary data displayed. This is not final result but the data is ready for further query and analysis. In addition to this the first objective of this study was successfully achieved in this steep. The next step was testing the developed geodatabase by develop pavement prioritization model for proper and scientific maintenance scenario.

All the data collected using Survey 123 Application prepared by ESRI, but the customization and questioner was develop by the researcher according to developed Geodatabase to synchronize the data finally. The application was support the external GNSS with millimeter accuracy and picture also taken from each deterioration area.

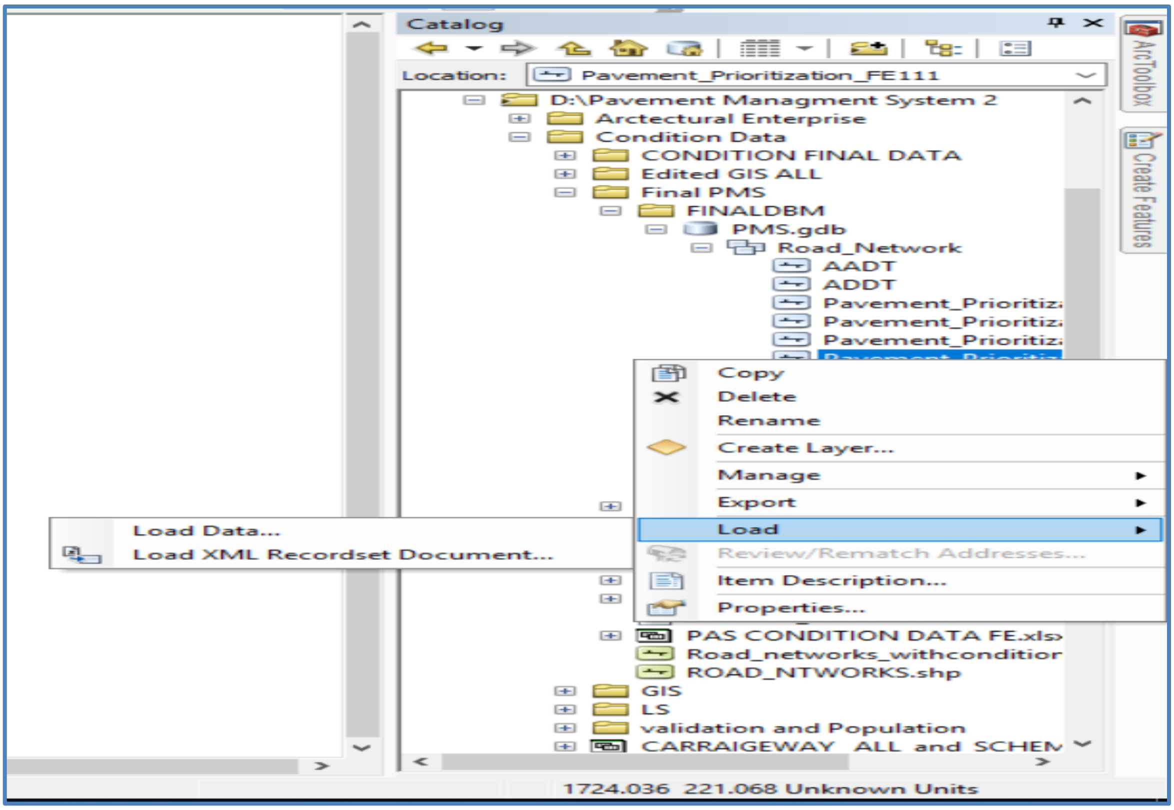


Figure: 4. 11. Data migration and populating in developed PMS

Table

Pavement_Prioritization_FE111

Shape *	Subcity	Woreda	RID_NEW	Road_Cat	Direction	Section	Surve	Align	AA1_WS_Typ	start_x	start_y	End_X	End_Y	Shape_Le	RID_NEW_1	Segme	Wid
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-1	SAS	Ascending	1	7/5/20	0	S221-01	473760.336	991618.13	473666.572	991584.017	99.999955	S221-01-1	1	9
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-2	SAS	Ascending	1	7/5/20	0	S221-01	473666.572	991584.01	473572.715	991549.707	100.00003	S221-01-2	2	7.5
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-3	SAS	Ascending	1	7/5/20	0	S221-01	473572.715	991549.70	473479.314	991514.600	100.00006	S221-01-3	3	7.1
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-4	SAS	Ascending	1	7/5/20	0	S221-01	473479.314	991514.60	473386.897	991477.300	100.00000	S221-01-4	4	7.1
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-5	SAS	Ascending	1	7/5/20	0	S221-01	473386.897	991477.30	473293.511	991442.651	99.999978	S221-01-5	5	7.2
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-6	SAS	Ascending	1	7/5/20	0	S221-01	473293.511	991442.65	473221.745	991424.081	74.449056	S221-01-6	6	7.2
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-1	CS	Ascending	1	7/5/20	0	C010-01-A	473715.076	991836.04	473814.867	991842.502	99.99997	C010-01-A-1	1	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-2	CS	Ascending	1	7/5/20	0	C010-01-A	473814.867	991842.50	473914.658	991848.962	99.99997	C010-01-A-2	2	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-3	CS	Ascending	1	7/5/20	0	C010-01-A	473914.658	991848.96	474013.379	991864.197	99.999997	C010-01-A-3	3	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-4	CS	Ascending	1	7/5/20	0	C010-01-A	474013.379	991864.19	474110.704	991887.125	100.00007	C010-01-A-4	4	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-5	CS	Ascending	1	7/5/20	0	C010-01-A	474110.704	991887.12	474191.892	991895.559	83.991953	C010-01-A-5	5	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-D-1	CS	Ascending	1	7/5/20	0	C010-01-D	474187.773	991919.89	474094.100	991891.253	99.999972	C010-01-D-1	1	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-D-2	CS	Ascending	1	7/5/20	0	C010-01-D	474094.100	991891.25	473996.716	991868.534	99.999873	C010-01-D-2	2	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-D-3	CS	Ascending	1	7/5/20	0	C010-01-D	473996.716	991868.53	473897.690	991856.205	99.99998	C010-01-D-3	3	7

4.5 Develop pavement Maintenance prioritization model

Based on the findings from the literature review and interviews, it is essential to develop a GIS-based Pavement Maintenance Management model to manage pavement maintenance effectively in AACRA.

4.5.1 Identify and Rating factor affecting pavement maintenance

In this study, 3 important factors have been identified through literature review and interview which should be taken into account for the proposed model of pavement maintenance management. These are pavement condition index (PCI), Average Annual Daily Traffic (AADT) and Road category. The above mentioned factors were taken as Multi criteria decision and analysis.

MCDA was therefore adopted for the road pavement prioritization. Weights were then assigned to the three major criteria identified to be the major contributing factors in the network level prioritization.

In this phase, the 3 factors affecting pavement maintenance priority were used to compute the output priority scores for the proposed model. Therefore, classifying, describing factors and assigning classification scales were necessary. The tasks of classifying factors will mainly follow the ERA pavement condition survey manual.

The pavement condition index was rated higher than the other two criteria, traffic condition and the road classification factor. The road has four road classes in the study area, principal arterial streets, secondary arterial streets, collectors' street and local streets were rated according to its importance as indicated in table 4.9. Similar ratings were done for the road surface condition and road traffic volume shown in tables 4.10 and 4.11 respectively.

i. Pavement Condition Indicator (RCI):

PCI were very important factor affecting criteria to prioritize pavement maintenance. However, the survey data beneath the PCI can be useful, such as cracking, rutting, texture pothole, bleeding etc. PCI is an important guidance, but its data should be validated and investigated further, as some data can be misleading.

In table 4.9 shows condition rating to prioritize the road for maintenance, this table shows the maintenance need rating , if the road segment is very poor condition rating high ,if the road segment is in very good condition rating very low vice versa. This data is populated in to geodatabase as a one factor or criteria to prioritize the road segment for maintenance. Example, as shown in table 4.9 road segment S221-01-1 found column 52 and row 1 the PCI value were "good", as per table 4.9 condition rating table very low rating for maintenance because of the pavement condition acquired in good condition. The reverse is true if the road is in very poor condition.

Table: 4. 9. Carriage Way Condition Attributes

Road Id	**Road class (5)**	**Ratings**	**Scale**
1	Very poor condition (PCI>40)	High	4
2	Poor condition (40 to 50)	Medium	3
3	Fair condition (50 to 70)	Low	2
4	Good condition (70 to 90)	Very Low	1

Table: 4. 10. Sample populated data in design geodatabase

1	29	34	35	36	37	38	39	40	41	47	48	49	50	51	52
R_ID	RID_NEW_	Av_Width	Pav_Type	BT_Pot_Ar	BT_Cra_Ar	BT_Fai_Se	BT_Blee_A	BT_Rav_A	BT_Rut_Ar	Shape_Le_	Pav_Area	T_Det_Area	P_Det	PCI	PCR
1	S221-01-1	8.000	BT	8	0	80	10	0	10	100.000	800.00015	108	13.500	86.500	Good
2	S221-01-2	7.367	BT	10	4	12	16	14	10	100.000	736.6668	66	8.959	91.041	Very_Good
3	S221-01-3	7.100	BT	6	0	10	32	12	0	100.000	710.00013	60	8.451	91.549	Very_Good
4	S221-01-4	7.100	BT	4	0	4	6	0	0	100.000	710.00013	14	1.972	98.028	Very_Good
5	S221-01-5	7.200	BT	16	0	12	0	8	0	100.000	720.00013	36	5.000	95.000	Very_Good
6	S221-01-6	7.200	BT	8	10	2	4	0	0	74.449	536.0329	24	4.477	95.523	Very_Good
7	C010-01-A	7.000	BT	14	0	0	30	0	0	100.000	699.99994	44	6.286	93.714	Very_Good
8	C010-01-A	7.000	BT	0	0	0	16	0	0	100.000	699.99994	16	2.286	97.714	Very_Good
9	C010-01-A	7.000	BT	0	4	20	0	0	0	100.000	699.99994	24	3.429	96.571	Very_Good
10	C010-01-A	7.000	BT	8	0	10	20	12	8	100.000	699.99994	58	8.286	91.714	Very_Good
11	C010-01-A	7.000	BT	2	10	2	8	0	6	83.992	587.94395	28	4.762	95.238	Very_Good
12	C010-01-D	7.000	BT	0	4	8	10	12	0	100.000	699.99948	34	4.857	95.143	Very_Good
13	C010-01-D	7.000	BT	0	0	0	0	0	0	100.000	699.99948	0	0.000	100.000	Very_Good
14	C010-01-D	7.000	BT	10	20	14	16	12	10	100.000	699.99948	82	11.714	88.286	Good
15	C010-01-D	7.000	BT	0	16	2	12	4	4	100.000	699.99948	38	5.429	94.571	Very_Good
16	C010-01-D	7.000	BT	0	0	8	0	4	8	86.700	606.89955	20	3.295	96.705	Very_Good
17	R001-08-A	11.000	BT	0	0	4	0	6	0	100.000	1100.0001	10	0.909	99.091	Very_Good
18	R001-08-A	11.000	BT	0	4	0	0	0	0	100.000	1100.0001	4	0.364	99.636	Very_Good
19	R001-08-A	11.000	BT	0	0	0	0	0	0	100.000	1100.0001	0	0.000	100.000	Very_Good
20	R001-08-A	11.000	BT	0	0	0	0	0	0	100.000	1100.0001	0	0.000	100.000	Very_Good
21	R001-08-A	11.000	BT	0	2	0	0	0	0	100.000	1100.0001	2	0.182	99.818	Very_Good
22	R001-08-A	11.000	BT	0	10	6	8	0	10	100.000	1100.0001	34	3.091	96.909	Very_Good
23	R001-08-A	11.000	BT	8	8	10	20	16	0	54.630	600.93003	62	10.317	89.683	Good

In table 4.10 above were showed the populated data in newly design geodatabase, in column 1 indicates the auto generated road ID (R_ID) of each road segment. Column 29 describe new geocoded Unique ID of in the given segment, column 34 describe the average width of the road, from column 36 to 41 different bitumen pavement deterioration described like deterioration area of pothole, cracking, bleeding, failed section, routing and raveling were mentioned. Columns 47 were describe the measured shape length of each segment every 100m. Column 48 describes pavement area calculated by multiplied road width by shape length. Column 49 describe for total deterioration of the pavement in the given segment the total deterioration were calculated by sum up deteriorate area of the pothole, cracking, bleeding, failed section, routing and raveling, i.e. sum of column 36, 37, 38, 39, 40 and 41. Column 50 represents percentage of deterioration. Column 51 shows in design geodatabase were the PCI of the given segment. The PCI classified in to very good, good, fair, poor and very poor condition according to ERA standard that is known as pavement condition rating (PCR) as indicated in column 52.

In general, the above explanation is shows how to calculate the PCI in this Geodatabase. This is not the final goal, but very important step acquiring the PCI value and rating to develop Pavement Maintenance prioritization model.

Figure 4.12 given below showed spatial analysis of pavement condition of the all road network classified in Arc GIS engine by rating pavement condition in to five, thus are very good, good, fair, poor and very poor but re categorized in to four for this study because in this pavement maintenance model very good condition pavement doesn't need maintenance . In this study three class of PCI were acquired that are very good, good and fair pavement condition but there is no poor and very poor according to the collected data as shown in the map above.

The brown color shows very good condition in network level and rated as no effect in this model, the purple color were shows pavement in acquired in good condition state and rated as very low effect. Light green color was shows the fair condition and rated low effect according to table 4.9.

In general the above pavement condition Index were the first factor or criteria and waited 5 from 5 by expert judgment review literature to develop pavement maintenance prioritization model.

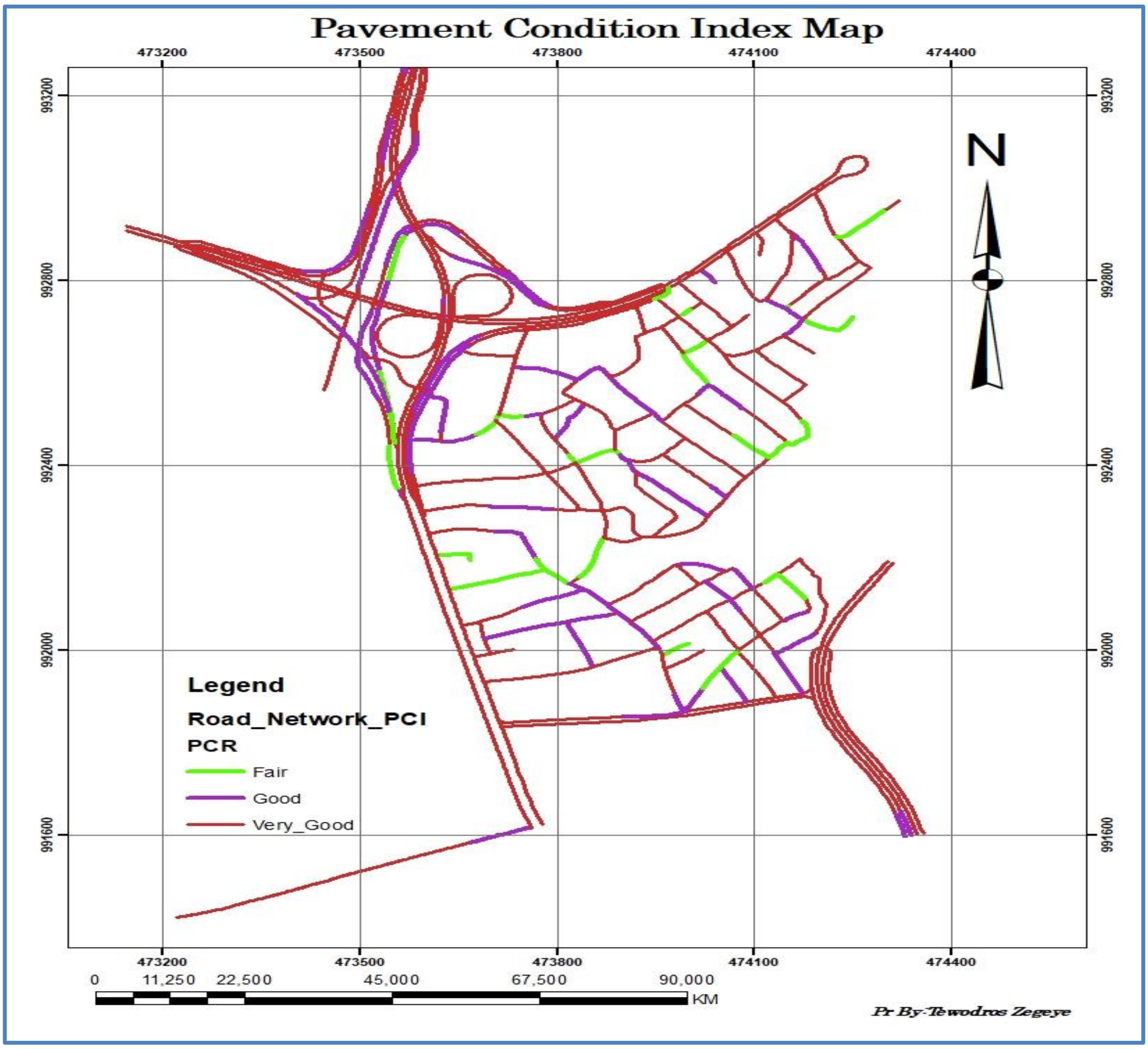


Figure: 4. 12. Spatial Classified PCI Map

In general the above pavement condition index was the first factor to prioritize highly attention needed for maintenance.

ii. Annual Average Daily Traffic (AADT): AADT represents the daily traffic volume, which indicates the actual use of the road, and that helps to determine treatment design and necessary pavement depth/strength. In addition to above reason in this study the second factor selected as MCDA were ADDT to prioritize highly attention needed for maintenance. According to the ERA manual the road in the study area were categorized in to four as shown in table 4.11 below.

Table: 4. 11. Traffic volume ratings (source: ERA Design Manual)

Road Id	AADT(4)	Ratings	Scale
1	>10000	High	4
2	3500 to 10000	Medium	3
3	1500 to 3500	Low	2
4	<1500	Very Low	1

Table 4.11 above showed the annual average daily traffic (AADT) of the study area. AADT is second criteria to select highly attention needed for maintenance. As shown on the map according to TIMS traffic count in PAS and RR has above 10,000 car pass per day and on LS below 1500 different car pass per day.

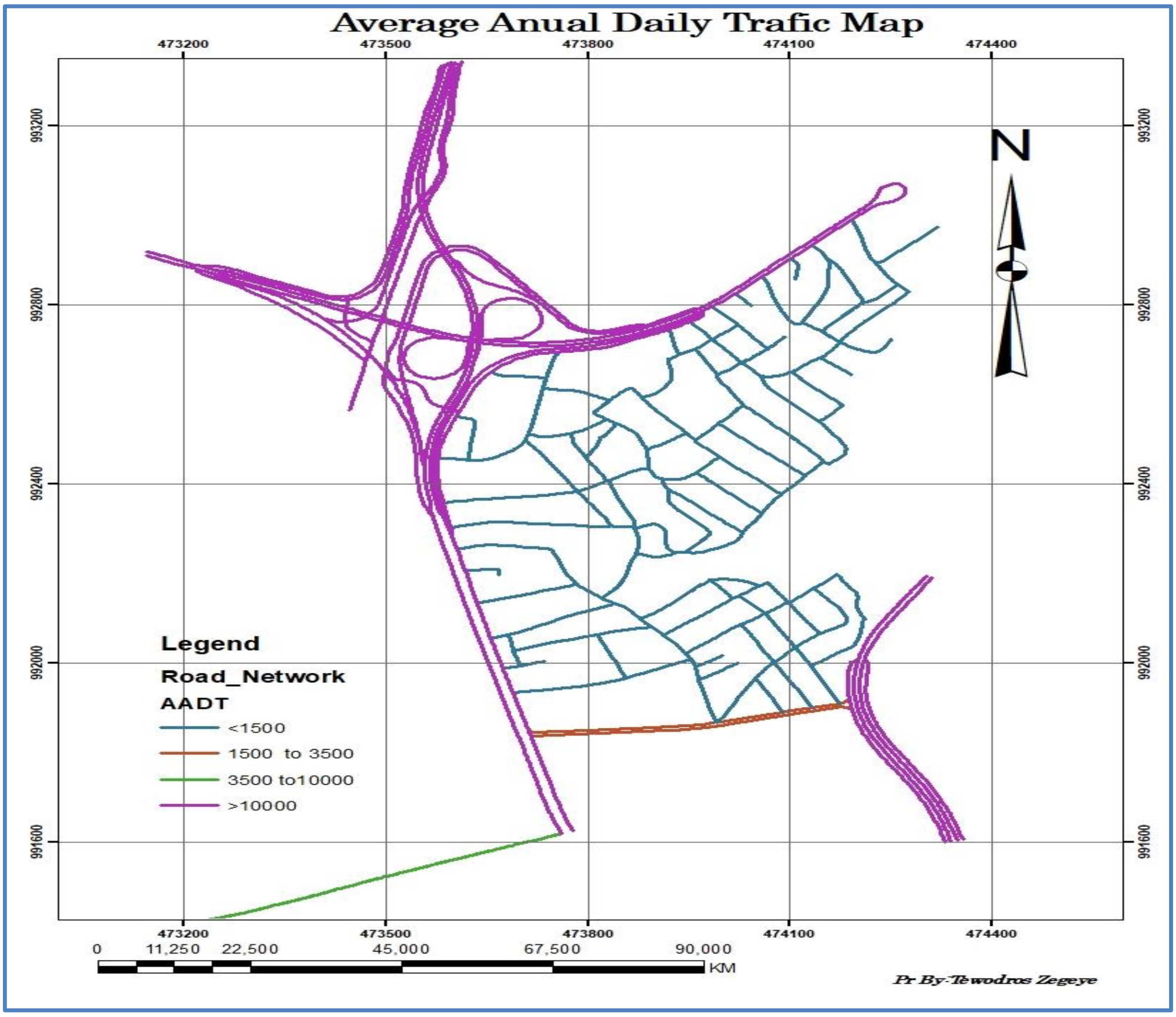


Figure: 4. 13. Populated Average Annual daily traffic map of Road Network

In general these factors were selected as the second factor or criteria and waited 4 from 5 by expert judgment to develop pavement maintenance prioritization model

iii. Importance/Classification of Road: Road classification indicates the importance of the road, and the typical uses of the road were a very important factor when prioritizing major maintenance works, in order to ensure the critical routes serviceable. In the study area the road were classified in to four according measured width of road versus to ERA design manual. Addis Ababa City Road Authority (AACRA) manages the road network of 10 sub-cities under Addis Ababa. The roads are classified into 5 types as mentioned below.

Ring Road (RR): RR passes through the outer periphery of the city and decongests the city traffic. *Principal / Primary Arterial Street* (PAS): are the primary or major routes of the city with 30-60 m right-of-way. *Secondary arterial street (SAS):* are the secondary routes which connect the PAS with about 20-30m right-of-way. *Collector streets (CS):* are the routes which have 15-30 m right-of-way. *Local streets (LS):* are the local roads which provide access to houses having right-of-way up to 15m. In general in this study the importance of the road reclassified in to four for the purpose of data management and analysis in the design geodatabase.

Table: 4. 12. Road Class rating

Road Id	Road class(4)	Ratings	Scale
1	Principal arterial street (PAS & RR)	High	4
2	Secondary arterial street (SAS)	Medium	3
3	Collectors street (CS)	Low	2
4	Local roads street (LS)	Very Low	1

According to table 4.12 above and figure 4.15 below shows the road in the study area, Local road Street represent in light purple and rated very low effect, collector street represent in violet color rated low effect, secondary arterial street represent in green color rated medium effect, the Ring Road and principal arterial road represent by coffee and Carolina color respectively and rated as high effect in periodization model in this study.

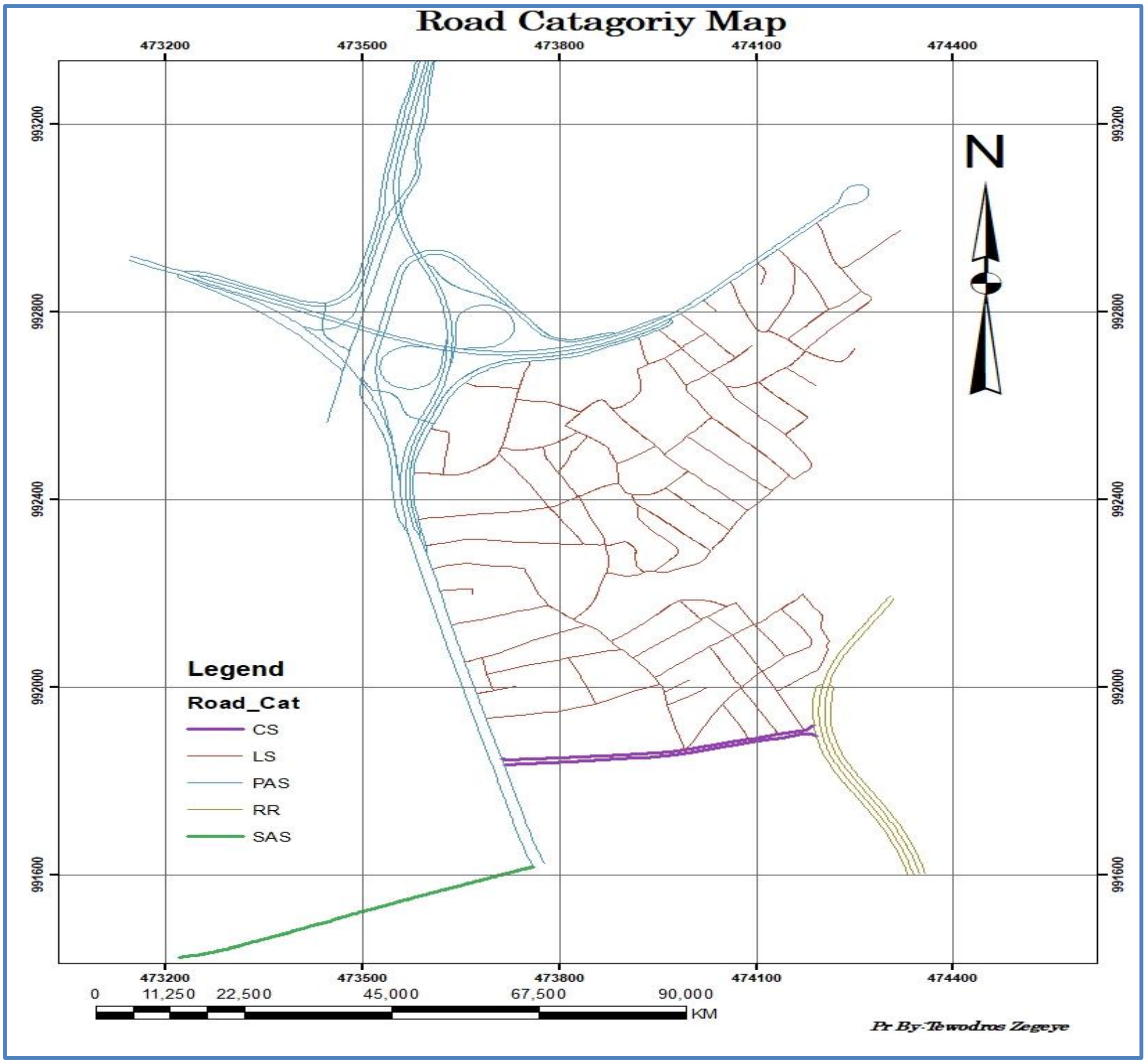


Figure: 4. 15. Populated Road Class and Classified road Category layers

In general, the third factor or criteria were road class and waited 4 from 5 by expert judgment and review literature to develop pavement maintenance prioritization model.

4.5.2 Calculation of Pavement Maintenance Priority Score (PMPS)

The next step will be to calculate PMPS, which indicates the ranking of alternatives. This is done by multiplication of the priority matrix and the vector of factors' weights. The output of this calculation is the vector that indicates ranking of alternatives. The AHP algorithm used to calculate the priority score is presented as follows:

$$PMPS = [(F_1 * W_1) + (F_2 * W_2) + (F_3 * W_3) + (F_4 * W_4)] \ldots\ldots (Eq.\ 4.1)$$

Where, F = Score of Factor (1 to 4)

W = Weight of Factor (5, 4, 4)

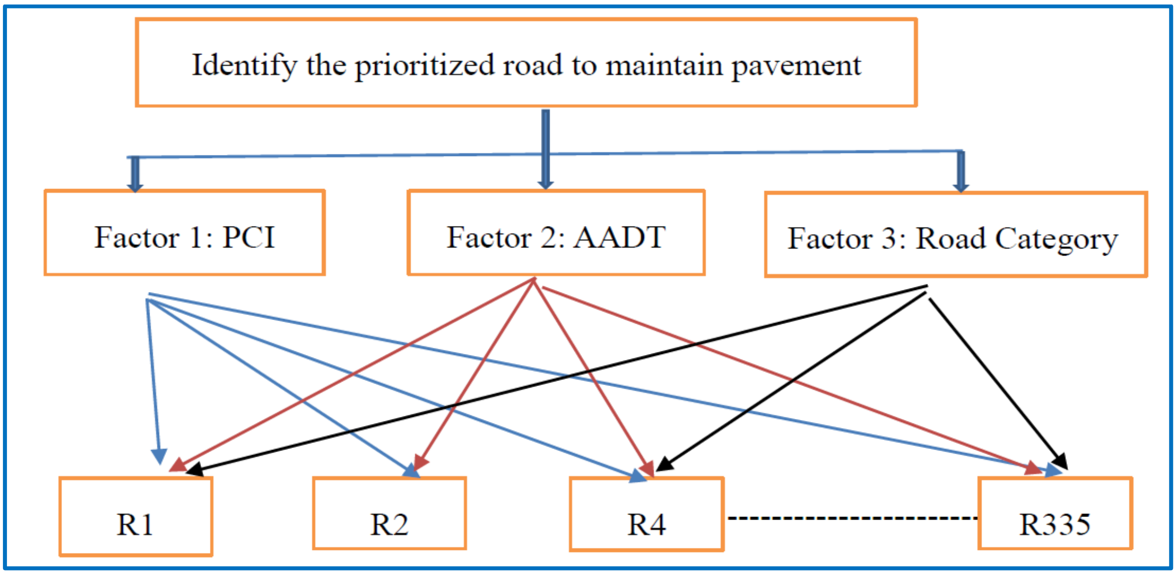


Figure: 4. 14. PMS Priority model

4.5.3 Test the developed Model for Pavement Maintenance Priority

In this stage populate the calculated PCI, AADT and rode class value. The developed geodatabase final model populated by primary and secondary collected data of pilot study of Addis Ababa Nifas silk woreda 8 to test the proposed model. This will help to check that it can be used and applied within similar woreda and sub city of Addis Ababa.

In general the conceptual distinctions of the model are outlined with an emphasis on the data fed into and out of it. The calculated AHP algorithm via excel software is then integrated or Join and relate the table into the newly design geodatabase by Unique ID. According to the interview AACRA gave special priority to roads identified by them as strategic roads; they were maintained year-to-year mainly due to government influence without considering technical and socio-economic factors for prioritization.

Table 4.13 below shows some examples of strategic roads identified by AACRA. It was found that there are no particular criteria followed by AACRA for prioritization of maintenance activities. The method used is subjective; roads were prioritized through discussion with the higher AACRA officials without following standards and criteria. So, before the pavement prioritization analyses taken the road mentioned in table 4.13 cheeked and give a priority without any competition.

Table: 4. 13. Strategic Roads identified by AACRA

No	Road name	Start of the section	End of the section
1	Minelik II Street	Meskel Square East	Economic Commission for Africa
2	Minelik II Street	Hilton Hotel	National Palace South
3	Niger Street	National Palace South	National Palace South-East
4	African Avenue/Bole Road	Olympia Square	Wollo Sefer Square
5	Ras Abebe Aregay	Mexico Square	ERA
6	Chad Street	Mexico Square	St Lideta Medical Collage
7	Jemo Keniyata Street Avenue	Meskel Square	Meskel Square West

In this phase all calculated value were added in to created geodatabase by join and relating the excel file for further analysis and visual display.

1	29	56	57	58
		Factor Scale		
R_ID	RID_NEW_I	PCI(FI)	AADT(F2)	R_Cat(F3)
1	S221-01-1	1	3	3
14	C010-01-D-3	1	2	2
23	R001-08-A-7	1	4	4
35	R001-08-RS-5	1	4	4
41	NL-08-L029_3	1	1	1
45	NL-08-L008	2	1	1
47	NL-08-L020	1	1	1
53	NL-08-L006	1	1	1
54	NL-08-L050	2	1	1
58	NL-08-L034	1	1	1
64	NL-08-L059	2	1	1
66	NL-08-L037_1	1	1	1
70	NL-08-L031_9	1	1	1
71	NL-08-L068	1	1	1
72	NL-08-L069	2	1	1
75	NL-08-L009-2	1	1	1
76	NL-08-L009-3	2	1	1

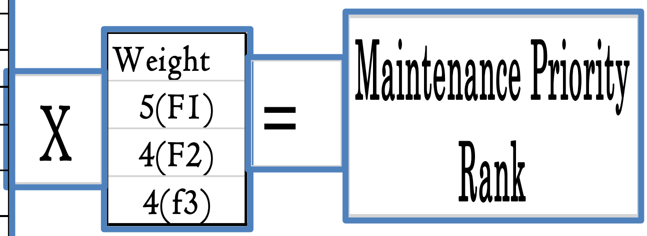


Figure: 4. 15. Sample calculation of maintenance priority

Figure 4.17 were shows how to prioritization done in newly developed geodatabase. The three factors were populated according to the given rate, this rate multiplied by the given weight. For PCI, AADT and road category were gave 5, 4 and 4 respectively.

In order to visualize each road in accordance with its priority score, priority values are classified in to 3 classes. Figure 4.18 below shows, the 335 roads segment with a color scheme where The red colored roads indicate to an immediate action required for maintenance, yellow colored roads indicate to a moderate action required for maintenance, lightest green colored roads indicate to least action required for maintenance,

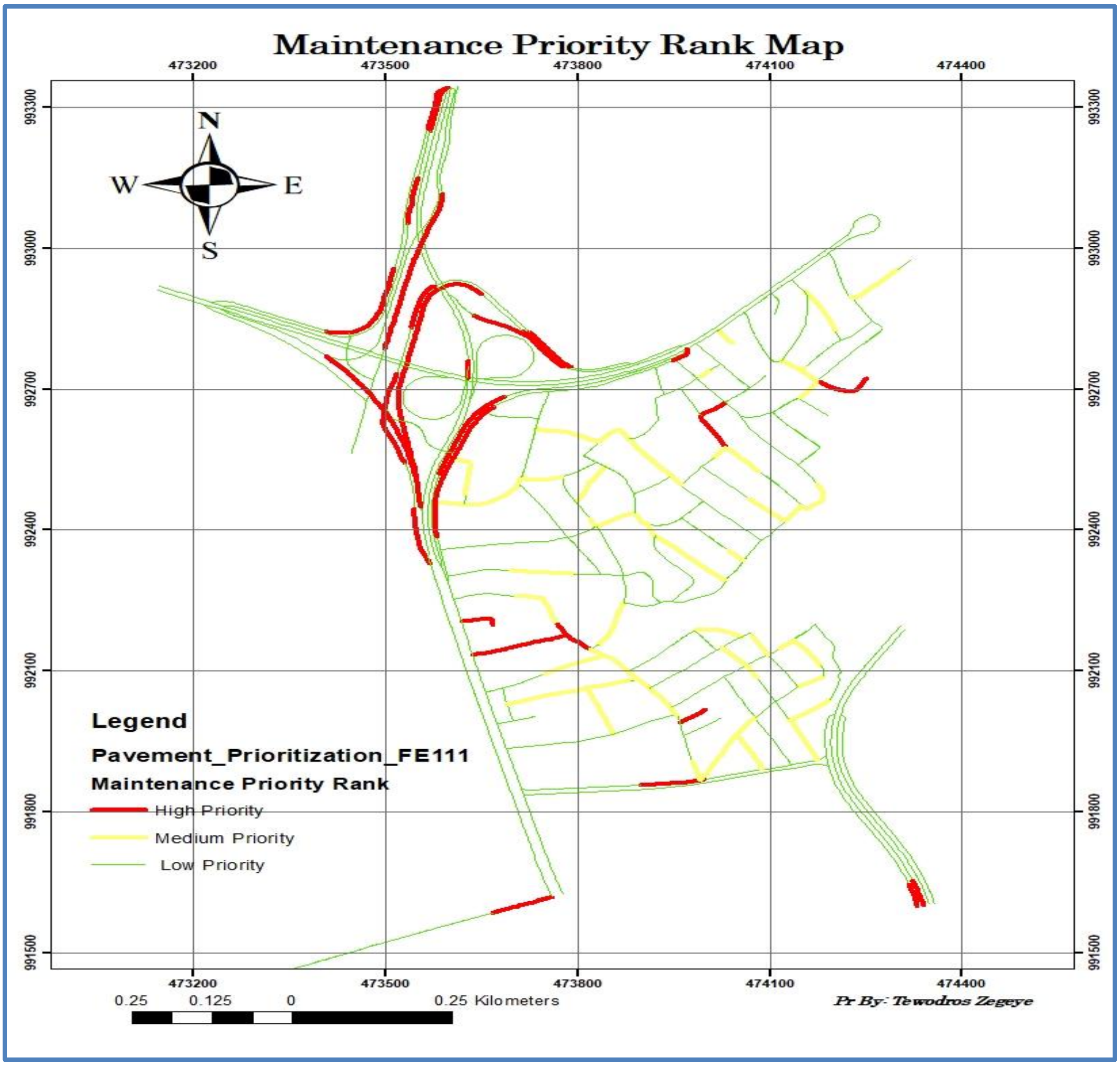


Figure: 4. 16. Classified Maintenance Priority for Roads in GIS

The road network was categorized into three for management purposes with three different colors for visual analysis and display. As shown in figure 4.18, high priority section are in red color whiles the medium and low priority sections are in the yellow and lightest green colors respectively. Policy makers use the results of the prioritization process to schedule maintenance activities.

The system is user friendly, cheap and one need not to be a database expert or an expert in GIS before he/she can operate it. If implemented, it will help decision-makers in taking decisions interactively with the aid of visualization of data in GIS without requiring any specialized technical skills. If implemented, it will help decision-makers in taking decisions interactively with the aid of visualization of data in GIS without requiring any specialized technical skills.

The pie chart shows in figure 4.19, about 13% of the road need first and high priority need from the total length of the road, 12% of the total pavement needs second priority and medium attention from current condition of the pavement condition. And about 75% of the pavements were in very good condition, so low priority and in third priority for maintenance.

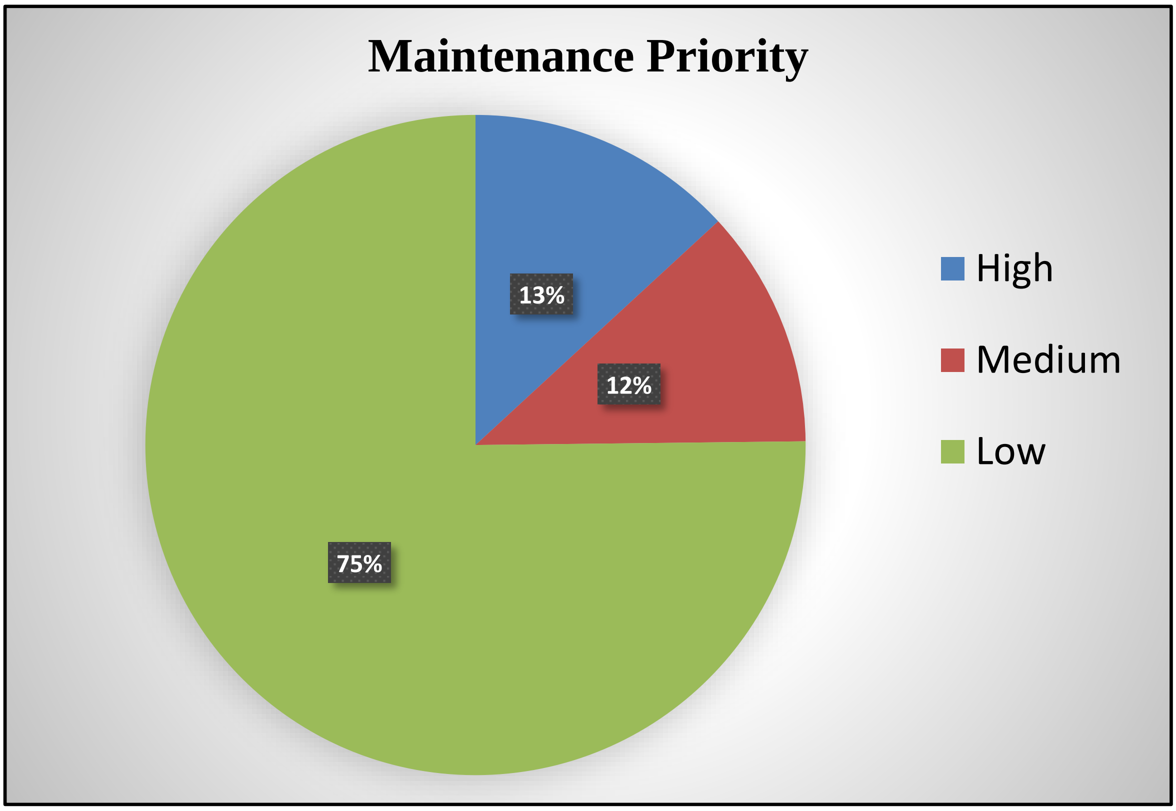


Figure: 4.19. Maintenance Priority in Percent in terms of Length

As shown in above figure 4.19, 13% of the pavement were need urgent maintenance as per the criteria, from this section 75% were principal arterial pavement, 16% were local streets and 5% secondary arterial streets as shown in figure 4.20 below.

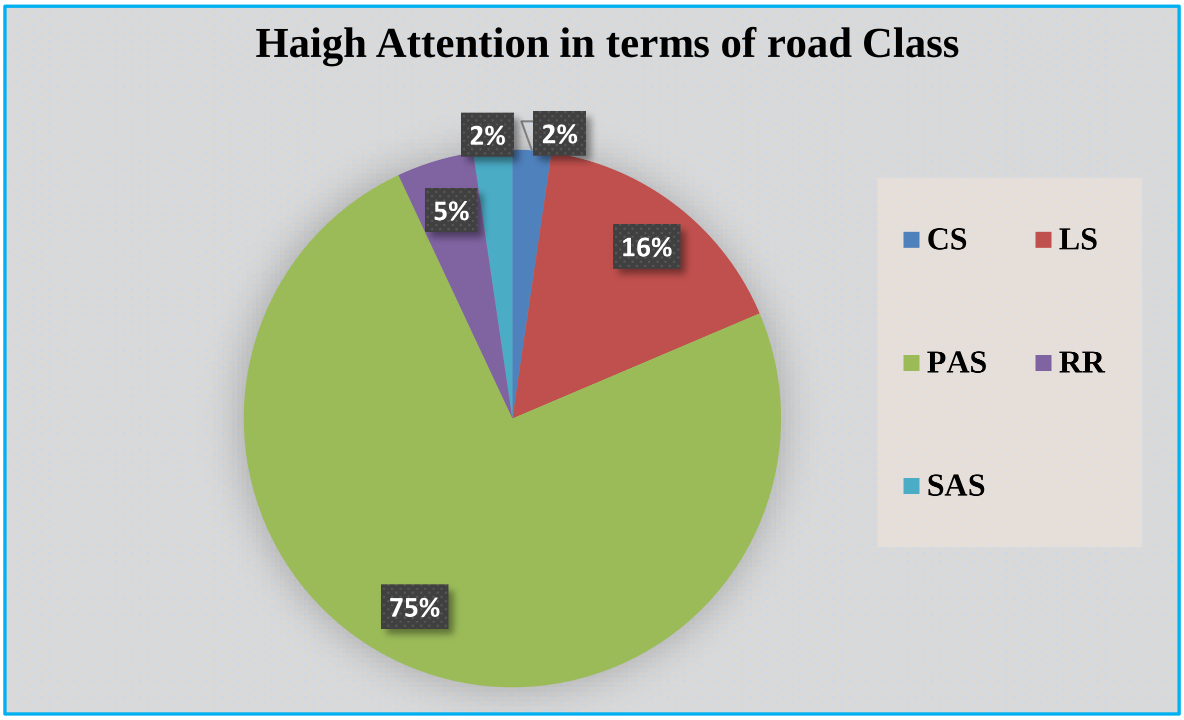


Figure: 4. 17. Primarily maintenance attention in terms road category

Some of the observations from the pilot area survey are:

✓ Higher category roads such as RR, PAS, SAS and CS have bituminous pavement surface, LS are generally cobble stone/gravel/earthen roads.

✓ RR, PAS, SAS and CS category roads have multi-lane divided carriageways and most of the LS category roads are single lane width.

✓ About 60 percent of the road length is paved with bituminous pavement, 40 percent are cobble stone.

✓ Bituminous pavements are mostly in good condition, common distresses found are raveling and potholes. Rutting is observed mainly in RR due to heavy axle vehicular movement.

4.6. Coupling Geodatabase to ArcGIS Online as a Hosted Feature layer

The first step in developing the application was to upload the geodatabase as a hosted feature layer to ArcGIS online. A hosted feature layer is a GIS feature service that can contain multiple feature classes, related tables, and relationships which are stored on ArcGIS Online and are accessible via web maps. The hosted feature layer, which consumes service credits based on the file size of the data, is the only option available to store this type of data on ArcGIS online.

To upload the geodatabase to ArcGIS Online, ArcGIS for Desktop (ArcMap) was used to create map a document file (.mxd) that contained the feature classes and tables previously imported during the creation of the geodatabase. During the creation of the map document, the layer order and layer symbology settings were applied. These settings were retained when the feature layer was published to ArcGIS online and saved time when creating a web map.

Once the map was created and settings were configured, the map was published as a service to ArcGIS Online as a hosted feature layer. During this step, the editing functionality of the feature service was disabled since the current purpose of the application was to only view the data. However, if needed in the future, the editing functionality can be enabled through the item details page of ArcGIS Online.

4.6.1 Steps followed during Webmap Preparation in this Study

Step-1 as shown in figure 4.21, before uploading and coupling of desktop ArcGIS geodatabase, the ArcGIS online login was created by giving user name and password.

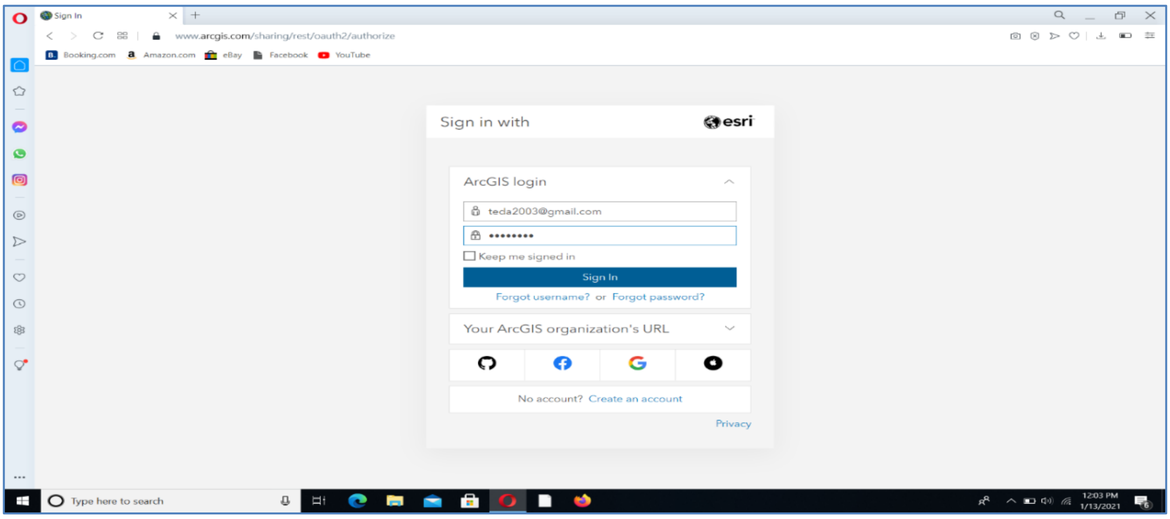


Figure: 4. 21. ArcGIS Online Login

Step-2 as shown in figure 4.22 the base map was selected by clicking on base map ''ESRI hybrid imagery'' because ESRI improve and update the spatial accuracy of the location.

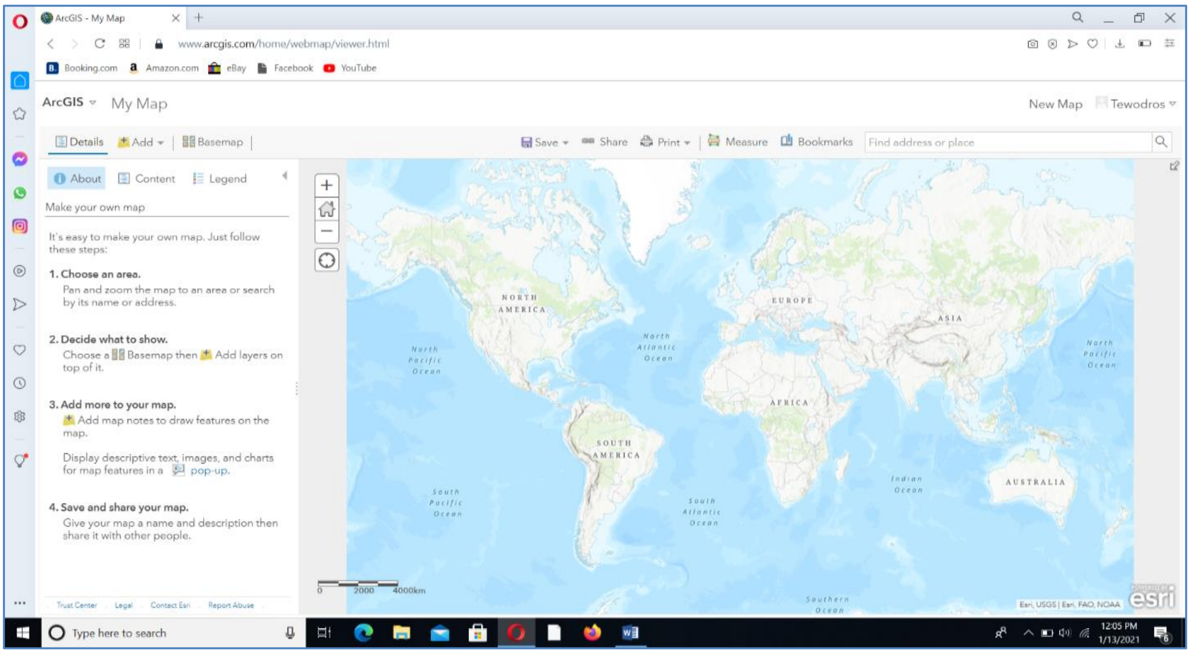


Figure: 4. 18. ArcGIS online Base Map

Step-3 the next step was zipped the newly created geodatabase, because ArcGIS online recommend zip the data before migrating ArcGIS online. So click on add layer button and select the file from local disk directory path. Figure 4.24 shows uploading steps.

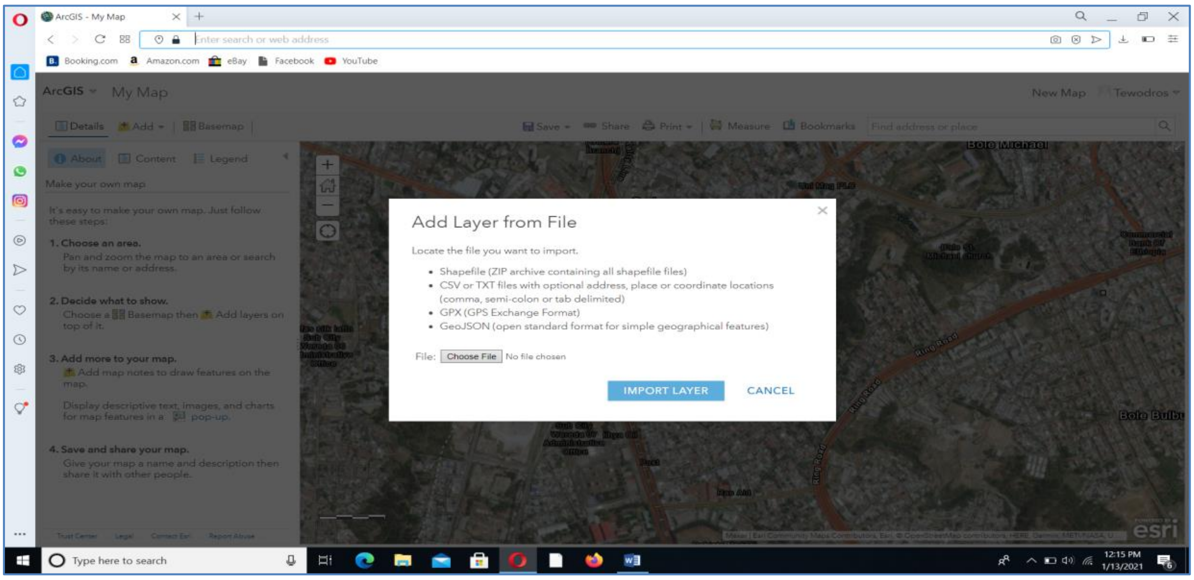


Figure: 4. 19. Uploading zipped Data in to ArcGIS Online

Steep-4 the upload data was cusumized,as shown in ArcGIS Desktop similar way anlysis, quary selection and puplsing was done here. Legend, book mark, zoom in/out pan in/out and dtermination of spatial extent was custumized in this steep. As shown in figure 4.23 below the custumization prosses of up loaded data.yryn.

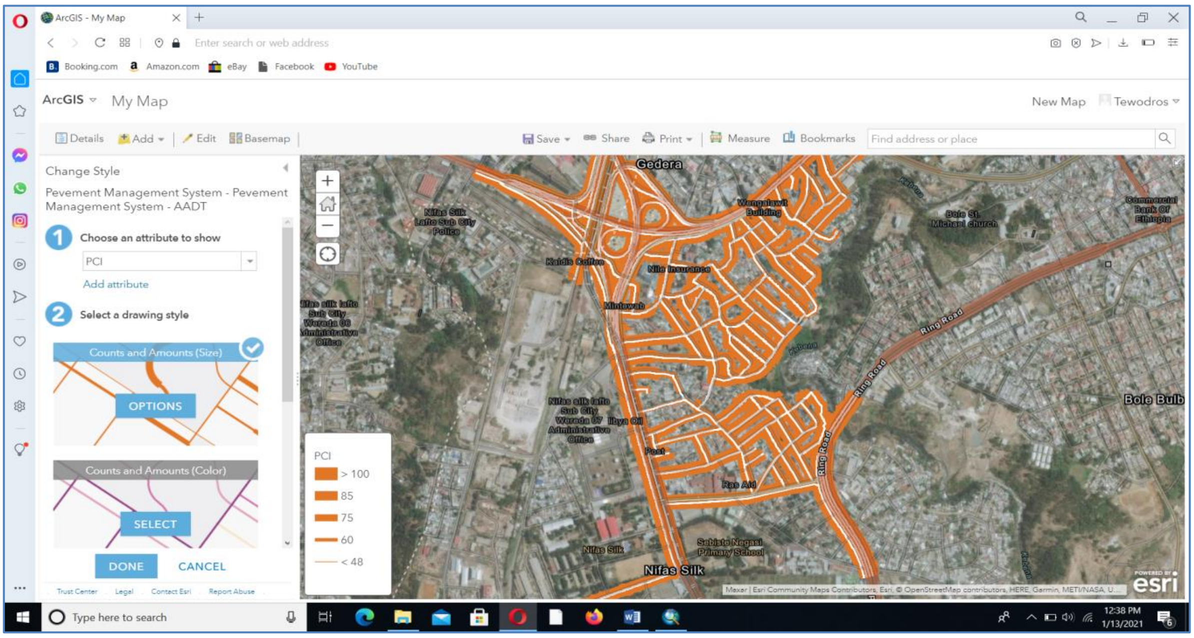


Figure: 4. 20. Webmap Preparation

Steep-5 in this stage the puplsid map was displaied, the webmap is ready for print out and sharing the map to the other stakeholder and road user. Figure 4.25 below show the final priorityzed road pavement in terms of maintenance attention.

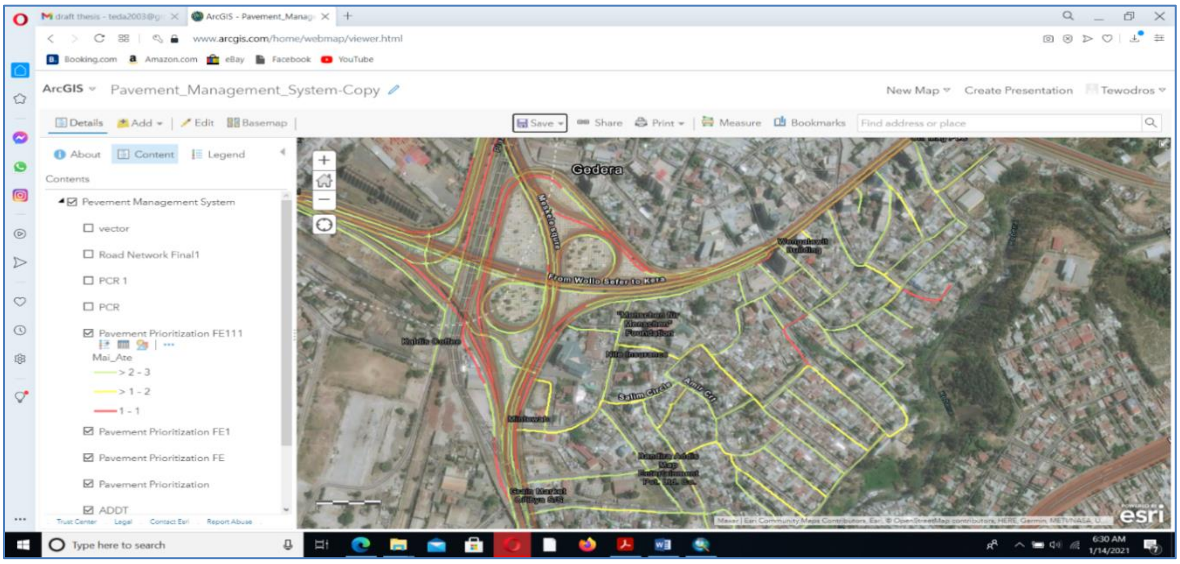


Figure: 4. 21. WebGIS based Display for Maintenance

Steep-6 this steep was final steep sharing the prpared map for selected group or public . the designed webGIS map viseted by entering https://www.arcgis.com/ in any explorer by entering the user name and passward every were in addis ababa or other world the internate conection avilable area.

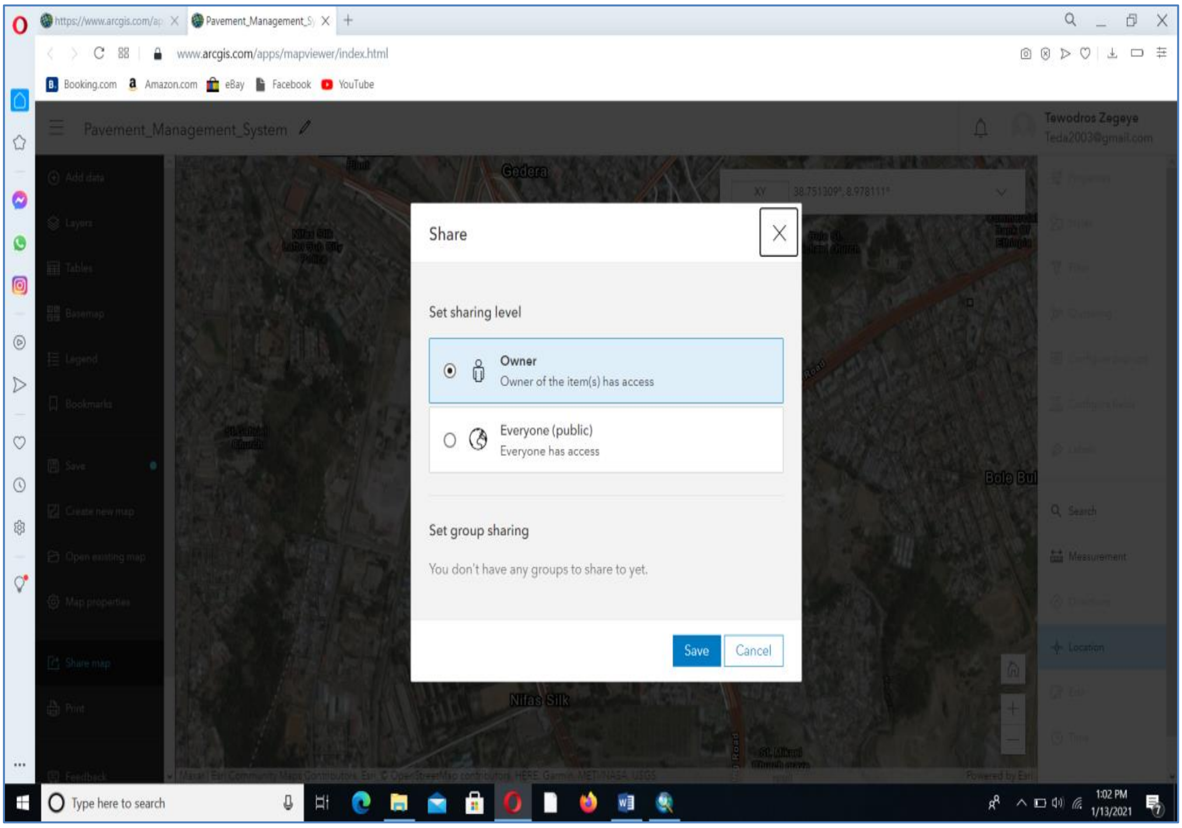


Figure: 4. 22. WebGIS Data Sharing

Once the map was created and settings were configured, the map was published as a service to ArcGIS online as a hosted feature layer. During this step, the editing functionality of the feature service was disabled since the current purpose of the application was to only view the data. However, if needed in the future, the editing functionality can be enabled through the item details page of ArcGIS online. Figure 4.26 shows the ArcMap document prior to publishing.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1. Conclusions

The study investigates the development of GIS based road pavement management system geodatabase and integration with webGIS for optimizing the pavement life time and used as framework for decision-makers through prioritizing road networks. In this study, webGIS based pavement management system geodatabase model is developed. The geodatabase is developed through conceptual, logical and physical design phases. The result of developed PMS geodatabase model implies that, it enables to store, manage, analyze, manipulate and display data that are linked spatially and attribute data. Moreover, it can be applied for praiotize road network which helps in decision making for effective, efficient and timely maintenance of road assets. Therefore, the study concludes the developed PMS geodatabase model can be used for performing road network trace analysis and management.

The developed PMS geo-database is tested through network analysis scenarios such as; praiotizing road networks and identifying the segment need urgent maintenance. On the developed geodatabase model road network were built. The result of the developed road network in the pilot study area was about 29.275km total length. The study identified, about 60% of the road length were paved with bituminous pavement and about 40% with cobble stone. The result from the study showed that, around 40 segment need urgent maintenance unless other ways the road damaged and increase the maintenance cost in double in short time.

Moreover, the map was published as a service to ArcGIS online as a hosted feature layer which enables to get detail information of the pavement conditions and all road network displays with spatial information digitally. Therefore, the study concludes the developed webGIS based pavement management system geodatabase model can be used for the whole Addis Ababa City in the future for proper management of road assets. It also provides an interactive recursive problems solving environment (process) in which users (road managers, planners and decision-maker) proceed by multi proposed and also making use of his experience, knowledge and intuition.

5.2. Recommendations

The result of the study implies few suggestions for practical utilization, in order to optimize the pavement life time and minimize vehicle operation cost. Based on the findings of the study, the following recommendations are forwarded for the improvement of road pavement maintenance planning and management practice in AACRA.

- AACRA has a shortage of budget, to construct the new road or maintained the existing road. Because road construction asked a huge capital to reconstruct a new road, to utilize the limited budget properly the enterprise should implement a web base pavement management system to save this limited resource. Since the developed model is designed to overcome problem including; maintenance cost, time, paper work and enables the professionals to focus on technical aspects rather than on routine paper works.
- As shown in this study result 40 segment need urgent maintenance unless other ways the road damaged and increase the maintenance cost in double in short time. So AACRA should have taken remedial action by maintaining this road pavement urgently.
- This study is prototype, AACRA should have scale up this system in other woreda and sub city to modernize the pavement maintenance management system.
- The stakeholder like Ethio telecom, Ethiopian electric Power, Addis Ababa water supply office etc. should have develop integrated web GIS geodatabase for better decision making, data sharing and planning because the system provides easy and flexible way of handling data.

- The other recommendations go to Regional Road Authority like Oromia road authority (ORA), Amhara Rural Road Authority (ARRA), South Rural Road Authority (SRRA) etc. to develop and implement this system.

- There is the need for a research like this to be carried out on areas such as drainage information system, roads accident information system, Bridge and culvert management system etc. for proper and adequate development of their geodatabase for quick decision-making in the areas mentioned.

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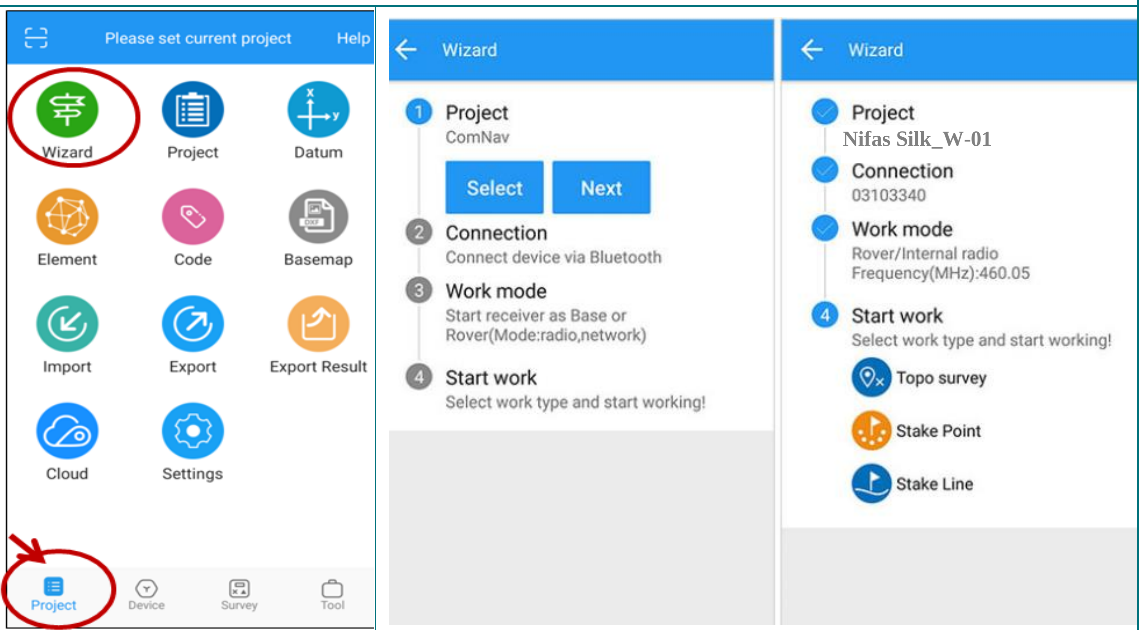
Appendix: 1. Data Collection Procedure using Survey Master App

Step 1: Select the Project interface, click on

Wizard: This sub-module is to create a new project or to select already created project.

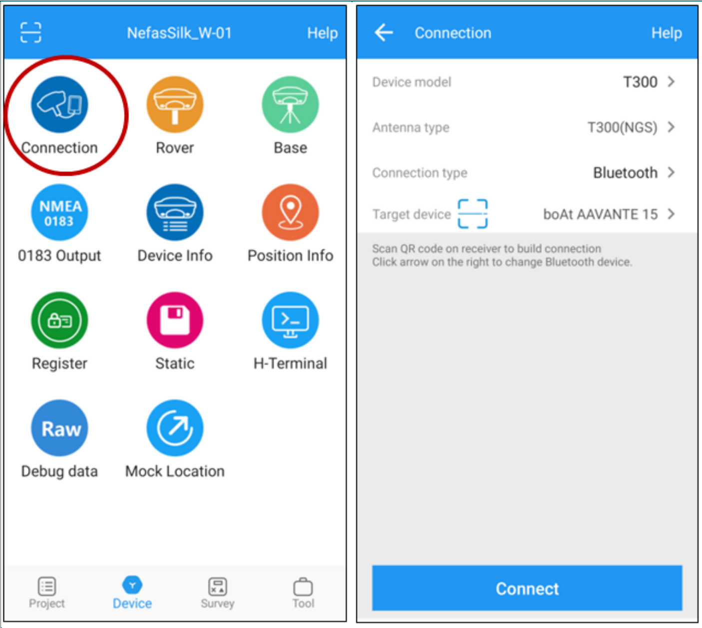
- Create a new project.
- e.g. **Project-01**,
- Configure connection with base station and then with rover through mobile Bluetooth.

Here one can select the predefined co-ordinate system such as Local grid, WGS, UTM or other to show on background of the survey interface



Step 2:

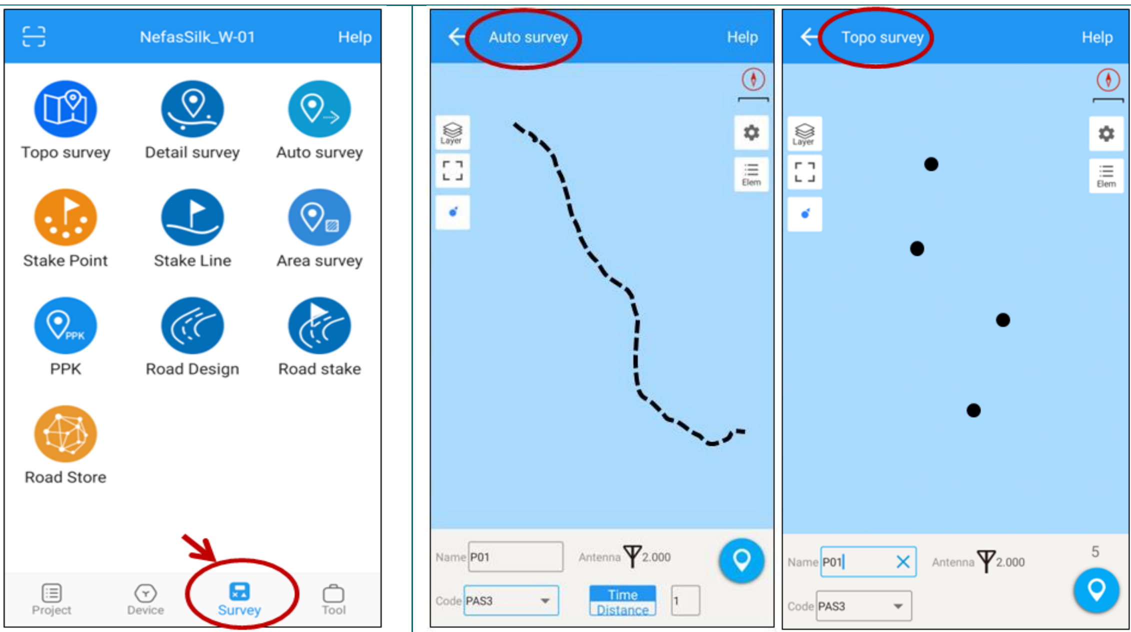
Click on 2nd interface **Device** and check the connections set the limit for accuracy of the horizontal and vertical coordinates fixed, so that if the accuracy exceeds the limit, it will show the warning message.



Step 3:

Click on 3rd interface **Survey** and select the type of survey. Enter the 'Road No.' in *Code* field and give a 'GPS ID' in *Name* field of that asset.

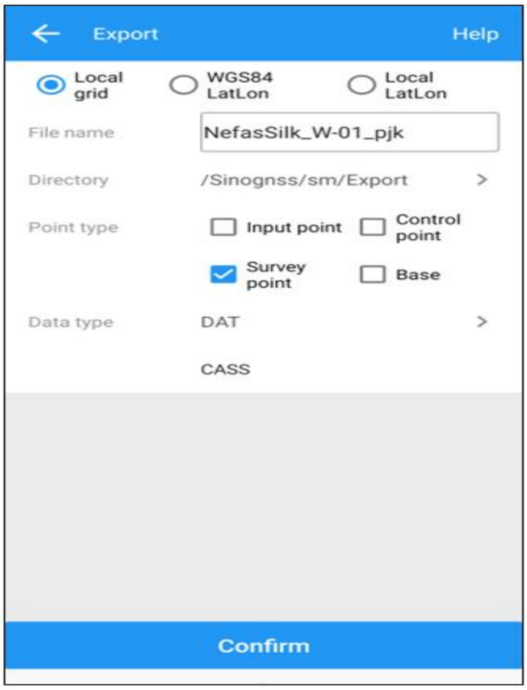
- **Topo survey**: To record the geo-coordinate of any *Point* asset, place the Rover on exact location of the asset, and then click on 'Location symbol' on the right bottom the tablet/mobile screen to record.
- **Auto survey**: In case of *linear* asset, the rover shall be moved along the asset, the geo-coordinates can be captured at defined interval of time or distance as set before.

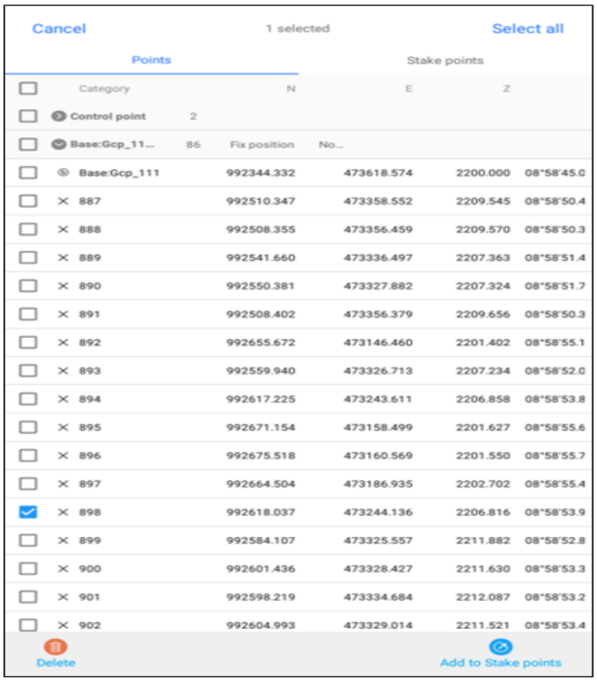


Step-4:

Export Data: After completion of the survey data can be exported in predefined formats such as .csv, .dxf, .kml, .shp and other formats. Also, survey points can be viewed and cross-checked using ‘COGO’ tool.

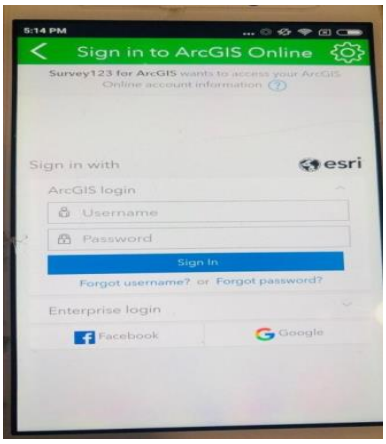

Export Result
Help
Ex. Stake Ps
Ex. Stake Ls
Export Survey Points
Export DXF
Export KML
Export RAW
Export HTML
Export SHP


Export
Help
Local grid
WGS84 LatLon
Local LatLon
File name
NefasSilk_W-01_pjk
Directory
/Sinognss/sm/Export
Point type
Input point
Control point
Survey point
Base
Data type
DAT
CASS
Confirm


Cancel
1 selected
Select all
Points
Stake points
Category
N
E
Z
Control point 2
Base:Gcp_11... 86 Fix position No...
Base:Gcp_111 992344.332 473618.574 2200.000 08°58'45.0
887 992510.347 473358.552 2209.545 08°58'50.4
888 992508.355 473356.459 2209.570 08°58'50.3
889 992541.660 473336.497 2207.363 08°58'51.4
890 992550.381 473327.882 2207.324 08°58'51.7
891 992508.402 473356.379 2209.656 08°58'50.3
892 992655.672 473146.460 2201.402 08°58'55.1
893 992559.940 473326.713 2207.234 08°58'52.0
894 992617.225 473243.611 2206.858 08°58'53.8
895 992671.154 473158.499 2201.627 08°58'55.6
896 992675.518 473160.569 2201.550 08°58'55.7
897 992664.504 473186.935 2202.702 08°58'55.4
898 992618.037 473244.136 2206.816 08°58'53.9
899 992584.107 473325.557 2211.882 08°58'52.8
900 992601.436 473328.427 2211.630 08°58'53.3
901 992598.219 473334.684 2212.087 08°58'53.2
902 992604.993 473329.014 2211.521 08°58'53.4
Delete
Add to Stake points

Appendix: 1.1. Data Collection Procedure using Survey 123 App

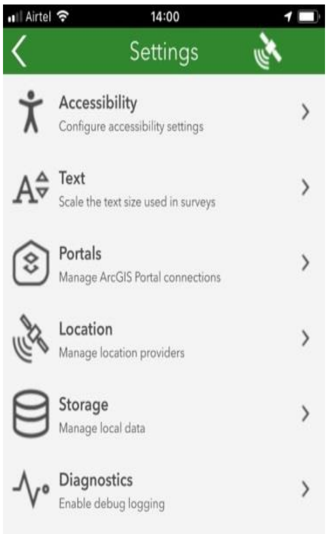
<table>
<tr>
<td>Step 1: Type ‘Survey 123 for ArcGIS’ application and download and enter login credentials.

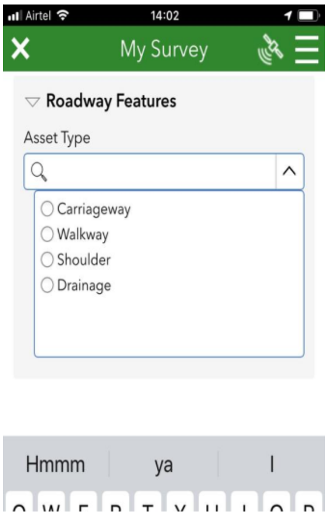
Username:


panafgis_ethiopia

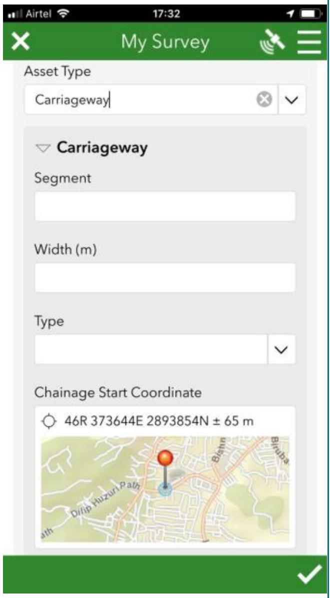
Password: ethiopia@panafgis1</td>
<td>Step 2: Download updated mobile applications ‘PMS’

</td>
</tr>
<tr>
<td>Step 3: Ensure the ‘Settings’ are updated

- Accessibility
- Text
- Portals
- Location
- Storage
- Diagnostics

</td>
<td>Step 4: Select ‘Collect’ and then any asset from ‘Roadway Features’. Assets in Roadway are;

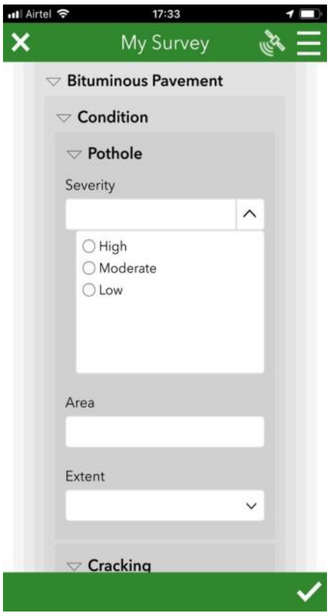
- Carriageway
- Shoulder
- Walkway
- Drainage

</td>
</tr>
</table>

Step 5: Select 'Carriageway' asset and fill the inventory information;



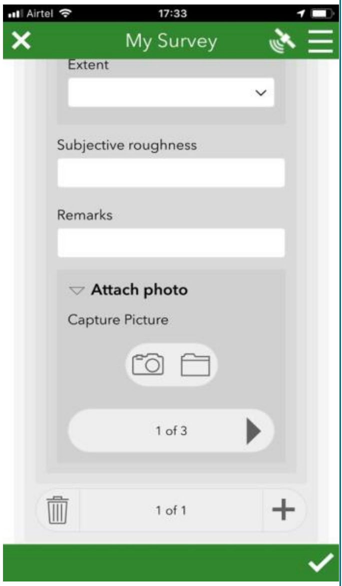
- Segment No.
- Carriageway width in m.
- Carriageway Type (from dropdown)
- GPS Coordinate of the start point of the segment

Step 6: Upon selection of Pavement Type, automatically relevant condition form is displayed. Fill the condition of distresses in terms of severity and extent.

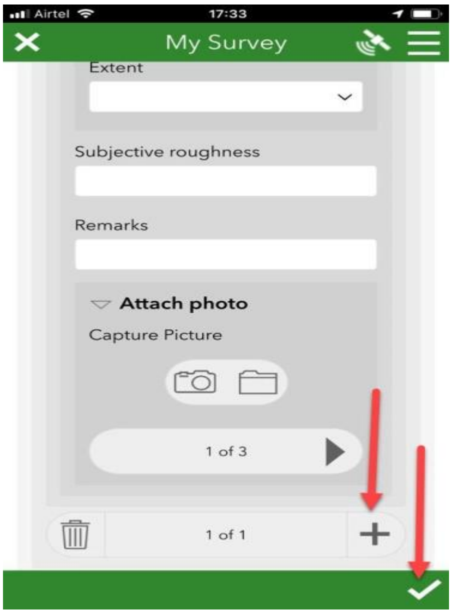


- Severity (Nil, Low, Medium, High)
- Extent (Nil, Intermittent, Frequent, Extensive and Area)

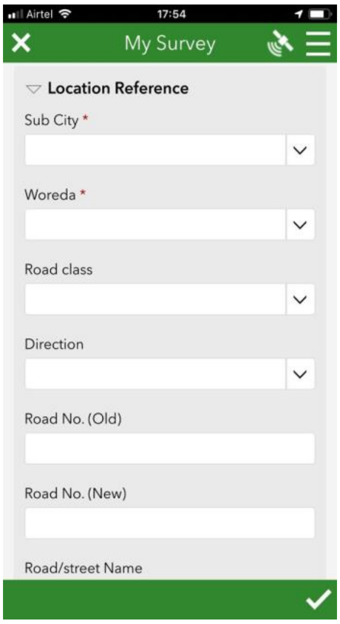
Step 7: Fill the condition of ***distresses*** such as ***Cracking, Pothole, Bleeding, Raveling, Edge Break,*** etc. and fill the roughness subjectively (in terms of m/km) and Remarks. Capture photographs of the relevant distresses observed in the entire segment.



Step 8: Select '+' to add new segment or Select '√' to save the data collected for the route.

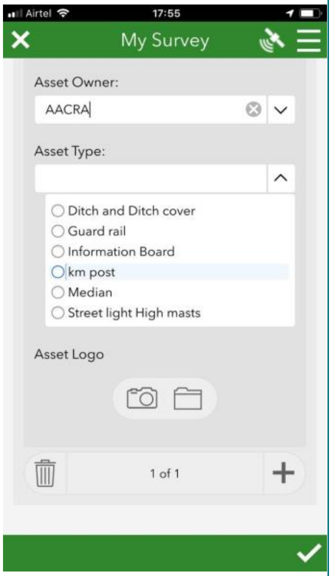


Step 9: For pavement data collection, the Steps 1 to 3 are same and then surveyor has to fill the **Location Reference** details of the route.

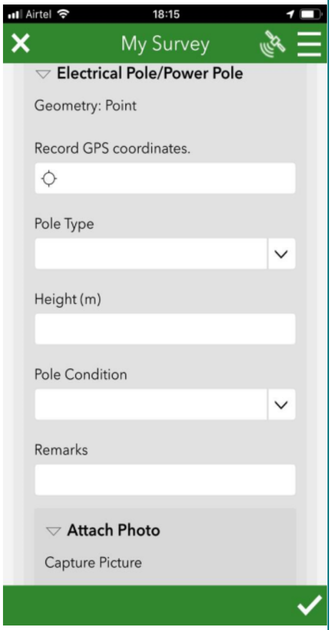
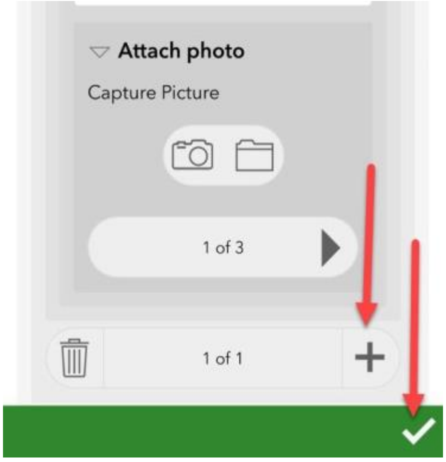


- Sub city (from dropdown menu)
- Woreda (from dropdown menu)
- Road Class (from dropdown menu)
- Direction (from dropdown menu)
- Road No. (Old) (Enter Text)
- Road No. (new) (Enter Text)
- Road / Street Name (Enter Text)
- GPS Coordinate of start point of segment
- Survey Date (mobile date)
- Remarks

Step 10: Fill the **Asset Identification** Details existing in the route.

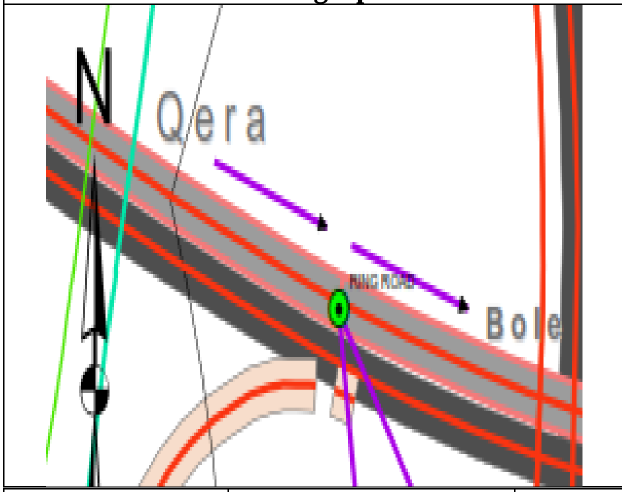


- Select **'Asset Owner'** (from dropdown)
- Automatically, assets owned by the respective stakeholder will be listed accordingly.
- Select '**Asset Type**' (from dropdown)

Step 11: Fill the inventory and condition details of all assets such as height, diameter, type, general condition etc. and capture image of the asset depicting its condition. 	**Step 12**: Select '+' to add new segment or Select '√' to save the data collected for the route. 

Appendix: 2. Monograph of Control Point 1 (Obtained from EMA)

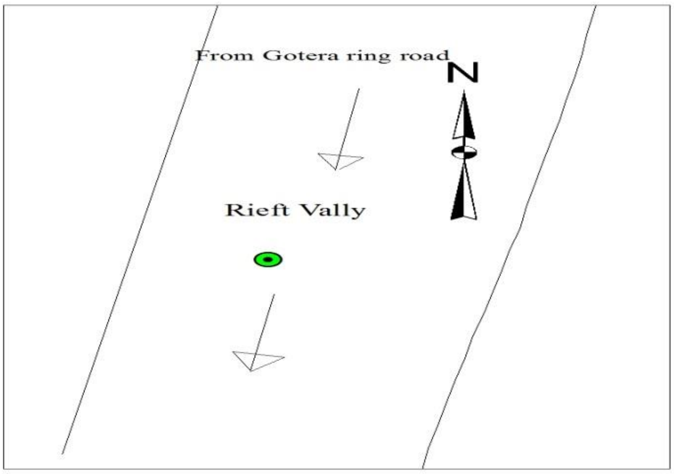
Project Name: TIAs data collection on pilot area **Control point ID**: From EMA		**Nature of control points** :– **Establishment date** :– July.-2019 **Area name** :– Gotera Ring Road	
Universal transverse Mercator system		**Zone - 37**	
Desirable horizontal & vertical Accuracy 10mm +1ppm & 20mm +2ppm			
Latitude = 38:45:35.00756E		**Easting** = 473485.8520	
Longitude= 8:58:51.01241N		**Northing** = 992529.7830	
Co-ordinate system: UTM	Datum: ADINDAN	Ellipsoid: Modified Clark 1880	Control point

Monograph	**Station Photo**
	

	Comnav	Static	15”	3
	Last Observation date	Min. Observation period	Operator Code	
	Julay-2019	30’		

Summary Sheet of Control Point 2

<table>
<tr><td colspan="2" rowspan="3">Project Name: TIAs data collection on pilot area
Control point ID: GPS-02</td><td colspan="2">Nature of control points:</td></tr>
<tr><td colspan="2">Establishment date: July.-2019</td></tr>
<tr><td colspan="2">Area name: Infront of Rift Vally University, Nefas Silk</td></tr>
<tr><td colspan="4">Universal transverse Mercator system Zone - 37</td></tr>
<tr><td colspan="4">Desirable horizontal & vertical Accuracy 10mm +1ppm & 20mm +2ppm</td></tr>
<tr><td colspan="2">Latitude = 38:45:39.35820E</td><td colspan="2">Easting = 473618.5741</td></tr>
<tr><td colspan="2">Longitude= 8:58:44.97668N</td><td colspan="2">Northing = 992344.3329</td></tr>
<tr><td colspan="2"></td><td colspan="2">Height</td></tr>
<tr><td>Co-ordinate system: UTM</td><td>Datum: ADINDAN</td><td>Ellipsoid: Modified Clark 1880</td><td>Control point</td></tr>
</table>

Monograph	**Station photo**
	

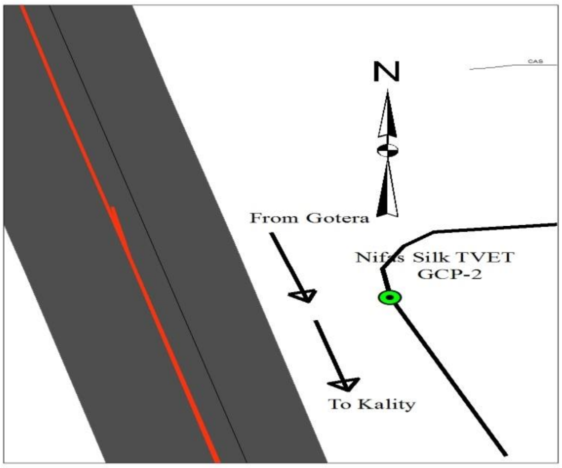
<table>
<tr><td rowspan="4">GPS survey General Information</td><td>Device Type</td><td>Operation Mode</td><td>Rec. Per.</td><td>Unit No.</td></tr>
<tr><td>Comnav</td><td>Static</td><td>15”</td><td>3</td></tr>
<tr><td>Last Observation date</td><td>Min. Observation period</td><td>Operator Code</td><td></td></tr>
<tr><td>July-2019</td><td>30’</td><td></td><td></td></tr>
</table>

Figure shows Monograph of Control Point 2

Summary Sheet of Control Point 3

Project Name: TIAs data collection on pilot area **Control point ID**: GPS-03	**Nature of control points** :– **Establishment date** :– July.-2019 **Area name** :– Infront of Nefas Silk LRT
Universal transverse Mercator system	**Zone - 37**
Desirable horizontal & vertical Accuracy 10mm +1ppm & 20mm +2ppm	
Latitude = 38:45:39.71574	**Easting** = 473629.0219
Longitude= 8:58:21.50797	**Northing** = 991623.5769
	Height

Co-ordinate system: UTM	Datum: ADINDAN	Ellipsoid: Modified Clark 1880	Control point

Monograph	**Station Photo**
	

GPS survey General Information	Device Type	Operation Mode	Rec. Per.	Unit No.
	Comnav	Static	15”	3
	Last Observation date	Min. Observation period	Operator Code	
	Julay-2019	30’		

Appendix 3: Validating Spatial Reference system

```
Validating Spatial References...
Validating Domains...
Validating Workspace Packages...
Validating Default Subtype Codes for Feature Classes...
Validation Complete! Found 0 errors, 0 warnings.
End Time: 8:09:17 PM
========================================
```

let: created: 8/13/2020 7:54:55 PM modified: 8/13/2020 7:55:00 PM 100%

Appendix 4: AACRA data collection format

Form 4-1: Bituminous Pavement Condition Survey

ASSAM ROAD ASSET MANAGEMENT SYSTEM (ARAMS)

BITUMINOUS PAVEMENT CONDITION SURVEY

Road Name: Road Class/ No.: SH/MDR/UR ________

Section Name: District: Chainage: From Km ________ To Km ________

Division: Survey Date (dd/mm/yy): Engineer:

Chainage (Km)		Cracking		Potholes		Ravelling		Rutting		Edge Break		Failed Section		Shoulder Drop-off	Remarks
From	To	Severity	Extent	Severity	Extent	Severity	Extent	Severity	Extent	Severity	Extent	Severity	Extent		

Appendix 5: Sample attribute collected data loaded in Design Geodatabase on arc GIS

Table

Pavement_Prioritization_FE111

Shape *	Subcity	Woreda	RID_NEW	Road_Cat	Direction	Section	Surve	Align	AA1_WS_Typ	start_x	start_y	End_X	End_Y	Shape_Le	RID_NEW_1	Segme	Wid
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-1	SAS	Ascending	1	7/5/20	O	S221-01	473760.336	991618.13	473666.572	991584.017	99.999955	S221-01-1	1	9
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-2	SAS	Ascending	1	7/5/20	O	S221-01	473666.572	991584.01	473572.715	991549.707	100.00003	S221-01-2	2	7.5
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-3	SAS	Ascending	1	7/5/20	O	S221-01	473572.715	991549.70	473479.314	991514.600	100.00006	S221-01-3	3	7.1
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-4	SAS	Ascending	1	7/5/20	O	S221-01	473479.314	991514.60	473386.897	991477.300	100.00000	S221-01-4	4	7.1
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-5	SAS	Ascending	1	7/5/20	O	S221-01	473386.897	991477.30	473293.511	991442.651	99.999978	S221-01-5	5	7.2
Polyline ZM	Nefas Silk Lafto	Woreda-08	S221-01-6	SAS	Ascending	1	7/5/20	O	S221-01	473293.511	991442.65	473221.745	991424.081	74.449056	S221-01-6	6	7.2
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-1	CS	Ascending	1	7/5/20	O	C010-01-A	473715.076	991836.04	473814.867	991842.502	99.9997	C010-01-A-1	1	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-2	CS	Ascending	1	7/5/20	O	C010-01-A	473814.867	991842.50	473914.658	991848.962	99.9997	C010-01-A-2	2	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-3	CS	Ascending	1	7/5/20	O	C010-01-A	473914.658	991848.96	474013.379	991864.197	99.99997	C010-01-A-3	3	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-4	CS	Ascending	1	7/5/20	O	C010-01-A	474013.379	991864.19	474110.704	991887.125	100.00007	C010-01-A-4	4	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-A-5	CS	Ascending	1	7/5/20	O	C010-01-A	474110.704	991887.12	474191.892	991895.559	83.991953	C010-01-A-5	5	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-D-1	CS	Ascending	1	7/5/20	O	C010-01-D	474187.773	991919.89	474094.100	991891.253	99.999972	C010-01-D-1	1	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-D-2	CS	Ascending	1	7/5/20	O	C010-01-D	474094.100	991891.25	473996.716	991868.534	99.999873	C010-01-D-2	2	7
Polyline ZM	Nefas Silk Lafto	Woreda-08	C010-01-D-3	CS	Ascending	1	7/5/20	O	C010-01-D	473996.716	991868.53	473897.690	991856.205	99.99998	C010-01-D-3	3	7

Appendix 6: Interviews Question and answer

Interview involved face to face communication between the interviewer and the interviewee. The purpose of the Interview was to know and summarize the current practice of Pavement management system of AACRA. The question was nine in general and listed below.

Q.N	Interview question and answer summarization
Q.1	Would you introduce yourself, position and experience in the road sector? Response of first Respondent Name: XXXXXX Position: Asset management department specialist Experience: 10 years Response of Second Respondent Name: XXXXXXX Position: Maintenance department Engineer Experience: above 16 years Date and Time: October 3,2020 from 10am-5:30am Location: AACRA Maintenance department head office
Q.2	Would you tell me the organizational structure of AACRA? How many staff do you have in road Asset management and maintenance Department respectively? <u>Response of first Respondent summery</u> According to his explanation in AACRA, there are different departments such as; the department that evaluates the current condition of the road, this department is known as asset management department. Currently, in this department, there are 11 technical personnel involved on road asset management team. Those are 3 Engineers, 6 data collector and 2 data encoders. <u>Response of Second Respondent summery</u> According to his explanation in AACRA organizational structure, there is a maintenance department; the responsibility of this department is maintaining the deteriorated road periodically. AACRA road maintenance department has 3 engineer, 2 technician, 5 Forman and 35 machine operator. Totally in this department there are 45 permanent employs.
Q.3	Do you have pavement management system in your company? If yes, what type of PMS you have using, is it web based? <u>Response of first Respondent summery</u> The respondent says there is no well-established pavement management system. before held the current position he heard some information about this system. AACRA tray to implement this system but no one knows about the created system. They are not use this system totally.as his additional explanation they are

	not use a web based data management system totally. But they are used desktop GIS to show and display the deteriorated pavement by collecting using a hand held GPS randomly. They have a plan to established this system .They are published the code and standard to implement this system. Response of Second Respondent summery No,
Q.4	How do you store, share, display, summarize, and analyze the collected data? Response of first Respondent summery The data were collected in paper format and then, encoded to Excel spread Sheet and store on personal desktop computer. And the data will be displayed on the desktop to know and identify the defect locations spatially. The data transfer from one department to the other is using USB removable disc. Response of Second Respondent summery According to his explanation most of the time the collected data take from Asset management department by flash but they are not use for analysis due to outdated data and the collected data are cover only small place.
Q.5	How did you identify the spatial location of the road networks? Response of first Respondent summery According to his explanation most of the time by digitizing from google earth and sometimes by using handheld GPS track the center line of the road. Response of Second Respondent summery By using handheld GPS.
Q#6	How to collect the condition of the road? Response of first Respondent summery Using the paper format fill out the deterioration and necessary data Response of Second Respondent summery By traveling car visualize and take some nots on the paper about the current condition of the major roads.
Q#7	How to prioritized and identified the maintenance need of the road throughout Addis Ababa all roads type category (like PAS, SAS, RR, CS and LS? Response of first Respondent summery According his explanation the department focus only PAS, SAS and RR, because it is difficult to cover all road in this much manpower. Response of Second Respondent summery Prioritized only identified road by government.
Q#8	Do you think geodatabase support your enterprise to manage, handle, store, analyze and prioritized the deteriorate road? Response of first Respondent summery Yes, We are going to establish this system Response of Second Respondent summery Yes, currently the state of the art or experience shows the importance of this system, So it is very important for our enterprise he says.

Q#9	What do you think about the WebGIS based pavement management and maintenance system? Response of first Respondent summery It is very important technology. He saw in other developed country during the experience sharing of the department. Response of Second Respondent summery He said that, "I think it has so many uses for our enterprise and our country in general"