

**Enhancing Infrastructure Asset Management in Adama City through  
Spatial Database Management System and Web Based Geographical  
Information System**



Abdi Girma

A Thesis Submitted to the department of Architecture engineering School of  
Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's  
in Architecture Engineering (Specialization in Geo-Informatics)

Office of Graduate Studies  
Adama Science and Technology University

Adama, Ethiopia

May, 2024

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## DECLARATION

I hereby declare that this research thesis entitled “**Enhancing Infrastructure Asset Management in Adama City through Spatial Database Management System and Web Based Geographical Information System**” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Abdi Girma

Name of student

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

## RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “**Enhancing Infrastructure Asset Management in Adama City through Spatial Database Management System and Web Based Geographical Information System**” prepared under my guidance by Abdi submitted in partial fulfillment of the requirements for the degree of Master’s in **Geoinformatics Engineering**. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dejene Tesema (Ph.D.)

Name of Major Advisor

\_\_\_\_\_

Signature

\_\_\_\_\_

Date

## APPROVAL SHEET

I, the advisor of the thesis entitled “**Enhancing Infrastructure Asset Management in Adama City through Spatial Database Management System and Web Based Geographical Information System**” and developed by Abdi hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Abdi Girma have read and evaluated the thesis entitled “**Enhancing Infrastructure Asset Management in Adama City through Spatial Data Management System and Web Based Geographical Information System**” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in **Geoinformatics Engineering**.

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Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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## **LIST OF ACRONYMS**

DBMS	Database Management System
WEBGIS	Web-based Geographic Information System
SQL	Structured Query Language
OSS	Open-Source Software
HTML	Hypertext markup language
CSS	Cascading style sheet
XML	Extendible markup language

## **ABSTRACT**

*Infrastructure asset management is crucial for ensuring the long-term sustainability and performance of urban systems. Adama City, like many developing urban centers, faces challenges in effectively managing its infrastructure assets. Despite the growing significance of this domain, there is a research gap in understanding and enhancing infrastructure asset management practices tailored to the local context of Adama City. This study aims to evaluate and improve the infrastructure asset management practices in Adama City by implementing a spatial database model and leveraging open-source tools. The research methodology involves data collection, assessment indicator development, data analysis, gap identification, requirement analysis, geodatabase design, and web-GIS implementation. The assessment of the current infrastructure asset management system in Adama City reveals several areas that require improvement, including the inventory system, data storage and management, road condition assessment, decision-making processes, operational planning, maintenance planning, capital works planning, and information systems. To address these identified gaps, the study developed a geodatabase model using ArcGIS and PostgreSQL with PostGIS extension. This model demonstrated its effectiveness in organizing and managing infrastructure and utility data. Furthermore, a web-based GIS application was implemented using the qgis2web plugin of QGIS, enabling users to interact with the infrastructure data through a user-friendly interface. The research findings suggest that there are ample open-source opportunities to improve infrastructure asset management systems in developing countries like Adama City. The spatial database model and web-GIS application developed in this study can serve as a template for other municipalities to enhance their infrastructure asset management practices and foster collaboration and data-driven decision-making.*

**Key Words:** ArcGIS, Postgresql, PostGIS, qgis2web plug-in, WEBGIS

# CHAPTER I: INTRODUCTION

## 1.1. Background of the Study

Infrastructure asset management is a critical discipline for ensuring the long-term sustainability and optimal performance of public and private infrastructure systems. These systems, which include transportation networks, utility grids, buildings, and other capital-intensive assets, are vital for supporting economic growth, public services, and quality of life. However, many infrastructure assets around the world are aging and in need of repair or replacement, leading to increased maintenance costs, service disruptions, and public safety concerns (Smith, 2018).

Effective infrastructure asset management involves a systematic, data-driven approach to making strategic decisions about the acquisition, operation, maintenance, rehabilitation, and disposal of physical assets. This includes conducting comprehensive condition assessments, forecasting future infrastructure needs, optimizing maintenance and renewal activities, and allocating limited funds in the most cost-effective manner. By adopting proven best practices in infrastructure asset management, organizations can extend the useful life of their assets, improve service delivery, and achieve greater returns on their infrastructure investments (Kuo et al., 2017).

As urban populations continue to grow and cities expand at an unprecedented rate, the demand for efficient infrastructure asset management becomes increasingly critical for ensuring the long-term sustainability of urban systems (Gibson, 2009; Fekade, 2000). Adama City, situated in the heart of Oromia, Ethiopia, is experiencing rapid urbanization and infrastructural development, necessitating the adoption of innovative approaches to effectively manage its diverse asset portfolio (Seyum, 2007).

Adama City, being a prominent economic and transportation hub, is witnessing significant population growth and urban expansion. The city's infrastructural development is characterized by the construction of roads, bridges, buildings, water supply networks, sewage systems, and other essential facilities to meet the rising demands of its inhabitants. However, the effective management of these assets throughout their lifecycle poses a considerable challenge to the city's authorities (W., 2021). Inadequate asset management practices can lead to suboptimal utilization of resources, increased operational costs, and

compromised service delivery. Therefore, the timely adoption of innovative approaches to infrastructure asset management is crucial for Adama City to address these challenges effectively (Debela, 2021).

To overcome the limitations of traditional asset management practices, the city needs to explore advanced techniques and technologies that can enhance the efficiency and effectiveness of its asset management processes (Zelege, 2008). This research aims to investigate the potential benefits and challenges associated with the adoption of innovative approaches, specifically focusing on spatial data management and Web-based Geographic Information Systems (WEBGIS), in enhancing infrastructure asset management in Adama City.

By integrating spatial data management techniques with a WEBGIS platform, Adama City can establish a centralized system for collecting, storing, analyzing, and visualizing spatial data related to its infrastructure assets (Zelege, 2008). This integrated approach enables the city's authorities to make informed decisions about asset maintenance needs and resource allocation. Moreover, it facilitates collaboration among different stakeholders involved in infrastructure management and provides a user-friendly interface to access and interpret asset information.

Through this research, the potential benefits of implementing a spatial data management and WEBGIS framework for infrastructure asset management in Adama City will be explored, with the aim of providing practical guidance and recommendations for the city's authorities and other urban centers facing similar challenges.

## **1.2. Statement of the Problem**

Adama City, like many urban centers, faces the challenge of managing its infrastructure assets effectively. Infrastructure asset management plays a crucial role in ensuring the optimal performance, maintenance, and sustainability of critical systems such as roads, bridges, water supply networks, and buildings (Haas R., 2016). However, to achieve these goals, it is essential to evaluate and enhance existing practices while leveraging technological advancements (Smith A., 2018).

Despite the growing significance of infrastructure asset management, there is a research gap in understanding and improving the practices specifically tailored to Adama City

(Lemma E., 2020). Existing literature primarily focuses on general frameworks and best practices, often overlooking the unique characteristics and challenges faced by individual cities (Wright B, 2017). As a result, there is limited knowledge and guidance on evaluating the infrastructure asset management practices in Adama City (Tsfaye M., 2019).

The existing practices in Adama City encounter challenges related to data management and accessibility. Infrastructure data is often dispersed, unstructured, and challenging to consolidate, impeding effective decision-making processes (Tadesse A., 2021). Furthermore, the limited utilization of open-source tools restricts the availability and accessibility of infrastructure data to stakeholders and the public, hindering transparency and collaboration (Berhanu T., 2018).

Addressing these challenges requires a comprehensive research effort that evaluates the current infrastructure asset management practices in Adama City. By conducting such research, Adama City can assess the strengths and weaknesses of its current practices, identify areas for improvement, and implement innovative solutions to enhance overall asset management (Wondimu G., 2022).

Improving data management through a spatial database model will streamline data organization, integration, and analysis, enabling better decision-making regarding asset maintenance, resource allocation, and infrastructure planning. Additionally, utilizing open-source tools to publish infrastructure data on the web will promote transparency, accessibility, and stakeholder engagement, fostering collaboration and informed decision-making (Gebremariam S., 2024).

By bridging the research gap and addressing the identified challenges, Adama City can enhance its infrastructure asset management practices, leading to improved performance, longevity, and sustainability of its infrastructure systems. The outcomes of this research will not only benefit Adama City but also contribute to the broader knowledge base on effective infrastructure asset management practices, providing insights and guidance for other cities facing similar challenges (Seyum D., 2007).

### **1.3. General Objective.**

The general objective of this research is to Evaluate and improve the infrastructure asset management practices in Adama city by implementing a spatial database model and utilizing open-source tools.

### **1.4. Specific Objective.**

1. Evaluate the existing infrastructure asset management practices in Adama city.
2. Develop a spatial database model to enhance the management of infrastructure data.
3. Utilize open-source tools to publish infrastructure data on the web.

### **1.5. Research Questions**

1. What are the strengths and weaknesses of the existing infrastructure asset management practices in Adama city?
2. How can a spatial database model be developed to improve the management of infrastructure data in Adama city?
3. How can open-source tools be effectively utilized to publish infrastructure data on the web in Adama city?

### **1.6. Significance of the Study**

This research holds immense significance for both Adama city and the broader field of infrastructure asset management. By conducting a comprehensive evaluation of current practices, developing a customized spatial database model, and harnessing the power of open-source tools for data publishing, this study aims to address critical gaps and challenges in infrastructure asset management within Adama city. The significance of this research can be comprehended through the following key aspects:

Firstly, the findings of this research will provide invaluable insights into the strengths and weaknesses of Adama city's existing infrastructure asset management practices. By identifying areas for improvement, the research outcomes will contribute to enhancing asset performance, optimizing maintenance efficiency, and facilitating more effective resource allocation. These improvements will ultimately lead to increased sustainability and longevity of the city's infrastructure systems.

Secondly, the development of a tailored spatial database model designed specifically for Adama city will revolutionize data management processes. This model will streamline data organization, integration, visualization, and analysis, empowering decision-makers with accurate and timely information for informed infrastructure planning and maintenance. Additionally, the utilization of open-source tools for publishing infrastructure data on the web will greatly enhance data accessibility, transparency, and stakeholder engagement. This will foster collaboration, encourage participation, and facilitate more inclusive and well-informed decision-making processes.

Furthermore, the research outcomes will serve as a valuable reference and guide for other cities grappling with similar challenges in infrastructure asset management. The methodologies, spatial database model, and open-source tools employed in this study can be replicated and adapted to suit the unique needs of different cities, fostering the broader adoption of effective asset management practices and promoting sustainable urban development on a larger scale.

Moreover, by addressing the specific research gaps in Adama city, this study contributes to the advancement of knowledge in the field of infrastructure asset management. It expands the understanding of contextual factors, challenges, and strategies involved in optimizing asset performance and maintenance within urban environments. The research outcomes will enrich the field by offering practical insights, best practices, and innovative approaches for managing infrastructure assets in diverse settings.

Lastly, effective infrastructure asset management directly influences the quality of life and socio-economic development of a city's residents. The research outcomes, by improving asset performance, will result in smoother transportation systems, reliable utilities, and safer built environments within Adama city. This will enhance productivity, attract investments, and ultimately improve the overall well-being of its residents.

## **1.7. Scope of the Study**

The thematic scope of the study comprises two main aspects. Firstly, it involves the development of an assessment framework to evaluate the current asset management practices within Adama city. This assessment framework will provide a structured and systematic approach to assess the effectiveness, efficiency, and sustainability of asset management processes.

Secondly, the research aims to develop a spatial database and implement a web GIS application. The spatial database will serve as a centralized repository for storing and managing spatial data relevant to Adama city's assets and infrastructure. The web GIS application will provide an efficient platform for data management and sharing, enabling stakeholders to access, visualize, and analyze the spatial data in a user-friendly manner.

The research was involved comprehensive data collection and analysis, including gathering asset-related data, conducting surveys, and engaging with relevant stakeholders. The assessment framework and spatial database will be developed based on established best practices and tailored to the specific needs of Adama city.

The outcomes of the study will contribute to enhancing asset management practices in Adama city by providing insights into the strengths, weaknesses, and areas for improvement. The developed assessment framework will enable better decision-making and planning for asset management, leading to improved efficiency, cost-effectiveness, and sustainability.

Furthermore, the implementation of the web GIS application will facilitate efficient data management and sharing among stakeholders. It will enhance collaboration, communication, and information exchange, supporting evidence-based decision-making and enabling effective urban management.

While the primary focus is on Adama city, the research outcomes, including the assessment framework and web GIS application, have the potential to be adapted and applied in other cities facing similar challenges. This broader applicability further enhances the significance and relevance of the study's findings.

## **CHAPTER II: LITRATURE REVIEW**

### **2.1. Theoretical Review**

The effective management and maintenance of infrastructure assets play a vital role in ensuring the sustainable development of rapidly growing urban areas like Adama City. Traditional asset management approaches often face challenges in meeting the unique needs of such cities, necessitating the development of comprehensive web-based systems. This literature review aims to explore existing research and initiatives pertaining to methods of assessing infrastructure assets, Available database and web technologies for infrastructure asset management and web-based infrastructure asset management systems, By examining relevant studies, this review will identify gaps and opportunities for the development of a tailored web-based infrastructure asset management system for Adama City.

### **2.2. Infrastructure Asset Management Assessment Indicators**

Infrastructure asset management involves the strategic planning, operation, and maintenance of physical assets to ensure their effective and efficient performance. Assessing the maturity and effectiveness of asset management practices is crucial for continuous improvement and informed decision-making. This literature review explores various assessment indicators and dimensions commonly used to evaluate infrastructure asset management. The following indicators are examined in this review: (1) Inventory methods, (2) Data storage and management, (3) Road condition assessment, (4) Decision making, (5) Operational planning, (6) Maintenance planning, (7) Capital works planning, and (8) Information systems.

#### **2.2.1. INVENTORY METHODS:**

Inventory methods assess the completeness, accuracy, and currency of asset inventories. Common indicators include the presence of standardized asset identification codes, documentation of asset characteristics, and the integration of geospatial information. The maturity levels may range from basic asset lists to comprehensive databases with detailed attribute data and spatial information (Smith et al., 2017).

### **2.2.2. DATA STORAGE AND MANAGEMENT:**

Data storage and management indicators evaluate the organization and accessibility of asset data. Key indicators include data integrity, data security measures, data governance policies, and data sharing mechanisms. Maturity levels may span from disparate data sources and formats to centralized databases with standardized data models and secure access controls (Smith et al., 2017).

### **2.2.3. ROAD CONDITION ASSESSMENT:**

Road condition assessment indicators focus on evaluating the methods and frequency of assessing infrastructure conditions. Indicators may include the adoption of standardized condition assessment protocols, frequency of inspections, and the use of advanced technologies such as pavement condition sensors. Maturity levels range from ad hoc inspections to systematic, data-driven condition assessment programs (Johnson and Brown, 2018).

### **2.2.4. DECISION MAKING:**

Decision-making indicators assess the integration of asset management practices into organizational decision-making processes. Indicators may include the use of risk-based decision frameworks, consideration of life-cycle costs, and alignment with strategic objectives. Maturity levels range from reactive decision-making based on immediate needs to proactive decision-making driven by data and long-term asset performance (Smith et al., 2017).

### **2.2.5. OPERATIONAL PLANNING:**

Operational planning indicators assess the development and implementation of plans and strategies for day-to-day asset management activities. Indicators may include the existence of maintenance schedules, resource allocation plans, and performance targets. Maturity levels range from ad hoc and reactive planning to comprehensive, data-informed plans aligned with organizational goals (Johnson and Brown, 2018).

#### **2.2.6. MAINTENANCE PLANNING:**

Maintenance planning indicators evaluate the effectiveness of asset maintenance strategies. Indicators may include the use of condition-based maintenance approaches, proactive asset renewal planning, and consideration of environmental and sustainability factors. Maturity levels range from reactive maintenance practices to proactive, risk-based maintenance plans optimized for asset performance (Smith et al., 2017).

#### **2.2.7. CAPITAL WORKS PLANNING:**

Capital works planning indicators focus on the management of asset investments and infrastructure development projects. Indicators may include the use of asset performance data in investment decision-making, consideration of whole-life costs, and integration with long-term asset management plans. Maturity levels range from ad hoc project-based planning to strategic, data-driven capital works programs (Johnson and Brown, 2018).

#### **2.2.8. INFORMATION SYSTEMS:**

Information systems indicators assess the technology infrastructure supporting asset management processes. Indicators may include the availability of asset management software, data integration capabilities, and user training and support. Maturity levels range from manual systems and spreadsheets to fully integrated, web-based information systems (Smith et al., 2017).

### **2.3. GIS Applications in Infrastructure Management**

GIS (Geographic Information System) has gained widespread recognition as a valuable tool for infrastructure management. Li et al. (2018) emphasize that GIS enables the integration of spatial data with other relevant information, which in turn facilitates various aspects of infrastructure management, including analysis, monitoring, and decision-making processes. By incorporating spatial data, GIS provides a comprehensive and visual representation of infrastructure assets and their associated attributes.

The successful implementation of GIS-based systems in various cities globally has demonstrated their effectiveness in improving infrastructure management practices. Albrecht et al. (2016) conducted a study that showcased the benefits of GIS in enhancing infrastructure management. These systems have been utilized to streamline data collection,

analysis, and visualization processes, leading to more informed decision-making and improved operational efficiency.

One of the key advantages of GIS in infrastructure management is its ability to integrate spatial data from different sources. Spatial data includes information such as geographical boundaries, locations of infrastructure assets, and associated attributes like condition, age, and maintenance history. By incorporating this spatial information into a GIS-based system, infrastructure managers can gain a holistic view of their assets and effectively analyze their current state. Moreover, GIS allows for real-time monitoring of infrastructure assets. By integrating sensor data, remote sensing technologies, and other monitoring tools, GIS-based systems enable infrastructure managers to track the condition and performance of assets. This real-time monitoring capability helps identify potential issues or anomalies promptly, allowing for proactive maintenance and minimizing the risk of failures or disruptions (Jia et al 2021).

Additionally, GIS provides a platform for data-driven decision-making in infrastructure management. By analyzing spatial data and generating visualizations, GIS enables infrastructure managers to identify patterns, trends, and correlations that may not be apparent in tabular data alone. This information can support informed decision-making processes regarding maintenance prioritization, resource allocation, and long-term planning.

Efficient inventory and asset management practices are crucial for maintaining infrastructure systems. Moeckel and Wilson (2016) emphasize the importance of accurate and up-to-date inventory data in enabling effective decision-making in infrastructure management.

GIS-based asset management systems have proven to be valuable tools for monitoring, evaluating, and prioritizing maintenance and repair activities. Kamp et al. (2017) highlight the benefits of using GIS in asset management, particularly in the context of infrastructure systems.

One of the key advantages of GIS-based asset management systems is their ability to provide a comprehensive and visual representation of infrastructure assets. By integrating spatial data with other relevant information, such as asset attributes, condition assessments,

and maintenance history, GIS enables infrastructure managers to have a complete overview of their assets. This holistic view helps in identifying critical assets, assessing their performance, and making informed decisions regarding maintenance and repair activities.

GIS-based asset management systems also support better monitoring of infrastructure assets. By utilizing real-time data feeds, sensor networks, and remote sensing technologies, these systems enable infrastructure managers to track the condition and performance of assets continuously. This real-time monitoring capability helps detect anomalies or potential issues promptly, allowing for proactive maintenance interventions and minimizing the risk of failures or disruptions (Kuo et al , 2017).

Furthermore, GIS facilitates the evaluation and prioritization of maintenance and repair activities. By analyzing spatial data and generating visualizations, GIS-based asset management systems enable infrastructure managers to identify patterns, trends, and correlations related to asset performance, deterioration, and usage. This information helps prioritize maintenance activities based on asset criticality, condition, and anticipated future demands. Moreover, GIS-based asset management systems support data integration and interoperability. They can integrate data from various sources, including internal databases, external datasets, and real-time monitoring systems. This integration enhances the accuracy and completeness of inventory data, enabling more robust decision-making processes (Longley et al 2015).

## **2.4. Open-Source GIS Tools**

Open-source GIS tools have emerged as valuable resources for infrastructure management, offering cost-effective and customizable solutions. Kuo et al. (2017) highlight several advantages of open-source GIS tools, including their flexibility, interoperability, and community-driven development. One of the key advantages of open-source GIS tools is their flexibility. Unlike proprietary software, open-source tools can be customized and tailored to meet specific needs and requirements of infrastructure management projects. This flexibility allows infrastructure managers to adapt the tools to their unique workflows and integrate them seamlessly into existing systems.

Interoperability is another significant advantage of open-source GIS tools. These tools are designed to support various data formats and standards, enabling the integration of diverse

datasets from different sources. This interoperability promotes data sharing and collaboration among stakeholders involved in infrastructure management. It also facilitates the integration of spatial data with non-spatial data, enhancing the overall analysis and decision-making processes (Karas et al 2019).

Community-driven development is a distinguishing characteristic of open-source GIS tools. Developers and users from around the world contribute to the improvement and enhancement of these tools through collaborative efforts. This collective input leads to continuous updates, bug fixes, and the development of new features. The active community support ensures that open-source GIS tools remain up-to-date, reliable, and responsive to the evolving needs of infrastructure management.

Open-source platforms such as QGIS and Open Layers have gained popularity in the field of infrastructure management. QGIS, for example, offers a user-friendly interface and a wide range of functionalities, making it accessible to users with varying levels of GIS expertise. It provides tools for data visualization, spatial analysis, and data editing, empowering infrastructure managers to efficiently work with their geospatial data. Similarly, Open Layers is an open-source JavaScript library that enables the integration of interactive maps into web applications. It provides a versatile platform for displaying and interacting with geospatial data online, making it a valuable tool for sharing infrastructure information and engaging stakeholders (Jiang et al, 2020).

## **2.5. INFRASTRUCTURE ASSET MANAGEMENT AND ASSESSMENT METHODS**

The effective management and assessment of infrastructure assets is a critical component of sustainable urban development and service delivery. Infrastructure assets, such as roads, water systems, energy networks, and public facilities, represent significant investments and play a crucial role in supporting economic growth, social well-being, and environmental sustainability (Vanier, 2001; Halfway, 2008). However, many municipalities and infrastructure managers face challenges in maintaining, rehabilitating, and optimizing the performance of these assets due to aging infrastructure, limited budgets, and changing operational demands (Grigg, 2012; Scholz & Tietje, 2002).

Infrastructure asset management (IAM) is a comprehensive approach that aims to maximize the value and performance of infrastructure assets throughout their lifecycle, from planning and design to operation and disposal (Gomes et al., 2013; Mirza, 2006).

IAM involves the systematic collection and analysis of data to support decision-making, the development of asset management plans and strategies, the implementation of maintenance and rehabilitation programs, and the continuous monitoring and evaluation of asset performance (Halfway, 2008; Vanier, 2001).

Various assessment methods have been developed and employed to support IAM, including condition assessments, risk assessments, and performance evaluations (Griggs, 2012; Halfway, 2008). Condition assessments involve the systematic inspection and evaluation of the physical state of infrastructure assets, providing insight into their remaining useful life and the need for maintenance or replacement (Halfway, 2008; Scholz & Tietje, 2002). Risk assessments, on the other hand, focus on identifying and quantifying the potential threats and vulnerabilities associated with infrastructure assets, enabling prioritization of interventions and resource allocation (Halfway, 2008; Mirza, 2006). Performance evaluations assess the functionality, efficiency, and effectiveness of infrastructure assets in meeting service delivery goals and user requirements (Scholz & Tietje, 2002; Vanier, 2001).

The application of advanced technologies, such as geographic information systems (GIS), building information modeling (BIM), and sensor networks, has further enhanced IAM practices by enabling the collection, integration, and analysis of comprehensive asset data (Halfway, 2008; Grigg, 2012). These technologies facilitate the development of robust asset inventories, the visualization of infrastructure networks, the modeling of asset performance, and the optimization of maintenance and rehabilitation strategies (Gomes et al., 2013; Halfway, 2008).

## **2.6. Database Design, Spatial Database and Database Management Systems**

The effective management and utilization of data is a fundamental aspect of infrastructure asset management and decision-making processes. Database design, spatial databases, and database management systems (DBMS) play a crucial role in organizing, storing, and retrieving the vast amounts of data generated by infrastructure assets and related systems.

Database design is the process of creating a structured, organized, and efficient system for storing and managing data (Elmasri & Navathe, 2016). This involves the identification of

data entities, their relationships, and the appropriate data models and schema to represent the information. Well-designed databases provide data integrity, security, and scalability, enabling effective data management and retrieval (Connolly & Begg, 2014).

Spatial databases, a specialized type of database, are designed to store, manage, and analyze geospatial data, which is essential for infrastructure asset management (Worboys & Duckham, 2004). Spatial databases incorporate the spatial characteristics of infrastructure assets, such as their location, shape, and topological relationships, enabling the integration of geographic information systems (GIS) and other spatial analysis tools (Rigaux et al., 2002).

The choice of DBMS is crucial for the effective management of infrastructure asset data. DBMS software, such as relational database management systems (RDBMS) and object-oriented database management systems (OODMS), provide the necessary tools and functionalities for data storage, querying, indexing, and transaction management (Date, 2006). The selection of a DBMS should consider factors such as data volume, performance requirements, scalability, and integration with other enterprise systems (Silberschatz et al., 2020).

The integration of database design, spatial databases, and DBMS is essential for infrastructure asset management. Spatially-enabled databases can store and manage the geospatial data associated with infrastructure assets, such as their location, condition, and maintenance history, while DBMS provide the necessary tools for data organization, querying, and analysis (Worboys & Duckham, 2004; Rigaux et al., 2002).

Furthermore, the application of advanced database technologies, such as cloud-based DBMS, NoSQL databases, and data warehousing, can enhance the scalability, performance, and analytical capabilities of infrastructure asset management systems (Silberschatz et al., 2020; Elmasri & Navathe, 2016). These technologies enable the integration of diverse data sources, the handling of large data volumes, and the development of sophisticated decision-support tools for infrastructure asset management.

## **2.7. Web GIS for infrastructure asset management**

The widespread adoption of geographic information systems (GIS) and the proliferation of web-based technologies have led to the development of Web GIS, a powerful tool for infrastructure asset management. Web GIS integrates GIS capabilities with the accessibility and interactivity of the web, enabling the effective management, visualization, and analysis of infrastructure assets and related data.

Web GIS provides a platform for the centralized storage, management, and dissemination of infrastructure asset data, including spatial and non-spatial information (Peng & Tsou, 2003). By leveraging web-based technologies, Web GIS allows for real-time data updates, remote access, and collaborative decision-making among infrastructure managers, planners, and stakeholders (Plewe, 1997).

One of the key advantages of Web GIS for infrastructure asset management is its ability to integrate and visualize various data sources, including spatial data from GIS, asset condition assessments, maintenance records, and sensor data (Esri, 2020). This integration enables infrastructure managers to obtain a comprehensive, spatially-enabled view of their assets, facilitating informed decision-making and optimized asset management strategies.

Web GIS platforms often incorporate advanced analytical and modeling capabilities, enabling infrastructure managers to perform tasks such as network analysis, risk assessment, and scenario planning (Longley et al., 2015). These tools can help identify asset criticality, prioritize maintenance and rehabilitation activities, and optimize resource allocation for infrastructure systems.

The web-based nature of Web GIS also facilitates the dissemination of infrastructure asset information to a wide range of stakeholders, including the public, policymakers, and regulatory agencies (Peng & Tsou, 2003). This transparency and accessibility can enhance public engagement, improve transparency in decision-making, and support regulatory compliance.

Furthermore, the integration of Web GIS with mobile technologies, such as smartphones and tablets, allows for the real-time collection and updating of infrastructure asset data in the field (Esri, 2020). This enhances the accuracy and timeliness of data, enabling more effective asset management and maintenance activities.

The successful implementation of Web GIS for infrastructure asset management requires the consideration of several key factors, including data quality, system integration, cybersecurity, and user training (Longley et al., 2015). Addressing these challenges can ensure the effective and secure deployment of Web GIS platforms in infrastructure management organizations.

## **2.8. Empirical Literature Review**

To evaluate the infrastructure asset management practices within a municipal organization, Smith et al. (2017) conducted a study. The assessment encompassed multiple aspects of asset management, including data management, decision-making processes, maintenance planning, and information systems. Through a combination of qualitative and quantitative methods such as surveys, interviews, and data analysis, the researchers identified areas in need of improvement. These areas included the inventory system, data storage and management, decision-making processes, and maintenance planning. The study underscored the significance of comprehensive assessments in identifying areas for enhancement in infrastructure asset management practices.

In a separate empirical study, Johnson and Brown (2018) assessed the effectiveness of infrastructure asset management practices within a transportation agency. The study focused on evaluating asset data management, decision-making processes, and resource allocation. The assessment employed a combination of performance metrics, surveys, and interviews with key stakeholders. The findings highlighted areas that required improvement, such as data accuracy, integration of asset information, and optimization of resource allocation. The study emphasized the importance of utilizing performance metrics and engaging stakeholders in evaluating infrastructure asset management practices.

Zhang et al. (2020) conducted an empirical assessment of infrastructure asset management practices within a city context. The study aimed to evaluate maintenance planning and resource allocation processes. The assessment involved analyzing maintenance records, conducting field inspections, and gathering feedback from stakeholders. The findings identified areas for improvement, such as the identification of critical assets, prioritization of maintenance activities, and optimization of resource allocation. The study emphasized

the value of data-driven assessments in identifying areas for improvement in infrastructure asset management practices.

Similarly, Liu et al. (2018) conducted an empirical assessment of infrastructure asset management practices within a geospatial context. The study aimed to evaluate the effectiveness of decision-making processes and information systems. Performance indicators, stakeholder interviews, and analysis of decision-making processes were employed in the assessment. The findings revealed challenges in data integration, decision-making processes, and the functionality of information systems. The study underscored the importance of utilizing performance indicators and engaging stakeholders in assessing infrastructure asset management practices.

Another research study by Xu et al. (2018) focused specifically on the application of open-source GIS tools for water infrastructure management. By integrating spatial data, such as water network layouts and asset attributes, into an open-source GIS platform, they enhanced data accuracy and decision-making processes related to water infrastructure systems. This integration allowed for improved visualization, analysis, and modeling of the water infrastructure, enabling informed decisions regarding maintenance, repair, and system upgrades.

These case studies highlight the advantages of open-source GIS tools in infrastructure management. The flexibility and functionality of open-source platforms allow infrastructure managers to tailor the tools to their specific needs and workflows. The integration of spatial data with asset management systems provides a comprehensive and visual representation of infrastructure assets, leading to more accurate assessments of asset condition and performance.

Furthermore, open-source GIS tools facilitate data accuracy and decision-making processes. The integration of diverse datasets, such as asset attributes, maintenance records, and geographical information, improves the overall accuracy of inventory data (Xu, et al. 2018). This, in turn, enables more informed decision-making regarding maintenance planning, resource allocation, and infrastructure upgrades.

The successful implementation of open-source GIS tools in infrastructure management demonstrates their potential for improving operational efficiency, cost-effectiveness, and

overall infrastructure performance (Zhang, et al. 2020). These tools offer customizable solutions that can be adapted to various infrastructure sectors, including transportation, water, energy, and telecommunications.

However, the existing literature has primarily focused on the management of specific assets, such as roads or water distribution lines, using open-source tools. There is a significant research gap when it comes to integrated infrastructure and utility management using open-source tools. Additionally, there is a lack of frameworks available to effectively handle this integrated management approach.

Previous studies have predominantly examined the management of individual assets within infrastructure systems. For instance, researchers have explored how open-source tools can enhance the maintenance and monitoring of road networks or water distribution lines. While these studies have provided valuable insights into asset-specific management strategies, they have overlooked the broader perspective of integrating multiple assets and utilities within a comprehensive management framework.

The integration of infrastructure and utility management is crucial because various assets and utilities, such as transportation networks, water supply systems, and energy grids, are interconnected and influence each other's performance. By considering the interdependencies and interactions between these components, a more holistic approach to management can be achieved, leading to optimized resource allocation, improved resilience, and enhanced overall system performance.

However, despite the significance of integrated management, there is a research gap in the literature concerning the application of open-source tools in this context. Open-source tools offer numerous advantages, including cost-effectiveness, flexibility, and the potential for collaborative development. Yet, their potential remains largely untapped for integrated infrastructure and utility management purposes, especially in developing countries like Ethiopia.

Furthermore, the lack of frameworks compounds this research gap. A comprehensive framework serves as a guiding structure that outlines the methodologies, processes, and decision-making mechanisms required for integrated management. It helps in organizing and streamlining the management approach, ensuring consistency and efficiency

throughout the system. However, the absence of such frameworks hinders the implementation of integrated management strategies using open-source tools.

Therefore, there is a critical need for further research that focuses on integrated infrastructure and utility management using open-source tools. This research should address the interdependencies between different assets and utilities, explore the potential benefits and challenges of using open-source tools, and develop frameworks that provide a systematic and structured approach to integrated management. Bridging this research gap will enable practitioners and policymakers to effectively leverage the advantages of open-source tools for integrated infrastructure and utility management, leading to improved performance, cost-effectiveness, and sustainability

## CHAPTER III: MATERIAL AND METHODS

### 3.1. Description of the Study Area

The study area (**Fig.3.1**) viz. Adama City is extending between geographic coordinates of at  $8^{\circ} 30' 52.1172''$ N latitude and  $39^{\circ} 16' 9.3252''$  E longitude at some 80 Kilometers away from Addis Ababa City. The maximum elevation of the city is 1712 meters above mean sea level. Owing to its geographical proximity to international port of Djibouti within the distance of about 777 Kilometers, the city is one of the preferred destinations for trade and industry.

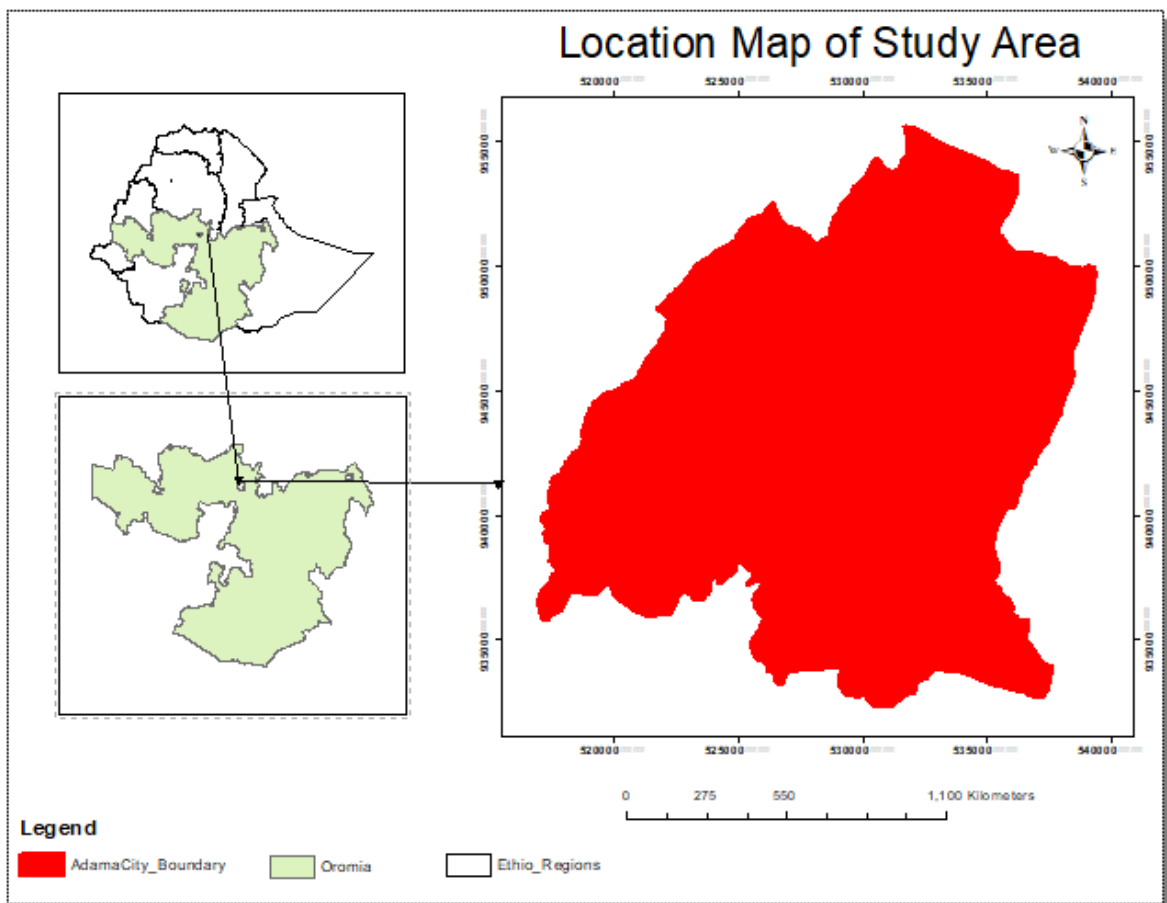


Figure 3.1. Location map Adama city

### 3.2. Required data and software

The primary focus of this research was on gathering and analyzing data pertaining to infrastructure and utilities, along with assessing the current state of assets and developing spatial database and publish on the web. To accomplish this, various software tools was utilized, including ArcGIS, QGIS, and additional plugins like QGIS WEB2 and Quicmap services. These tools will aid in conducting a comprehensive study and enable the researchers to effectively examine and understand the infrastructure and utility systems, as well as the condition of assets.

#### 3.2.1. DATA SOURCE

The studies were mainly supported by geospatial datasets gathered from Adama municipality Construction Bero.

TABLE 3.1: DATA AND THEIR SOURCES

No	Data	Source
1	AMP Reports	Adama municipality
2	Existing Geodatabase	Adama municipality
3	Infrastructure Data	Adama municipality
4	Utility Data	Adama municipality

### 3.2.2. REQUIRED SOFTWARE

The following software applications were utilized in this research

TABLE 3.2: REQUIRED SOFTWARE

No.	software	Purpose
1	ArcGIS 10.8	For mapping, Geodatabase Creation
2	Postgresql/PostGIS	Spatial database management system
3	QGIS Plug-in /qgis2web, Quick Map services	For web GIS application
4	Notepad++	For organizing and running the codes

### 3.3. Description of Methodology

The methodology comprises several key steps to enhance infrastructure asset management practices in Adama city. To begin, a comprehensive literature review is conducted, focusing on existing studies, frameworks, and best practices in infrastructure asset management. Data is then collected from various sources, including the infrastructure Geodatabase, maintenance records, financial reports, and Asset management plan from Adama city's infrastructure departments. Additionally, interviews are conducted with key stakeholders to gather their valuable perspectives. Assessment indicators are developed based on different literature review. The collected data is analyzed to identify patterns, trends, strengths, weaknesses, and areas for improvement in infrastructure asset management practices. Comparative analysis was performed to benchmark Adama city's practices against industry standards with the developed assessment indicators to identify gaps and areas for enhancement. Based on these findings, recommendations are provided to improve infrastructure asset management practices in Adama city.

Furthermore, the methodology involves requirement analysis to identify specific needs for infrastructure asset management. A spatial database model is designed to efficiently store, organize, and retrieve infrastructure data, incorporating the identified requirements. Data integration is carried out, integrating various data sources such as GIS data, asset inventories, maintenance records, and spatial information into the spatial database model. The spatial database model is then tested and validated using sample data to ensure its functionality, performance, and usability.

To devise an efficient spatial database model that can adeptly store, organize, and retrieve infrastructure data while aligning with the specified requirements, a systematic research methodology can be employed. This methodology encompasses three key stages: conceptual, logical, and physical database modeling. In the conceptual stage, entities relevant to infrastructure asset management, such as roads, bridges, buildings, and utilities, are identified and their relationships and attributes defined. The logical stage involves translating the conceptual model into a relational database design, including mapping entities, relationships, and attributes to tables, establishing primary and foreign keys, and ensuring data normalization. Finally, in the physical stage, the logical design is transformed into a physical implementation, considering the target database management system and optimizing storage structures, access methods, spatial indexing techniques, and performance optimization strategies. By following this research methodology, an effective spatial database model can be crafted to proficiently handle infrastructure data management needs.

In addition, the methodology includes the selection of open-source tools suitable for publishing infrastructure data on the web. Factors such as data formats, visualization capabilities, scalability, and user-friendliness are considered during the tool selection process. The infrastructure data is prepared to ensure data quality, consistency, and compatibility with the selected tools. The chosen open-source tools are implemented to create a web-based platform for publishing infrastructure data. Finally, the web-based platform is thoroughly tested for functionality, performance, and compatibility across different browsers, with optimization measures implemented as necessary.

The research approach is illustrated in the accompanying figure.

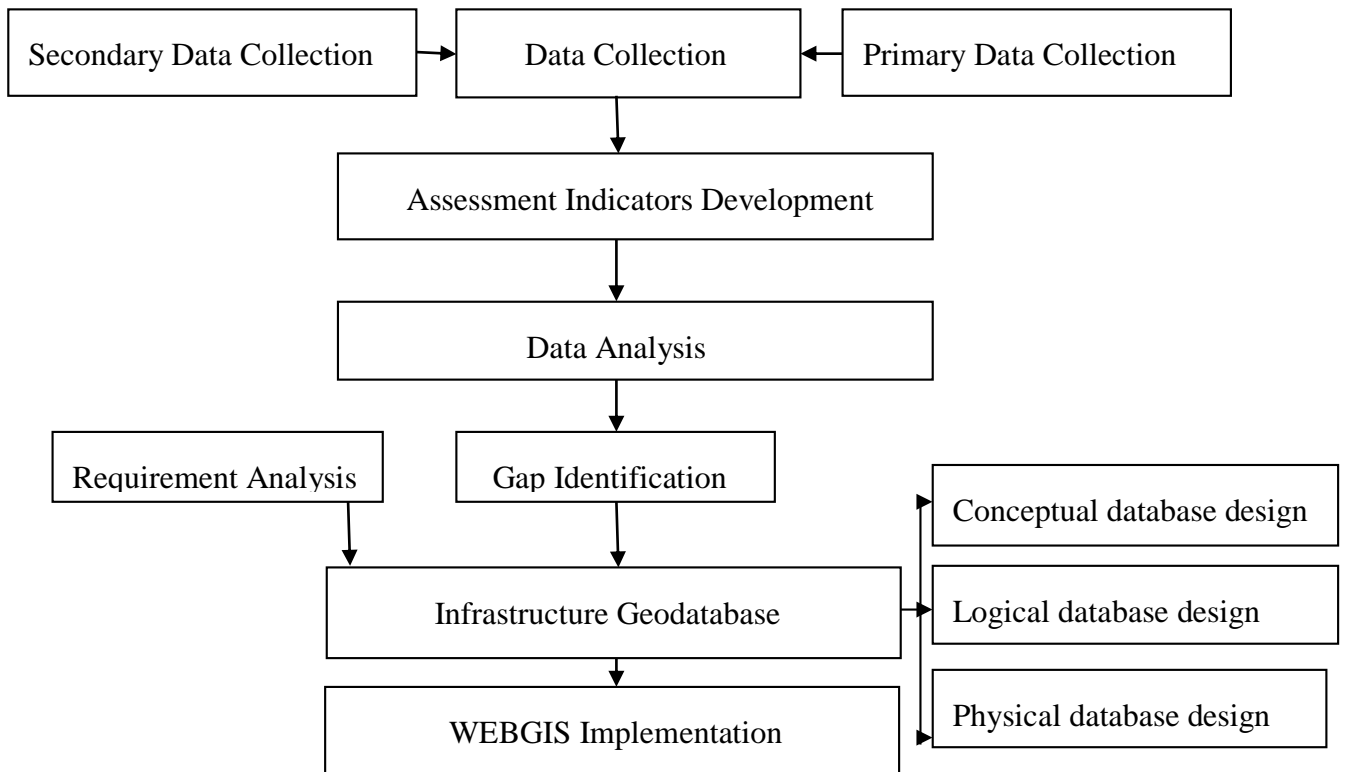


Figure 3.2 Researches Methodological Flowchart

### 1. Literature Review:

The literature review is a crucial first step in the proposed research methodology to enhance infrastructure asset management practices in Adama City. This comprehensive review serves several key purposes. Firstly, it helps the researcher identify the current state of knowledge by examining existing academic and industry studies related to infrastructure asset management. This exploration of the latest developments, theories, and models in the field provides a solid understanding of the current understanding and best practices in infrastructure asset management. Secondly, the literature review analyzes successful approaches by investigating frameworks, strategies, and case studies of effective infrastructure asset management practices implemented by other cities, municipalities, or organizations. Understanding these successful approaches can aid in identifying potential solutions and adaptable strategies for Adama City.

Thirdly, the literature review recognizes emerging trends in the field, exploring the latest technologies, data management techniques, and innovative practices that are shaping infrastructure asset management. Identifying these emerging trends can help the researcher anticipate future challenges and develop forward-looking solutions for Adama City. Fourthly, the literature review establishes a strong theoretical foundation for the research project by providing an understanding of the underlying principles, concepts, and frameworks that guide effective infrastructure asset management. This theoretical grounding ensures that the research is rooted in established knowledge and best practices. Finally, the literature review helps the researcher identify gaps in the existing knowledge and research, pinpointing areas where further exploration or empirical investigation is needed, particularly in the context of Adama City. Identifying these gaps guides the researcher in focusing their efforts on addressing the specific needs and challenges of the city.

## **2. Data Collection:**

The data collection phase of the research methodology was a comprehensive approach that involved gathering information from multiple sources to develop a deep understanding of Adama City's infrastructure asset management practices. The researcher accessed and analyzed the city's infrastructure Geodatabase, which contained detailed spatial and attribute data on the location, type, condition, and performance of the various infrastructure assets. Additionally, the team collected and reviewed the maintenance records, financial reports, and existing asset management plans to gain insights into the city's infrastructure maintenance strategies, funding allocation, and strategic approach to asset management. To further enrich the data collection process, the researchers conducted interviews with key stakeholders, including city officials, infrastructure managers, and service providers. These interviews provided valuable perspectives and insights into the operational, managerial, and organizational challenges faced by the city in effectively managing its infrastructure assets. By combining data from these diverse sources, the researcher developed a holistic understanding of Adama City's infrastructure asset management practices, which informed the subsequent steps of the research methodology.

The data collection phase of the research methodology was a comprehensive and multi-faceted approach that enabled the researcher to develop a deep and holistic understanding of Adama City's infrastructure asset management practices.

The first step involved accessing and analyzing the city's infrastructure Geodatabase, which served as a rich source of spatial and attribute data. The Geodatabase contained detailed information on the location, type, condition, and performance of the various infrastructure assets within Adama City. By examining this comprehensive database, the researchers were able to gain a thorough understanding of the city's infrastructure landscape, identifying patterns, trends, and potential gaps or inconsistencies in the data.

In addition to the Geodatabase, the researcher collected and reviewed the maintenance records for Adama City's infrastructure assets. These records provided valuable insights into the city's infrastructure maintenance strategies, including the frequency and nature of repair activities, maintenance schedules, and the allocation of resources. Analyzing these records allowed the researchers to identify areas where the city's asset maintenance practices could be optimized or improved.

The financial reports related to Adama City's infrastructure investments, budgets, and expenditures were another crucial data source. By examining these financial records, the researchers were able to assess the city's prioritization of infrastructure assets, identify the sources of infrastructure funding, and evaluate the adequacy and sustainability of the city's resource allocation for asset management.

Furthermore, the researcher reviewed the existing asset management plans developed by Adama City's infrastructure departments. These plans provided valuable insights into the city's strategic approach to managing its infrastructure assets, including asset condition assessments, life-cycle planning, and risk management strategies. Analyzing these plans enabled the researchers to understand the current policies, practices, and challenges faced by the city in maintaining and improving its infrastructure assets. To complement the quantitative data gathered from the various sources, the researcher also conducted interviews with key stakeholders, including city officials, infrastructure managers, and service providers. These interviews offered a deeper understanding of the operational, managerial, and organizational challenges faced by Adama City in effectively managing its infrastructure assets. The stakeholders' perspectives and insights helped the researchers

identify potential solutions, best practices, and innovative approaches that could be tailored to the city's specific needs.

By combining the data from the infrastructure Geodatabase, maintenance records, financial reports, asset management plans, and stakeholder interviews, the researcher developed a comprehensive understanding of Adama City's infrastructure asset management practices. This multifaceted data collection approach ensured that the research was grounded in real-world evidence and the perspectives of those directly involved in the city's infrastructure management, setting the stage for the subsequent phases of the research methodology.

### **3. Indicator Development**

The development of assessment indicators was a critical step in the research methodology, as it provided a structured framework to evaluate the effectiveness of Adama City's infrastructure asset management practices. Drawing from the insights gained during the literature review, the researcher carefully crafted a set of indicators that would capture the multifaceted dimensions of the city's infrastructure management.

The indicators were designed to assess various aspects of asset management, including the condition of the infrastructure assets, the maintenance practices employed by the city, the allocation of resources for infrastructure upkeep, the quality of service delivery to the community, and the alignment of Adama City's approaches with industry standards and best practices. By developing a comprehensive set of indicators, the researchers ensured that the evaluation process would provide a holistic understanding of the strengths, weaknesses, and areas for improvement in the city's infrastructure asset management. These indicators would serve as the foundation for the subsequent data analysis and assessment phases, enabling the researcher to objectively and systematically evaluate Adama City's infrastructure management performance and identify opportunities for enhancement.

#### **4. Data Analysis:**

The data collected during the comprehensive research process was meticulously analyzed to gain a deep understanding of Adama City's infrastructure asset management practices. The researcher employed a rigorous analytical approach, identifying patterns, trends, strengths, weaknesses, and areas for improvement within the city's asset management strategies. A comparative analysis was performed, benchmarking Adama City's practices against the assessment indicators developed earlier in the research methodology. This comparative evaluation enabled the identification of critical gaps and opportunities for enhancing the city's infrastructure management, laying the foundation for the subsequent requirement analysis and solution design phases.

#### **5. Requirement Analysis:**

Recognizing the importance of tailoring the proposed solutions to the unique context and needs of Adama City, the researcher conducted a thorough requirement analysis. This crucial step involved a deep dive into the specific challenges, pain points, and priorities faced by the city in managing its infrastructure assets. By engaging with key stakeholders, including city officials, infrastructure managers, and service providers, the researchers gained valuable insights into the operational, managerial, and organizational constraints that hindered the city's ability to effectively maintain and optimize its infrastructure. The requirement analysis ensured that the recommended solutions would be closely aligned with Adama City's unique circumstances, addressing the most pressing issues and delivering tangible improvements to the city's infrastructure asset management.

#### **6. Spatial Database Design:**

Building upon the insights gained from the data analysis and requirement assessment, the researcher embarked on the design of a comprehensive spatial database model. This model was envisioned to serve as a centralized and efficient platform for storing, organizing, and retrieving Adama City's infrastructure data. The database design process involved a multi-stage approach, starting with conceptual modeling to establish the overall structure and relationships within the database. This was followed by logical modeling, where the researcher refined the data entities, attributes, and integrity constraints to ensure the database's functionality and performance. Finally, the physical database modeling stage

focused on the implementation-level details, such as the choice of database management system, data storage structures, and indexing strategies, to ensure the scalability and responsiveness of the spatial database. By meticulously designing this robust and flexible spatial database, the researcher laid the groundwork for Adama City to effectively manage, analyze, and leverage its infrastructure data to support informed decision-making and asset management strategies.

## **7. WEBGIS Applications**

The researcher recognized the paramount importance of developing a robust and user-friendly web-based platform to facilitate Adama City's infrastructure data management and visualization. After a careful evaluation of various open-source tools and technologies, the researchers selected the most appropriate solutions that would best meet the city's requirements.

The selection process considered a range of factors, including the ability to handle diverse data formats, the availability of sophisticated visualization capabilities, the potential for scalability to accommodate growing data volumes, and the overall user-friendliness of the platform. By thoroughly assessing these crucial criteria, the researcher ensured that the chosen tools would seamlessly integrate with Adama City's existing infrastructure data and provide a seamless, intuitive experience for end-users.

## **CHAPTER IV: RESULTS AND DISCUSSIONS**

In this chapter, the findings and outcomes derived from the conducted research will be discussed and presented. The comprehensive overview of the results obtained will be provided, representing the culmination of the study. The various aspects explored during the research process will be delved into, and the implications and significance of the findings will be discussed. Valuable insights will be offered, and the existing body of knowledge in the field will be contributed to through a meticulous analysis and interpretation of the collected data.

### **4.1. Designed Assessment Framework**

Based on the Assessment dimensions presented in the literature, a new assessment framework is created in this research. This framework consists of eight dimensions which are: (1) Inventory methods, (2) Data Storage and management, (3) Road Condition Assessment, (4) Decision Making (5) Operational Planning,(6) Maintenance Planning,(7) Capital Works Planning,(8) Information Systems. Each dimension contains certain indicators and level of maturity.

TABLE 4.2: DESIGNED ASSESSMENT FRAMEWORK

		Level of maturity				
	Component	Indicators	Minimum	Core		Advanced
1	Inventory methods	<p>Reference system</p> <p>Inventory Methods and frequency of data collection</p> <p>Technology/Instrument</p>	<p>Basic road inventory system consisting of:</p> <p>Basic network referencing system based on the basis of routes.</p> <p>Item Inventory conducted for major defects.</p> <p>Manual data collection with two or more data collectors that record the data with pen and paper.</p>	<p>As for Minimum plus:</p> <p>Referencing system has greater granularity and Item inventory recording basic road surface type, Deterioration Type, Deterioration area by Route and length /Area within each Route</p>	<p>As for Core plus:</p> <p>GPS based inventory system, With hand-held computers/ Data collectors.</p> <p>Detail and frequent Inventory</p>	<p>As for Mature plus:</p> <p>Automatic data collection with the use of some type of data collection vehicle or equipment, e.g., video cameras, laser sensors, etc. to capture, store, and process the collected data</p>

2	Data Storage and management	Data base performance /Technology  Level of detail  Simplicity and Security	Data stored in a spreadsheet like:  Location of assets,  current value of assets,  Depreciation value,  Maintenance information  The remaining life of an asset, Estimated Current Value	Data stored in Relational data base	Data stored in Geodatabase	Data stored in enterprise spatial Geodata base
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3	Road Condition Assessment	Condition assessment techniques  Technology	Condition assessment at route level via visual inspection.  Road condition reported in terms of good, fair, poor.  Senior/experienced staff judgment to decide Levels for each Road asset type.	As for Minimum plus:  Condition assessment is conducted with remaining useful life or percentage deterioration with simple excel formula	As for Core plus:  Condition assessment is conducted automatically with Scripts written with Programming language.	As for Mature, and the condition is evaluated with modern instrument and software mounted on the vehicle.
4	Decision Making	Decision making techniques	Decisions based mainly on staff judgment and agreed road administration priorities	Formal decision-making techniques, based on multi-criteria analysis	Formal decision making and prioritization techniques are applied	As for Mature, however the framework allows for maintenance, renewal and upgrading projects to be

				(i.e. consideration of economic, social and environmental costs and benefits)	to all maintenance and capital principal asset programme within each main budget category.  Principal assumptions and estimates are tested for sensitivity to results	optimized across all activity areas.  Formal risk-based sensitivity analysis is carried out
5	Operational Planning		Operational responses to emergency related closure of roads or bridges resulting from traffics accidents understood by road administration staff, but plans may not be well	As for basic. Emergency response plan is developed for closure of principal assets.	Emergency response plan is updated every 3 years.  Safety of infrastructure in relation to traffic	Operational plan analyzed, tested and improved every 3 years.  Optimization of day-to-day planning of Asset utilization

			documented  Planning of day to day maintenance undertaken.	Demand management is considered for road sections where overloading is a problem.  The needs of stakeholders are considered in scheduling of day-to-day maintenance activities.	assessed, including black spot analysis, remedial works design and layout and traffic management measures.  Planning of day-to-day maintenance is optimized in terms of the availability and use of resources. Environmental impact to roads assessed Asset utilization is measured for roads and bridges on a sub-section basis	efficiency  Operational programme are analyzed using cost-benefit analysis techniques
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6	Maintenance Planning	Planning approach	<p>An understanding of how Road asset functions relate to organizational objectives.</p> <p>Compliant with legislation and regulations Maintenance records kept</p>	<p>Maintenance prioritized according to road classification and safety requirements.</p> <p>Asset condition used to identify and prioritize maintenance need.</p> <p>Strategy for routine maintenance of assets established.</p>	<p>Periodic maintenance interventional levels for strengthening of sealed roads to be determined by cost benefit analysis as a function of traffic levels, construction type and environment</p>	<p>Periodic maintenance of roads established by multicriteria analysis, which considers economic, social and environmental costs and benefits, as a function of traffic levels, construction type and environment.</p>
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7	Capital Works Planning	Planning approach	Schedule of proposed capital projects (and costs) in place based on staff judgment to future requirements, taking in to consideration government policy and political drivers	Projects have been identified using information from a wider range of sources including operational staff, estimates of service lives. Traffic demand modeling and accident analysis costs estimated	As for “Core”, plus analysis has been carried out for projects in the 3-5 year planning horizon. Major capital projects for the next 10 years identified and broad multi-criteria socio-political-economic benefit estimates have been carried out	Long term capital investment programmes are developed using advanced decision-making techniques
8	Information Systems	Technology	Asset register in place which can record core attributes of Road assets	Asset register in place which can record	More automated analysis reporting on a	Strategic planning, programming, preparation and operations

		Performance		attributes of Road asset.	wider range of information.	management functionality
		Estimating and costing		Road user request tracking and planned maintenance functionality enabled	Key operations, scheduled maintenance prioritized, back log maintenance requirements, unplanned maintenance and condition and performance information held.	Fully integrated. Economic, financial, principal asset and road user service systems
		Planning and scheduling		System enables manual reports for valuation, renewal forecasting Compatible with data		Fully integrated all advanced Road asset management functions are enabled.

## **4.2. Assessment of Adama City's Asset Management System**

The assessment of Adama City's asset management system is conducted, and the results are presented in this section. The evaluation framework comprises eight dimensions that form the basis for the assessment. These dimensions include:

### **4.2.1. INVENTORY METHODS:**

This dimension focuses on gathering comprehensive information about the physical location, attributes, utilization, maintenance history, planned work, costs, resources, and other relevant details related to the assets. The data collection process is guided by the agency's decision-making requirements and available resources.

The measurement of inventory methods involves three indicators:

1. **Reference System:** This indicator assesses the existence and effectiveness of a reference system for managing asset inventory.
2. **Inventory Methods and Frequency of Data Collection:** This indicator evaluates the methodologies employed and the frequency at which data is collected for the asset inventory.
3. **Technology/Instrument:** This indicator examines the technological tools or instruments used for inventory management.

To obtain primary data for this dimension, semi-structured interviews are conducted with officials from both management and subject matter experts within the organization. These interviews help gather insights and perspectives on the inventory methods employed.

The assessment results for each dimension in the framework are presented based on their efficiency or maturity level. This enables a comprehensive analysis of the road asset management system in Adama City and provides valuable insights for further improvement and decision-making.

#### **4.2.1.1. REFERENCE SYSTEM**

Assigning a Unique Reference Identifier (ID) to each road asset element is a crucial step in conducting a road inventory. In this study, the organization aimed to implement the method RN\_AS\_AD\_0001\_00 for assigning a unique ID to each route. The ID structure consists of various components: "RN" represents Road Network, "AS" represents the surface material, "AD" represents the code for Adama city, "0001" signifies the route ID assigned to a specific route, and "00" is a code reserved for further breakdown of the road element.

However, after analyzing responses from experts and relevant documents, it was found that the Unique Reference Identifier was not implemented as originally intended. Instead, the organization adopted an incremental approach, incrementing the Road Asset IDs by one number whenever a new asset was introduced or digitized. Additionally, they assigned a route ID for each segment of a route.

It is worth noting that the most appropriate method would involve assigning the route ID to the entire route and identifying the segments of the route using stations or nodes. This approach ensures a more accurate representation of the road network and facilitates efficient data management and analysis.

By identifying this discrepancy in the implementation of the Unique Reference Identifier, the study highlights the importance of adhering to the intended reference system. Implementing the appropriate method for assigning IDs to road assets contributes to better data organization, analysis, and decision-making within the road asset management system of Adama city.

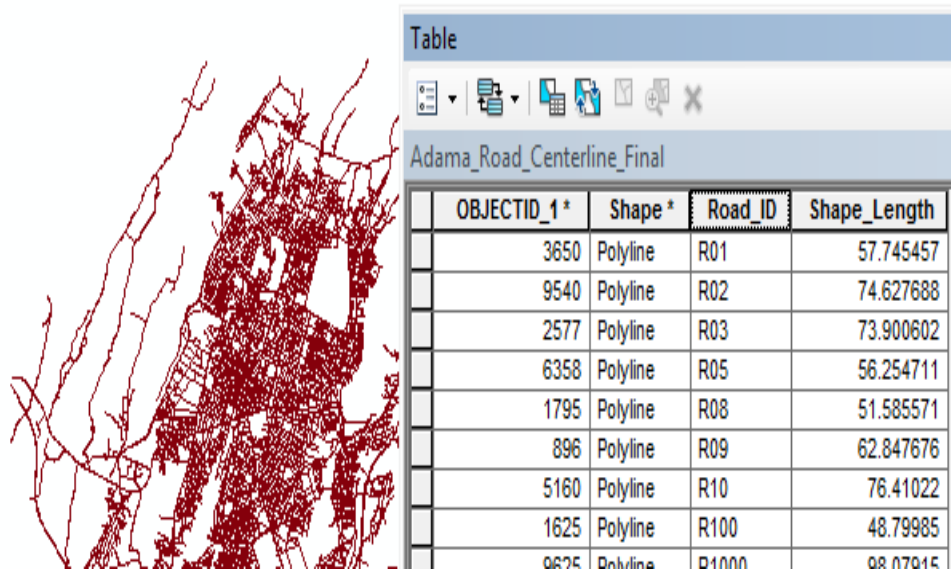


Fig 4.1 Sample reference system used.

#### 4.2.1.2. INVENTORY METHODS, FREQUENCY OF DATA COLLECTION, AND TECHNOLOGY/INSTRUMENT

The organization has devised an inventory format for data collection and conducts the inventory on an annual basis. The collected data primarily focuses on recording essential information, such as the road surface type, deterioration type, deterioration area based on routes, and length/area within each route. The manual data collection method is employed, involving four data collectors who record the data using pen and paper.

While there are advanced instruments available in the market for road asset inventory, such as GPS and vehicles equipped with laser scanners, the organization currently relies solely on meters and visual inspection. However, given the city's growth and the construction of various road projects, it is crucial to enhance the inventory methods and instruments for more efficient data collection in the future.

For future data collection, the agency could consider incorporating data collectors equipped with GPS-enabled mobile applications. This implementation would significantly improve the accuracy and efficiency of data collection processes. Furthermore, for asphalt pavement structural inventory, adopting a small laser scanner to detect defects or deformations could provide more detailed information and contribute to better asset management.

By highlighting the limitations of the current inventory methods and instruments, the study emphasizes the need for upgrading and modernizing data collection techniques. Implementing advanced technology and instruments would not only streamline the data collection process but also enhance the quality and depth of information gathered for the road asset management system in Adama city.

#### **4.2.2. DATA STORAGE AND MANAGEMENT**

The dimension of data storage and management plays a crucial role in ensuring an efficient road asset management system. This dimension is evaluated based on three indicators: (1) Database Performance/Technology, (2) Level of Detail, and (3) Simplicity and Security

##### **4.2.2.1. DATABASE PERFORMANCE/TECHNOLOGY:**

The organization currently utilizes ArcGIS geodatabase and Excel tables as their chosen platforms for storing and managing road asset information. However, upon examination, it was identified that the existing database performance lacks in several key areas.

One concern is data consistency and integrity within the database. This indicates that the data may not always be accurate, up-to-date, or reliable, potentially leading to errors or discrepancies in asset information.

Another issue is the presence of redundant data, suggesting that there may be unnecessary duplication of information within the database. This redundancy can result in inefficiencies as it consumes storage space and can cause confusion or inconsistencies when managing and updating the data.

Additionally, the current database lacks adequate mechanisms for data sharing and security. This means that sharing and collaborating on road asset information may not be seamless or adequately protected. There is a need for improved data sharing capabilities to facilitate collaboration among different stakeholders while ensuring the security and confidentiality of the information.

To address these limitations, it is recommended that the organization explores alternative database solutions that offer better performance in terms of data consistency, integrity, redundancy management, data sharing, and security mechanisms. This could involve implementing a more robust and specialized database system specifically designed for road

asset management. Alternatively, the organization could consider adopting modern technologies such as cloud-based databases or data management platforms that provide enhanced features and capabilities.

By identifying the shortcomings in the current data storage and management practices, the study emphasizes the importance of upgrading the database infrastructure and technology to ensure reliable, efficient, and secure management of road asset information in Adama city.

#### **4.2.2.2. LEVEL OF DETAIL**

The organization is responsible for storing various types of information about the roads under their management. This includes essential details such as the road's location, length, width, road types, deterioration type, deterioration area, current value of assets, depreciation value, maintenance information, remaining life of assets, estimated current value, and more.

However, it was observed that the information in the database is not regularly updated. This lack of timely updates can result in outdated or inaccurate data, which can impede effective decision-making and asset management processes.

Furthermore, it was found that there is a deficiency in detailed information about the assets and their performance recorded at specific stations along the road. This means that crucial data points, such as specific locations on the road where assets are situated or their performance characteristics are not adequately documented. This missing information can limit the organization's ability to track asset conditions, identify patterns of deterioration, and prioritize maintenance or replacement efforts.

To address these issues, it is recommended that the organization establishes a systematic and regular process for updating the information in the database on a yearly basis. This ensures that the data remains accurate and reliable for decision-making purposes. Regular updates will enable the organization to have up-to-date information on the condition and performance of their assets.

Furthermore, it is crucial to implement a comprehensive recording system that captures detailed information about each asset and its performance at specific stations along the

road. This includes recording asset characteristics, deterioration patterns, and maintenance history at specific locations. By doing so, the organization will have a more comprehensive understanding of the condition and performance of their assets, enabling better asset management and maintenance planning.

By emphasizing the importance of maintaining an updated database and capturing detailed information, the study highlights the need for a more comprehensive and accurate representation of road assets. This facilitates informed decision-making, effective monitoring of asset conditions, and improved maintenance strategies in Adama city.

#### **4.2.2.3. SIMPLICITY AND SECURITY**

To simplify calculations for fields such as percentage depreciation, Estimated Current Value, and Asset Deficit, the organization currently relies on Excel software. The resulting Excel table is then linked to the ArcGIS spatial geometry using a common Route ID. However, the organization faces significant challenges in terms of database security and backup mechanisms, particularly when it comes to accessing road information from previous years.

During the desk study, it was observed that experts updated the current road asset information without backing up the data from previous years. This lack of backup poses a risk to the organization's historical data, making it difficult to retrieve road information from previous years for analysis or comparison purposes.

Currently, the responsibility of recording new road asset information and updating the condition of existing roads lies with a single expert. While this approach provides some level of security, relying solely on one person for managing the organization's asset information is not advisable. Instead, it is recommended that the organization distributes the road asset information among different experts while assigning the role of database administration to a single individual. This distribution of responsibility ensures data integrity, accuracy, and security.

As the city continues to grow and new road projects are undertaken, it becomes imperative to improve the database for efficient data storage and management. The database should be carefully designed and implemented within a specific database management system, or it can be integrated with other systems such as the road management system or financial

system. This integration would facilitate seamless data exchange, enhance data accuracy, and enable comprehensive analysis and reporting capabilities for better decision-making.

In summary, enhancing database security, implementing regular backups, distributing asset information among experts, and improving the database design and integration are vital steps for efficient data storage, management, and utilization in the future. These measures will ensure the protection of valuable data, enable easy access to historical information, and enhance the organization's ability to make informed decisions regarding road asset management in Adama city.

#### **4.2.3. ROAD CONDITION ASSESSMENT METHODS**

Assessing the condition of road assets is crucial for evaluating their current state and determining appropriate management strategies. This assessment is typically carried out through performance measures selected by the agency, aligning with their objectives. Performance measures for physical assets can include condition indices, the percentage of the network rated as being in good condition, and the remaining lifespan of the asset network. Within the realm of road condition assessment methods, two indicators can be identified: (1) Condition assessment techniques and (2) Technology.

##### **4.2.3.1. Condition Assessment Techniques:**

Condition assessment techniques are employed to evaluate the condition of roads. Currently, this assessment is conducted at the route level using techniques such as visual inspection, typically performed by experienced staff members. The assessment results are then reported using simple Excel formulas to determine the road condition classification, such as good, fair, or poor, based on remaining useful life or the percentage of deterioration.

However, it is important to note that assessing the condition at the segment level using modern approaches is preferable. This involves utilizing advanced methods and technologies to gather more detailed and accurate data about each individual segment of the road network.

By adopting a modern approach, such as utilizing specialized equipment like laser scanners or other sensor technologies, it becomes possible to capture precise measurements of

various parameters including pavement distress, surface defects, and structural integrity. This level of detailed assessment enables a more comprehensive understanding of the condition of each road segment, facilitating the identification of specific areas that require immediate attention or maintenance.

Moreover, modern approaches often incorporate data analysis techniques, such as machine learning algorithms or predictive models, to assess the condition of road segments more efficiently and accurately. These methods can analyze large volumes of data and provide valuable insights into deterioration patterns and expected future performance of the road network. In summary, while the current practice of condition assessment involves visual inspection at the route level and simple calculations, there is a need to transition towards assessing road condition at the segment level using modern approaches. By leveraging advanced technologies and data analysis techniques, it is possible to obtain more detailed and accurate information about the condition of each road segment, leading to more effective maintenance and management strategies. This shift towards segment-level assessment allows for targeted interventions and better resource allocation, ultimately improving the overall condition and performance of the road network in Adama city.

#### **4.2.3.2 TECHNOLOGY**

The research findings highlight that the organization currently relies on outdated methods for assessing the condition of roads and recommends the adoption of modern technology as a more efficient and rapid alternative. Embracing modern technology offers significant advantages over traditional assessment methods in terms of accuracy, efficiency, and speed.

Modern technology, such as laser scanners, ground-penetrating radar, and imaging systems, can capture detailed information about the structural condition of roads. These tools provide precise measurements and data on parameters like pavement thickness, surface distress, rutting, and cracking. This level of detail enables a comprehensive understanding of the road's condition and facilitates targeted maintenance and repair efforts.

Additionally, modern technology incorporates advanced data analysis techniques, including artificial intelligence and machine learning algorithms. These algorithms can

process large volumes of data and identify patterns, trends, and potential risks or failures more efficiently than manual analysis. This empowers the organization to make informed decisions based on robust data-driven insights.

By leveraging modern technology, the organization can improve the overall assessment process by reducing human error, increasing assessment speed, and enhancing the accuracy and reliability of the results. It also enables streamlined operations, effective resource allocation, and prioritization of maintenance activities based on the actual condition of the road.

In conclusion, although the organization has not yet embraced modern technology for road condition assessment, it is highly recommended to integrate these tools and techniques. Doing so will enable more efficient and rapid assessment of the road's structural condition, ultimately leading to improved maintenance strategies and better overall management of the road network.

To implement this recommendation, the organization can consider utilizing open-source tools like QField and QGIS, which facilitate field data collection and analysis. These tools provide user-friendly interfaces and a wide range of functionalities for capturing and analyzing road condition data. Additionally, machine learning techniques can be employed using frameworks such as TensorFlow and scikit-learn to enhance road condition assessment. Leveraging these technologies will significantly enhance the efficiency and accuracy of road condition assessment, enabling better-informed decision-making and optimized resource allocation.

#### **4.2.4. DECISION MAKING**

Comparing projects using cost-benefit analysis (CBA) allows for a straightforward evaluation based on a single metric—the monetized value. CBA takes into account all costs and benefits associated with a project over its lifespan, considering the time value of money by discounting future flows to present values. One of the key strengths of CBA is its ability to enable decision-makers to compare and rank different project alternatives based on a single indicator.

Social Cost-Benefit Analysis (SCBA) takes this evaluation a step further by prioritizing projects that maximize net present values for society as a whole. By considering the overall

impact on society, SCBA provides a framework for selecting projects that generate the greatest social benefits relative to costs.

In recent years, multi-criteria decision analysis (MCDA) has gained popularity as a systematic approach to structuring investment decisions involving multiple aspects. MCDA allows decision-makers to reconcile different factors associated with proposed investments, including non-monetary and qualitative considerations. This approach proves valuable in situations where information or analytical resources are limited.

One of the strengths of MCDA is its ability to incorporate various criteria and assign weights to them, synthesizing them into a decision model. This makes MCDA applicable to a wide range of problems and easily understandable by decision-makers. These models are particularly relevant for issues of sustainable development due to their capacity to handle complex situations involving multiple criteria, different scales and aspects, various types of data, and uncertainties.

Furthermore, MCDA offers the flexibility to involve multiple decision-makers, allowing for a collaborative and inclusive decision-making process. Engaging stakeholders in the MCDA process helps increase knowledge and encourages the proposal of alternative solutions, ensuring a more comprehensive analysis of the available options.

In summary, cost-benefit analysis provides a useful tool for comparing projects based on monetary values, while social cost-benefit analysis prioritizes projects with the greatest net benefits for society. Multi-criteria decision analysis complements these approaches by incorporating non-monetary and qualitative factors, offering a structured methodology for decision-making in complex situations. It promotes transparency, can accommodate various problems, and encourages stakeholder engagement to enhance knowledge and propose alternative solutions for sustainable development.

The decision-making dimension was evaluated using indicators of required data, decision-making techniques, and the level of decision-making.

**Data Required:**

The research findings indicate that the agency's decision-making process considers various factors, with location, initial cost, and functional condition identified as highly important.

These factors significantly influence the agency's decisions regarding asset management and investment.

Location plays a critical role as it affects the accessibility, connectivity, and potential impact of an asset on the surrounding area. Recognizing the importance of geographical context, the agency considers location when making decisions related to asset placement and infrastructure development.

The initial cost of an asset is another key consideration. It reflects the financial investment required for acquisition or implementation. By evaluating the initial cost, the agency can assess the feasibility and affordability of different options and allocate resources accordingly.

The functional condition of an asset is also deemed important. This refers to the asset's ability to effectively and efficiently fulfill its intended purpose. The agency acknowledges that assets in good functional condition are more likely to deliver the desired outcomes and provide value for money.

On the other hand, the research indicates that the agency considers the structural condition and community feedback as somewhat important factors. While these factors are taken into account, they may not carry the same weight as location, initial cost, and functional condition in the decision-making process.

The structural condition of an asset relates to its physical integrity, durability, and maintenance requirements. Considering this factor ensures the long-term sustainability and resilience of the asset.

Community feedback is also recognized as valuable input in the decision-making process. It reflects the perspectives, needs, and preferences of the community or stakeholders affected by the asset. By considering community feedback, the agency can enhance public participation, improve transparency, and align projects with community expectations.

However, the research highlights a limitation in the agency's decision-making process—the lack of data on asset usage and life cycle cost. This means that the agency does not incorporate information on how the asset is utilized or the costs associated with its entire life cycle, including operation, maintenance, and disposal. This omission may impact the

agency's ability to fully assess the long-term cost-effectiveness and sustainability of different asset alternatives.

In conclusion, the agency gives significant consideration to factors such as location, initial cost, and functional condition in their decision-making process. They also take into account the somewhat important factors of structural condition and community feedback. However, the lack of data on asset usage and life cycle cost represents a limitation in the decision-making process, as it restricts the agency's ability to comprehensively evaluate the long-term implications and cost-effectiveness of different asset options.

Decision-making technique:

According to the research findings, the agency primarily relies on historical practices, staff experience, community interest, and budget availability when making project selection decisions. However, the research recommends the adoption of modern techniques, specifically multicriteria analysis, to enhance the decision-making process.

Multicriteria analysis is a systematic approach that enables decision-makers to evaluate and compare different alternatives based on multiple criteria. By assigning appropriate weights to selected criteria, such as economic, social, and environmental factors, the agency can ensure a more comprehensive and balanced assessment of projects.

Implementing multicriteria analysis allows the agency to move beyond relying solely on past practices and subjective judgments. It provides a structured framework for decision-making that considers a broader range of factors and offers a more objective basis for project selection.

Furthermore, the research suggests that the agency should implement prioritization and decision-making techniques tailored specifically to new road construction and maintenance. These techniques can assist the agency in effectively allocating resources and prioritizing projects based on their urgency, impact, and alignment with strategic goals.

By utilizing prioritization techniques, the agency can systematically rank projects and determine their relative importance. This ensures that projects with higher priority, such as those addressing critical safety issues or serving high-demand areas, receive appropriate attention and resources.

Moreover, decision-making techniques can help evaluate the trade-offs and benefits associated with different project options. These techniques involve analyzing the costs, benefits, risks, and impacts of each alternative, enabling informed decisions that align with the agency's objectives and stakeholder expectations.

By incorporating modern techniques like multicriteria analysis, prioritization, and decision-making techniques, the agency can enhance its project selection process. This approach allows for a more systematic and transparent evaluation of projects, considering economic, social, and environmental factors. It supports evidence-based decision-making, improves resource allocation, and promotes the delivery of projects that best meet the needs of the community and align with the agency's objectives.

In conclusion, while the agency has been relying on historical practices, staff experience, community interest, and budget availability for project selection, there is a need for improvement. The research suggests adopting modern techniques like multicriteria analysis, prioritization, and decision-making techniques. By utilizing these approaches, the agency can make more informed decisions, considering a broader range of criteria and ensuring the prioritization of projects that align with strategic goals and deliver the greatest benefits to the community.

The research findings highlight that the agency has established a decision-making framework at various levels, including strategic planning, budgeting, project selection, and prioritization. However, the current methods employed by the agency are predominantly manual, indicating a need for increased automation to enhance efficiency and accuracy in decision-making processes.

The agency acknowledges the significance of fiscal planning, the development of alternative projects, project selection, and resource allocation within the decision-making life cycle. Fiscal planning involves setting and managing budgets to ensure the availability of financial resources to support projects and initiatives. The development of alternative projects entails exploring different options, assessing their feasibility, considering their benefits, and evaluating their alignment with strategic goals. Project selection and resource allocation involve identifying and prioritizing projects based on their value, impact, and the availability of resources.

While the research emphasizes the importance of fiscal planning, development of alternatives, project selection, and resource allocation, it also indicates that other stages within the decision-making life cycle hold some level of importance. These stages include performance evaluation and monitoring, program optimization, performance-based budgeting, program delivery, project implementation, and auditing.

Performance evaluation and monitoring involve assessing the effectiveness and efficiency of projects and programs, tracking progress, and making necessary adjustments to improve outcomes. Program optimization aims to enhance the overall performance and results of programs through continuous improvement and adjustments of strategies and resource allocation. Performance-based budgeting links funding decisions to program performance and outcomes, ensuring that resources are allocated to initiatives that deliver desired results.

Program delivery refers to the implementation and management of projects and programs, ensuring that they are executed according to plan and achieve their intended objectives. Project implementation involves the actual execution of individual projects, including activities such as procurement, construction, and stakeholder engagement. Auditing is important to ensure compliance with regulations, policies, and procedures, as well as to ensure the effective and efficient utilization of resources.

While these stages may be considered somewhat important within the decision-making life cycle, they still hold significance in the overall effectiveness and efficiency of the agency's operations. They contribute to accountability and transparency in project implementation and resource utilization.

In summary, the agency has established a decision-making framework encompassing strategic planning, budgeting, project selection, and prioritization. To improve these processes, the research suggests incorporating more automated applications. The agency recognizes the importance of fiscal planning, development of alternatives, project selection, and resource allocation. Additionally, stages such as performance evaluation and monitoring, program optimization, performance-based budgeting, program delivery, project implementation, and auditing are acknowledged, albeit with a somewhat lower level of importance. By focusing on these stages and considering automation, the agency

can enhance the efficiency, accuracy, and overall effectiveness of its decision-making processes.

#### **4.2.5. OPERATIONAL PLANNING**

The research findings emphasize the significance of operational planning in the context of emergency maintenance for roads and road-related facilities. Emergency maintenance refers to the actions taken to restore damaged road infrastructure caused by accidents or natural events.

A key aspect highlighted by the research is the unpredictable nature of emergencies. It is impossible to predict when accidents or natural disasters will occur and result in damage to the road infrastructure. Consequently, emergency maintenance requires immediate response to address the situation promptly and restore the affected areas to their normal functioning state.

Operational planning is crucial for effective emergency maintenance. It involves developing strategies, procedures, and protocols to guide the response and repair efforts during emergency situations. Operational planning takes into account factors such as resource allocation, coordination of personnel and equipment, communication protocols, and mobilization of necessary resources.

During emergency maintenance, time is of the essence. Swift response and efficient deployment of resources are vital to minimize disruptions, ensure public safety, and restore normal traffic flow. Operational planning ensures that the necessary steps and actions are predetermined, enabling a rapid and coordinated response.

The research underscores the urgency and immediate nature of emergency maintenance. Accidents or natural disasters can cause significant damage to road infrastructure, impairing transportation and posing risks to users. By promptly initiating emergency maintenance, authorities can mitigate these risks and expedite the restoration of affected areas.

In conclusion, operational planning plays a crucial role in emergency maintenance for roads and road-related facilities. Since emergencies are unforeseeable, immediate action is required to restore normal operating conditions. Operational planning involves the development of strategies, procedures, and protocols to guide response efforts and

facilitate a swift and coordinated response. By prioritizing emergency maintenance and implementing effective operational planning, authorities can minimize disruptions, enhance public safety, and promptly restore the road infrastructure.

The research findings indicate that the agency relies on data assessment to measure the dimension of operational planning. The agency collects data from various sources, and this data assessment process is particularly highlighted in situations involving heavy rain, where the agency aims to gather relevant information for operational planning.

Data assessment involves collecting information from two primary sources: the community and experts. Gathering community input is crucial for operational planning as it provides valuable insights, feedback, and observations from individuals who directly interact with and utilize the road infrastructure. This community input helps the agency understand the specific needs and challenges faced during heavy rain, such as flooding or road hazards. By incorporating community perspectives, the agency can better tailor its operational plans to address these specific needs.

In addition to community input, the agency also relies on the expertise of specialists and professionals. These experts possess specialized knowledge and experience related to road infrastructure and heavy rain situations. Their insights and advice are essential in understanding the potential impacts of heavy rain on roads and identifying appropriate measures for operational planning. Experts may provide technical guidance, recommend specific actions or interventions, and share best practices based on their knowledge and expertise.

The data collector plays a key role in the operational planning process by gathering and compiling the necessary data for decision-making. During heavy rain situations, the data collector focuses on collecting data that is particularly relevant to this weather condition. This can include information on rainfall patterns, flood-prone areas, historical data on road damage during heavy rain, and other relevant factors. This data serves as a foundation for assessing risks, identifying vulnerable areas, and determining appropriate strategies for operational planning and response.

By combining information from the community and the expertise of specialists, the agency can develop more comprehensive and informed operational plans. This approach ensures

that the agency considers both the needs and perspectives of the community and the technical insights provided by experts. By incorporating diverse sources of data, the agency can make more effective decisions and implement appropriate measures to address the challenges posed by heavy rain and minimize disruptions to road infrastructure.

The research findings indicate that the agency engages in operational planning for day-to-day maintenance activities, particularly focusing on minor or routine tasks such as clearing roads or structures. This planning process involves scheduling and organizing resources and personnel to carry out these maintenance activities efficiently and effectively.

Additionally, the research highlights the development of an emergency response plan specifically for major asphalt roads. This plan is designed to address and manage emergency situations that may occur on these roads, such as accidents, severe weather events, or other incidents requiring immediate action. The emergency response plan likely outlines protocols and procedures to be followed in such situations, ensuring a coordinated and timely response to mitigate risks and restore normal conditions.

However, the research identifies a potential gap in the operational planning process, which is the inadequate consideration of stakeholder needs. Stakeholders can include residents, businesses, commuters, and other entities directly or indirectly affected by maintenance activities and emergency responses. Their perspectives, concerns, and expectations should be taken into account to ensure that the planning process aligns with their needs and priorities.

Considering stakeholder needs in operational planning is crucial for several reasons. First, it helps to ensure that maintenance activities and emergency response plans are tailored to address the specific challenges and requirements of the community. By understanding stakeholders' perspectives, the agency can make informed decisions that prioritize their safety, convenience, and overall satisfaction.

Furthermore, incorporating stakeholder input enhances transparency and accountability. Engaging stakeholders in the planning process allows for open communication, fostering trust and understanding between the agency and the community. It also enables stakeholders to provide valuable feedback and suggestions, which can lead to more effective and efficient maintenance activities and emergency responses.

To address this gap, the research suggests that stakeholders and their needs should be included in the operational planning process. This can be achieved through various means, such as conducting surveys, holding public consultations or meetings, and actively seeking feedback from the community. By involving stakeholders in the planning process, the agency can gain valuable insights, identify potential issues or concerns, and ensure that maintenance activities and emergency response plans align with the expectations and priorities of the community.

In conclusion, while the agency engages in operational planning for day-to-day maintenance activities and has developed an emergency response plan for major asphalt roads, the research highlights the need to adequately consider stakeholder needs in the planning process. By incorporating stakeholder perspectives and expectations, the agency can enhance the inclusivity, effectiveness, and community-centered nature of maintenance activities and emergency responses.

#### **4.2.6. MAINTENANCE PLANNING**

Research findings indicate that road maintenance planning involves three types of maintenance works: routine, preventive, and periodic. Each type serves a specific purpose in monitoring and addressing defects and damage to ensure the optimal condition of the road network.

1. **Routine Maintenance:** Routine maintenance involves daily inspections of various road elements, such as pavement, slopes, drainage systems, bridges, and other structures and facilities. The goal is to identify any defects or damage and promptly report them to the operation office. Depending on the severity, follow-up maintenance works are undertaken throughout the year or at specific intervals. Routine maintenance helps monitor the road network's condition, detect problems early on, and take appropriate actions to prevent further deterioration.

2. **Preventive Maintenance:** Preventive maintenance refers to repair activities that target the underlying causes of deterioration, aiming to prevent costly rehabilitation work in the future. It focuses on addressing issues that could lead to more significant damage or degradation if left unattended. By proactively tackling these causes, preventive

maintenance extends the lifespan of the road infrastructure and reduces the need for major repairs or reconstruction.

3. **Periodic Maintenance:** Periodic maintenance involves detailed inspections performed at specific intervals, such as seasonal or yearly, depending on the road facilities' type and nature. This type of maintenance includes comprehensive checking and testing of various structures and facilities to assess their condition. Defects and damages identified during the inspections are reported for repairs or other necessary remedies. Maintenance plans covering multiple years are developed based on the findings from periodic inspections. These plans outline the maintenance activities to be carried out over a specified period, ensuring the systematic and timely upkeep of the road infrastructure.

By implementing a combination of routine, preventive, and periodic maintenance, road authorities can effectively monitor and manage the condition of their road networks. Routine inspections allow for the identification of immediate issues, while preventive maintenance addresses the underlying causes of deterioration. Periodic inspections provide a more detailed assessment, leading to the development of long-term maintenance plans.

Overall, maintenance planning plays a crucial role in preserving and extending the lifespan of road infrastructure. It ensures the safety and functionality of the roads, reduces the need for costly repairs, and enhances the overall quality of transportation networks. By employing a comprehensive maintenance approach, road authorities can optimize the condition of their road networks and provide better experiences for road users.

The research results indicate that the dimension of maintenance planning was measured by examining the data used and the indicators of planning methods. The agency utilizes a variety of data sources to facilitate maintenance planning activities, considering factors that are crucial for making informed decisions regarding asset maintenance and resource allocation.

The data used in maintenance planning encompasses several categories that provide valuable insights. The condition of the asset is an essential factor, as it allows the agency to assess the current state and quality of the road infrastructure or other facilities undergoing maintenance. This information helps in evaluating deterioration levels, identifying potential issues, and determining appropriate maintenance actions. Additionally,

understanding the specific types of deterioration present is important, as each type may require specific maintenance approaches or interventions.

Maintenance planning also requires an understanding of the maintenance activities needed to address identified deterioration or defects. Analyzing these maintenance requirements enables the agency to define the scope of work, such as repairs, replacements, or upgrades, and allocate the necessary resources of materials, equipment, and labor accordingly. The available budget is a crucial factor in decision-making, as it determines the feasibility of various maintenance options and helps prioritize projects based on financial constraints.

The research emphasizes the importance of considering community interest in maintenance planning. Taking into account the preferences, concerns, and priorities of the community ensures that the agency's maintenance planning aligns with the needs and expectations of the public. This community input enhances transparency, accountability, and overall public satisfaction with the maintenance activities carried out.

Furthermore, analyzing previous maintenance history provides valuable insights into past actions, outcomes, and the effectiveness of maintenance approaches. Reviewing this history allows the agency to assess the performance of previous maintenance activities, identify trends, and make informed decisions for future planning.

However, the research suggests that additional data is needed to further enhance maintenance planning. Factors such as traffic volume, road usage patterns, environmental considerations, and technological advancements should be incorporated. Traffic volume and road usage patterns provide crucial information about the intensity and types of vehicles utilizing the road infrastructure, enabling the agency to anticipate wear and tear and plan appropriate maintenance interventions. Environmental factors, including weather conditions and geological considerations, play a significant role in asset deterioration and maintenance planning. Technological advancements offer opportunities to leverage innovative tools and techniques for more efficient and effective maintenance practices.

By incorporating these additional data categories, the agency can develop more comprehensive and robust maintenance plans. Traffic volume and road usage patterns allow for better anticipation of maintenance needs, while environmental factors help account for external influences on asset deterioration. Technological advancements can

provide insights into emerging maintenance approaches, enabling the agency to adopt more advanced and sustainable practices.

In conclusion, while the agency currently uses various data sources for maintenance planning, the research highlights the need to incorporate additional factors such as traffic volume, road usage patterns, environmental considerations, and technological advancements. By integrating these data categories, the agency can further enhance its maintenance planning processes, leading to more informed decision-making, improved resource allocation, and ultimately, better management of road infrastructure assets.

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By incorporating these additional data categories, the agency can develop more comprehensive and robust maintenance plans. Traffic volume and road usage patterns allow for better anticipation of maintenance needs, while environmental factors help account for external influences on asset deterioration. Technological advancements can provide insights into emerging maintenance approaches, enabling the agency to adopt more advanced and sustainable practices.

In conclusion, while the agency currently uses various data sources for maintenance planning, the research highlights the need to incorporate additional factors such as traffic volume, road usage patterns, environmental considerations, and technological advancements. By integrating these data categories, the agency can further enhance its maintenance planning processes, leading to more informed decision-making, improved resource allocation, and ultimately, better management of road infrastructure assets.

The research findings indicate that governments face the challenge of allocating limited resources for infrastructure development, particularly considering the projected financing gaps in the future. To aid in this decision-making process, governments can rely on social

cost-benefit analysis (SCBA) as a robust tool for evaluating infrastructure projects and establishing priorities.

SCBA involves assessing the costs and benefits of projects from a societal perspective, taking into account both the economic and social impacts. This comprehensive analysis provides policymakers with a thorough evaluation of the potential outcomes associated with each project. By quantifying and comparing the monetary and non-monetary benefits against the costs incurred, SCBA enables informed decision-making.

When systematically applied, SCBA serves as the basis for prioritizing projects. By assigning a value to the social benefits and costs associated with each project, governments can rank them based on their expected net benefits. This prioritization ensures that resources are allocated to projects that offer the greatest overall social welfare, maximizing the return on investment.

However, it is important to acknowledge that conducting extensive economic analyses for every project in a comprehensive manner may not always be immediately feasible due to capacity and resource limitations. Governments may face constraints such as a lack of technical expertise, time constraints, or limited financial resources required for conducting thorough economic evaluations for all projects.

In such situations, governments may need to adopt alternative approaches to decision-making. These approaches could involve using simplified assessments or focusing on key projects that are of strategic importance or have significant potential impacts. While these alternatives may provide a more expedient way of prioritizing projects, they may not capture the full range of economic and social benefits that could be considered through a comprehensive SCBA.

It is important for governments to recognize the limitations imposed by capacity and resource constraints and work towards building the necessary capabilities over time to conduct more extensive economic analyses across their full project sets. This will enable a more informed and rigorous approach to infrastructure project prioritization, ensuring that resources are allocated to projects that offer the greatest overall societal benefits and contribute to long-term sustainable development.

The evaluation of the dimension of Capital Road project works Planning focused on analyzing the data used and the indicators of the planning approach. The research findings highlight the importance of considering various factors and gathering information from multiple sources to ensure comprehensive planning for capital road projects.

Community interest is a crucial aspect of capital road project planning. Engaging with the local community and understanding their needs, preferences, and concerns is essential. By incorporating community perspectives into the planning process, decision-makers can ensure that the proposed road projects align with the expectations and requirements of the affected people. This approach promotes transparency, accountability, and public acceptance of the projects.

Feasibility studies play a vital role in the planning process by evaluating the technical, economic, legal, and environmental aspects of the proposed road projects. These studies provide valuable insights into the viability and potential impacts of the projects, helping decision-makers assess their feasibility and desirability. Feasibility studies also identify potential risks or challenges that need to be addressed during planning and implementation.

Estimating the cost of the project is another critical factor in the planning process. Decision-makers need to determine the financial requirements of the road projects to assess their affordability and financial feasibility. Cost estimation includes various components such as construction, materials, labor, land acquisition, and associated infrastructure. Understanding the anticipated costs allows for effective budgeting and resource allocation.

Demand modeling is an essential tool used in road project planning. It involves analyzing current and projected transportation patterns, traffic flows, and user demand. By considering factors such as population growth, urban development, and transportation trends, decision-makers can anticipate future demand for road infrastructure. This information helps design road projects that can accommodate the anticipated traffic volume and meet user needs.

The availability of funding is a crucial consideration in the planning process. Identifying potential funding sources and exploring various options allows decision-makers to assess the financial feasibility of implementing the road projects. This may involve government funding programs, public-private partnerships, toll revenues, or other financing

mechanisms. Considering these options helps identify the most viable funding sources and develop a realistic financial plan.

In conclusion, the research findings emphasize that capital road project planning involves considering multiple perspectives and gathering information from various sources. Community interest, feasibility studies, project costs, demand modeling, and funding options all play significant roles in the planning process. By incorporating these factors, decision-makers can ensure that road projects align with community needs, are financially viable, and can meet future transportation demands.

#### **4.2.7. CAPITAL WORK PLANNING**

The evaluation of the dimension of Capital road project works Planning focused on analyzing the data used and the indicators of the planning approach. The research findings highlight the importance of considering various factors and gathering information from multiple sources to ensure comprehensive planning for capital road projects.

Community interest is a crucial aspect of capital road project planning. Engaging with the local community and understanding their needs, preferences, and concerns is essential. By incorporating community perspectives into the planning process, decision-makers can ensure that the proposed road projects align with the expectations and requirements of the affected people. This approach promotes transparency, accountability, and public acceptance of the projects.

Feasibility studies play a vital role in the planning process by evaluating the technical, economic, legal, and environmental aspects of the proposed road projects. These studies provide valuable insights into the viability and potential impacts of the projects, helping decision-makers assess their feasibility and desirability. Feasibility studies also identify potential risks or challenges that need to be addressed during planning and implementation.

Estimating the cost of the project is another critical factor in the planning process. Decision-makers need to determine the financial requirements of the road projects to assess their affordability and financial feasibility. Cost estimation includes various components such as construction, materials, labor, land acquisition, and associated infrastructure. Understanding the anticipated costs allows for effective budgeting and resource allocation.

Demand modeling is an essential tool used in road project planning. It involves analyzing current and projected transportation patterns, traffic flows, and user demand. By considering factors such as population growth, urban development, and transportation trends, decision-makers can anticipate future demand for road infrastructure. This information helps design road projects that can accommodate the anticipated traffic volume and meet user needs.

The availability of funding is a crucial consideration in the planning process. Identifying potential funding sources and exploring various options allows decision-makers to assess the financial feasibility of implementing the road projects. This may involve government funding programs, public-private partnerships, toll revenues, or other financing mechanisms. Considering these options helps identify the most viable funding sources and develop a realistic financial plan.

In conclusion, the research findings emphasize that capital road project planning involves considering multiple perspectives and gathering information from various sources. Community interest, feasibility studies, project costs, demand modeling, and funding options all play significant roles in the planning process. By incorporating these factors, decision-makers can ensure that road projects align with community needs, are financially viable, and can meet future transportation demands.

#### **4.2.8. INFORMATION SYSTEM**

The discussion on the theme of Information Systems revolves around three key aspects: ICT infrastructure/Technology, Performance, Estimating and costing, and Planning and scheduling.

Regarding ICT infrastructure/Technology, the research findings reveal that the investigated agency lacks a dedicated Information and Communication Technology (ICT) infrastructure and an asset register. Instead, individual experts within the agency rely on their personal computers to record the core attributes of road assets. This indicates a lack of centralized systems or databases for effectively managing and tracking the agency's road assets.

The agency heavily relies on manual systems and Excel spreadsheets to generate reports related to valuation and renewal forecasting. This suggests that the assessment of the value

of road assets and the forecasting of their renewal needs are primarily carried out manually, without the support of specialized software or automated systems.

The absence of an ICT infrastructure and asset register poses several challenges for the agency. Without a centralized system, maintaining up-to-date and accurate records of road assets becomes difficult. Information may be scattered across different devices, hindering access and sharing of critical data. This decentralization can lead to inconsistencies, data duplication, and inefficiencies in asset management.

Moreover, relying on manual systems and spreadsheets for valuation and renewal forecasting reports introduces the risk of errors and inconsistencies in the data. Manual data entry is prone to human errors, and spreadsheet-based solutions may lack robust data validation and verification mechanisms. These limitations can affect the reliability and accuracy of reports, potentially impacting decision-making related to asset management, budgeting, and planning for road asset renewals.

To address these limitations, it is recommended that the agency invest in establishing an ICT infrastructure and an asset register. This would involve implementing a centralized database or asset management system capable of efficiently capturing, storing, and managing the core attributes of road assets. Such a system would provide a comprehensive view of the agency's assets, facilitate data sharing and collaboration among staff, and improve the accuracy and reliability of asset-related reports.

Additionally, transitioning from manual systems and spreadsheets to dedicated software solutions for valuation and renewal forecasting would enhance efficiency, reduce errors, and offer more robust data analysis capabilities. These software solutions can automate calculations, facilitate data validation, and generate accurate reports, enabling the agency to make informed decisions regarding asset valuation and renewal planning.

In conclusion, the research findings emphasize the limitations in the agency's ICT infrastructure, asset management practices, and reporting systems. Overcoming these limitations through the implementation of suitable ICT solutions and standardized asset management processes can significantly enhance the agency's ability to effectively manage and maintain its road assets.

### Estimating and Costing Performance:

According to the research findings, the agency utilizes a replacement cost approach to estimate the value of its assets. This approach involves determining the cost of replacing an asset with a new one that has similar utility and functionality. The agency calculates the estimated value of the asset based on its replacement cost using the current unit rate.

Furthermore, the agency determines the depreciated value of the asset by taking into account the asset's age and the extent of deterioration. This indicates that the agency considers the lifespan of the asset and the level of wear and tear to estimate its current value. However, it is worth noting that there is a lack of comprehensive documentation regarding the asset's maintenance, repairs, and previous valuations, as historical information is not recorded in a database.

The research findings also highlight that the agency relies on simple formulas within an Excel sheet for asset valuation instead of utilizing modern methods or systems. This suggests that the estimation process may lack sophistication and advanced modeling techniques that could provide more accurate and comprehensive asset valuations.

Using simple formulas in an Excel sheet can limit the agency's ability to account for various factors that can impact asset values, such as market trends, technological advancements, or changes in demand. It may also restrict the agency from conducting scenario analysis or considering alternative valuation methods that could yield more robust and insightful results.

To improve the estimation of asset values, it is recommended that the agency considers implementing modern methods and systems specifically designed for asset valuation and forecasting. These systems can incorporate advanced modeling techniques, track historical data, and maintain comprehensive databases to enhance the accuracy and reliability of asset valuation estimates. By leveraging such tools, the agency can make more informed decisions regarding asset management, budgeting, and future planning.

In summary, the research findings highlight the agency's reliance on a replacement cost approach and simple formulas in Excel for asset valuation. The lack of historical asset information and the absence of modern valuation methods and systems indicate areas for improvement in the agency's asset estimation practices. Implementing advanced tools and

capturing comprehensive asset data can contribute to more accurate and informed decision-making

### **4.3. Developed Database models**

In this phase, a systematic methodology was employed to design and create an infrastructure geodatabase. The driving factors behind this process were the identification of gaps in infrastructure asset management practices and a thorough analysis of requirements. The following sections will outline the specific steps taken to design and develop the infrastructure geodatabase, emphasizing the important factors considered and decisions made along the way. The results obtained from this process will also be presented in detail.

#### **4.3.1. CONCEPTUAL DATABASE MODEL:**

In the conceptual database model, the primary focus is on identifying and defining the entities involved in efficient asset management for a specific infrastructure and utility data. These entities are essential components of the system and serve as the building blocks for organizing and representing the data. Examples of these entities include Road, Median, Drainage, Electric Pole, Electric Line, Water Distribution Line, Water Transmission Line, Reservoir, Walkway Line, Transformer, Bridge, and Administrative Building.

The conceptual model also determines the relationships and associations between these entities. For instance, a Road entity may have relationships with other entities like Median, Drainage, and Bridge, indicating their interconnectedness within the system. These relationships help establish the logical connections and dependencies among different entities.

Moreover, attributes or properties are defined for each entity to capture relevant information. These attributes provide specific details about each entity, such as its location, condition assessments, capacity, and other pertinent data. By defining the attributes, the conceptual model ensures that the necessary information is stored and associated with each entity.

Overall, the conceptual database model offers a high-level representation of the spatial database model, outlining the entities, relationships, and attributes necessary for efficient asset management in the given context.

#### **4.3.2. LOGICAL DATABASE MODEL:**

The logical database model involves the translation of the conceptual model into a relational database design suitable for implementation within the ArcGIS and PostgreSQL/PostGIS software. It focuses on creating a structured framework that can effectively store and manage the data related to the infrastructure and utility assets.

In the logical model, the entities, relationships, and attributes identified in the conceptual model are mapped to tables, columns, and relationships in the relational database. Each entity becomes a table, and the attributes associated with the entities become the columns within those tables. This mapping process ensures that the data is organized in a structured manner, facilitating efficient data retrieval and manipulation.

To maintain data integrity and enable efficient data retrieval, primary keys are determined for each table. Primary keys ensure the uniqueness of each record within a table, enabling easy identification and referencing of specific data entries.

The relationships between tables are established using foreign keys, which represent the associations between related entities. By linking tables through foreign keys, the logical model establishes the connections between different entities in the database, enabling efficient retrieval of related information.

Normalization techniques are applied to the tables to eliminate redundancy and ensure data integrity. By organizing the data into separate tables and eliminating redundant information, the logical model optimizes data storage and minimizes the chances of inconsistencies or anomalies in the database.

Furthermore, appropriate data types and constraints are defined for each column in the tables. Data types specify the format and type of data that can be stored in a particular column, ensuring consistency and accuracy. Constraints, such as unique constraints or data validation rules, are applied to enforce specific rules or conditions on the data stored in the columns, ensuring data quality and validity.

In summary, the logical database model transforms the conceptual model into a structured and organized relational database design. It maps entities to tables, attributes to columns, and establishes relationships between tables using primary and foreign keys. By following principles of normalization and defining appropriate data types and constraints, the logical

model ensures data integrity and facilitates efficient data retrieval and management within the ArcGIS and PostgreSQL/PostGIS software.

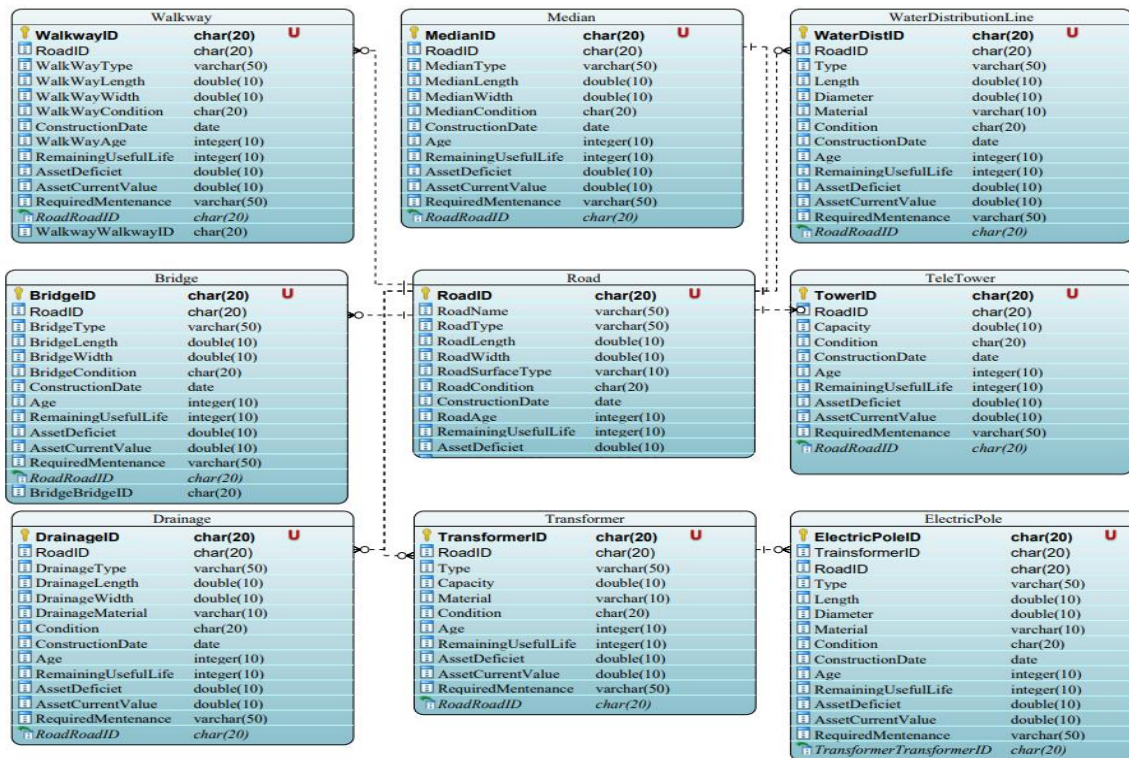


Figure 4.2 Logical database Model

The presented logical diagram provides a visual representation of the relationships between multiple tables within the context of road infrastructure management. It highlights the connections and associations between the road table and other relevant tables in the database.

Specifically, the road table exhibits a one-to-many relationship with the water distribution table. This relationship implies that a single road can be associated with multiple water distribution records, while each water distribution record is linked to only one road. This association is established using the road ID as the key, which acts as a unique identifier for each road and facilitates the relationship between the two tables.

Similarly, the road table demonstrates one-to-many relationships with the walkway, drainage line, and transformer tables. This indicates that a road can have multiple walkways, drainage line, and transformer records associated with it, while each of these records is connected to only one road. Once again, these relationships are established based

on the road ID as the common identifier, enabling the tables to be linked together effectively.

Additionally, the road table is connected to the median table through a one-to-one relationship. This means that each road record corresponds to one median record, and vice versa. The road ID serves as the identifier that connects the road and median tables, ensuring the accuracy and uniqueness of the relationship.

To summarize, the logical diagram provides a clear overview of how the road table connects with other tables in the database. It demonstrates that the road table has various types of relationships, such as one-to-many and one-to-one, with the water distribution, walkway, drainage line, transformer, and median tables. These relationships are established using the road ID as the key, allowing for efficient data retrieval and management within the road infrastructure management system.

#### **4.3.3. PHYSICAL DATABASE MODEL**

The physical database model encompasses the conversion of the logical database design into a concrete implementation that is well-suited for the ArcGIS and PostgreSQL/PostGIS software. This transformation takes into account the specific requirements of the target database management system (DBMS) and ensures optimal storage and retrieval of spatial data.

To achieve efficient storage and retrieval, the physical model carefully determines the appropriate storage structures and access methods. These decisions are made by considering the capabilities and features provided by PostgreSQL/PostGIS. For instance, the model takes advantage of the spatial indexing capabilities offered by the DBMS. This involves selecting and defining suitable indexing strategies, such as spatial indexes or R-tree indexes, which are specifically designed to enhance the performance of querying spatial data. By implementing these indexing techniques, the physical model optimizes the speed and efficiency of spatial data retrieval operations.

Additionally, the physical model configures the database to fully support the spatial data types and spatial functions provided by PostgreSQL/PostGIS. This ensures compatibility and enables seamless manipulation and analysis of spatial data within the database. By

leveraging the spatial data capabilities of the DBMS, the physical model facilitates effective handling of spatial data, allowing for advanced spatial operations and analysis.

Furthermore, the physical model considers performance optimization techniques to enhance the efficiency of spatial data storage and retrieval operations in the ArcGIS and PostgreSQL/PostGIS environment. Techniques such as partitioning and clustering are evaluated and implemented as needed. Partitioning involves dividing the database into smaller, more manageable segments, which can improve query performance by enabling parallel processing and reducing the volume of data accessed. Clustering techniques are employed to physically organize related data together, optimizing data locality and minimizing disk input/output (I/O) operations. By employing these performance optimization techniques, the physical model enhances the overall efficiency of spatial data storage and retrieval operations.

In summary, the physical database model translates the logical database design into a tangible implementation that suits the requirements of the ArcGIS and PostgreSQL/PostGIS software. It considers the specific capabilities of the target DBMS and determines appropriate storage structures, access methods, and indexing strategies to optimize the storage and retrieval of spatial data. The model configures the database to support spatial data types and functions, enabling efficient manipulation and analysis. Performance optimization techniques, such as partitioning and clustering, are also applied to maximize the efficiency of spatial data operations within the ArcGIS and PostgreSQL/PostGIS environment.

The image shows five stacked table windows in ArcGIS, each representing a different infrastructure feature class. Each window has a title bar, a toolbar with icons for navigation and selection, a header row with field names, and a data row showing a single record selected.

FID	Shape *	OBJECTID	Road_ID	Walkway_ID	Shape_Leng	OBJECTID_1	Left_Kerbi	Right_Kerb	Owner	Road
1										

(0 out of 910 Selected)

X_Coord_St	X_Coord_En	Y_Coord_En	Y_Coord_St	Locality_N	Pipe_Lin_3	Condition_	Constructi
1							

(0 out of 1118 Selected)

FID	Shape *	OBJECTID	Road_ID	Shape_Leng	OBJECTID_1	RouteID	Constructi	Maintenanc	Condition	Dra
1										

(0 out of 2070 Selected)

FID	Shape *	OBJECTID	Name	Road_ID	Median_ID	Shape_Leng	OBJECTID_1	NodeFrom	NodeTo	Lengt
1										

(0 out of 376 Selected)

FID	Shape *	OBJECTID_1	Road_ID	Shape_Leng	OBJECTID	RouteID	Road_Bridg	Left_kerbi	Right_Kerb	Roa
1										

(0 out of 12827 Selected)

Fig4.3 Sample Infrastructure tables Implemented in ArcGIS

The figure presented depicts the tangible implementation of a logical database within the ArcGIS software. It showcases a geodatabase schema designed specifically for managing spatial data related to road infrastructure. The schema comprises several feature classes, namely Road Centerline, Median Centerline, Drainage Line, Water Distribution Line, and Walkway Line.

This physical database implementation leverages the geodatabase schema to effectively organize and store spatial data pertaining to the road network. The Road Centerline feature class stores information about the geometry and attributes of roads, specifically focusing on their centerlines. Similarly, the Median Centerline feature class is responsible for storing data related to the geometry and attributes of medians located within the road

network. The Drainage Line feature class holds details about the geometry and attributes of drainage lines associated with the road infrastructure.

To facilitate the management of water supply along the roads, the Water Distribution Line feature class is used to store spatial data specific to distribution lines. It captures information about the geometry and other attributes relevant to water distribution infrastructure. Lastly, the Walkway Line feature class captures information about the geometry and attributes of walkways or pedestrian paths integrated with the road infrastructure.

By implementing this physical database structure within the ArcGIS software, users gain the ability to efficiently manage and analyze spatial data related to road networks, medians, drainage lines, water distribution lines, and walkways. The database structure enables effective storage, retrieval, querying, and visualization of geospatial information. This, in turn, facilitates various geospatial analyses and supports decision-making processes within the domain of road infrastructure management. Users can leverage the database to perform tasks such as analyzing road conditions, identifying maintenance needs, assessing pedestrian accessibility, and planning infrastructure improvements, ultimately enhancing the efficiency and effectiveness of road infrastructure management initiatives.

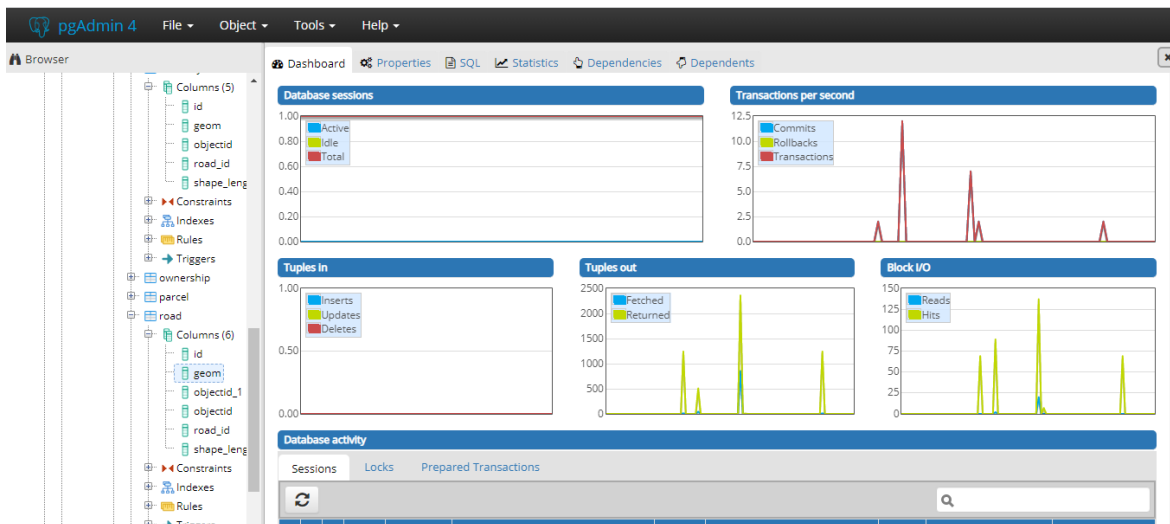


Fig4.4 Physical Geodatabase Implementation in postgresql database

The presented figure showcases the utilization of PostgreSQL, a spatial database management software, along with the PostGIS extension for storing infrastructure data in a spatial database.

This combination of technologies enables an efficient approach to managing spatial data and facilitates smooth integration with a web GIS application as the backend server database.

By employing PostgreSQL as the spatial database management software, infrastructure data can be effectively organized and stored in a structured manner, ensuring efficient data management practices. The inclusion of the PostGIS extension further enhances the capabilities of PostgreSQL, enabling the storage, retrieval, and analysis of spatial data within the database. The extension provides valuable functionalities such as spatial indexing, spatial functions, and spatial query optimization, making PostgreSQL well-suited for handling geospatial data.

The integration of PostgreSQL with the web GIS application as the backend server database establishes a seamless connection, allowing the application to efficiently access and retrieve infrastructure data. Leveraging the spatial functionalities provided by PostGIS, the web GIS application can perform comprehensive spatial analyses, generate maps, and present infrastructure information in a user-friendly manner.

#### **4.4. WEBGIS based Infrastructure Asset Management**

In this section, the research result introduces the process of publishing infrastructure asset information on the web. The entire workflow, starting from map preparation in QGIS to parameter setting in QGIS Web 2 and ultimately publishing the web map on the GITHUB server, is thoroughly illustrated and discussed.

The first step involves map preparation in QGIS, where the researchers carefully organize and arrange the infrastructure asset information. This includes selecting and configuring the relevant layers, applying appropriate symbology, and ensuring the accuracy and completeness of the data.

Following the map preparation phase, the parameter setting in QGIS Web 2 is carried out. The researchers configure the necessary settings and options in QGIS Web 2, a web mapping platform, to enable the seamless transfer and display of the prepared map on the web. This step ensures that the map is compatible with web-based environments and can be accessed by users through a web browser.

Once the map is prepared and the parameters are set, the next stage involves preparing the web map for publication. The researchers employ various techniques and tools to optimize the web map's performance and user experience. This may include optimizing the map's loading speed, enabling interactive features, and ensuring the map's responsiveness on different devices and screen sizes.

Finally, the research result highlights the process of publishing the web map on the GITHUB server. GITHUB, a widely used web-based hosting service, allows for the seamless sharing and dissemination of the prepared web map. By publishing the map on the GITHUB server, the researchers make it accessible to a wider audience, facilitating easy exploration and utilization of the infrastructure asset information.

Overall, this research result provides a comprehensive overview of the step-by-step process involved in publishing infrastructure asset information on the web. The combination of map preparation in QGIS, parameter setting in QGIS Web 2, web map preparation, and publishing on the GITHUB server ensures the effective dissemination and accessibility of the infrastructure asset data.

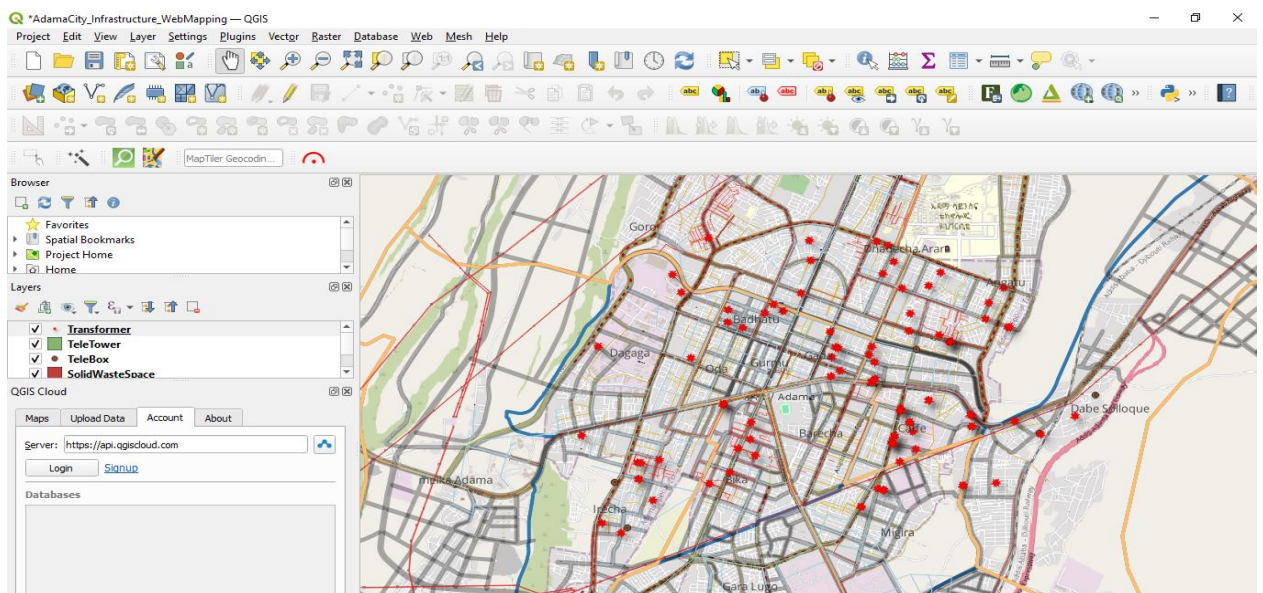


Figure 4.5 preparations of Infrastructure and utility map on QGIS

The research result showcases the process of generating a comprehensive map of the infrastructure and utilities in Adama City. The creation of this map involved several steps and tools.

To begin with, the QGIS software was employed as the primary tool for map preparation. The researchers utilized the Quickmap Services Leaflet, a web-based mapping library, as the base map layer. This library offers a user-friendly interface that facilitates the creation of interactive maps.

Next, the symbology and colors of the map elements were adjusted to ensure both visual appeal and ease of interpretation. The representation of various infrastructure and utility features, such as roads, water pipes, power lines, and more, was carefully depicted using appropriate symbols and colors. This meticulous selection and application of symbols and colors aimed to enhance the clarity and comprehensibility of the map.

Overall, Figure 4.5 provides a detailed illustration of the step-by-step process involved in creating a map that accurately portrays the infrastructure and utilities of Adama City. The combination of QGIS software, the Quickmap Services Leaflet, and thoughtful symbology adjustments resulted in an informative and visually appealing map representation.

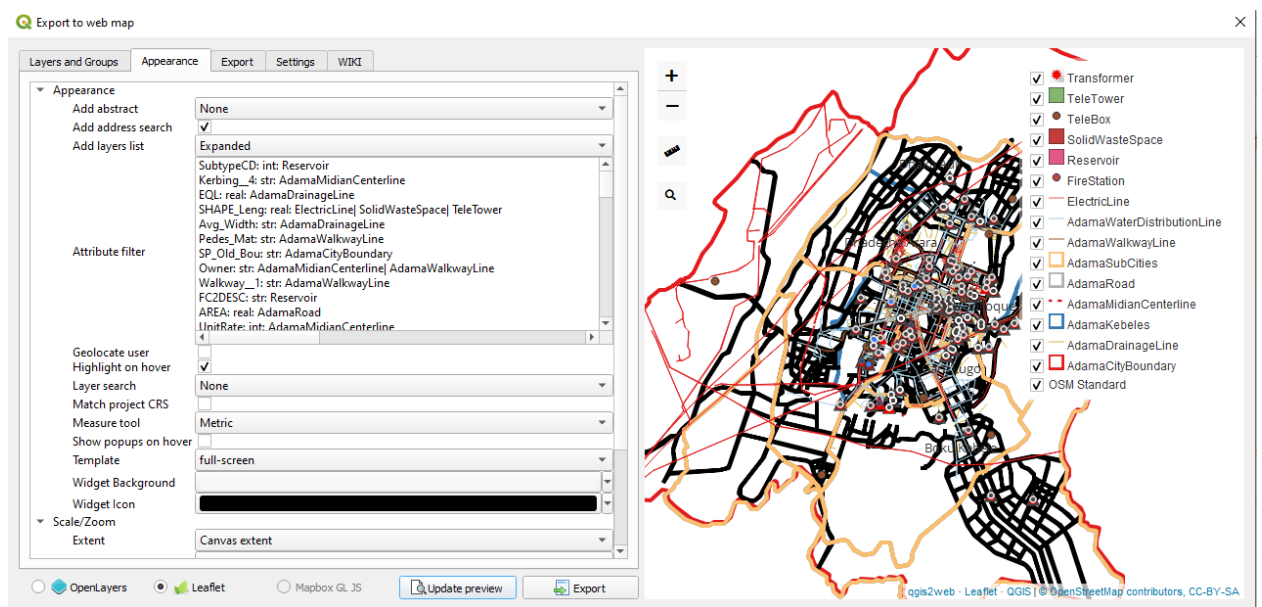


Figure 4.6 Customized infrastructure and utility Informations

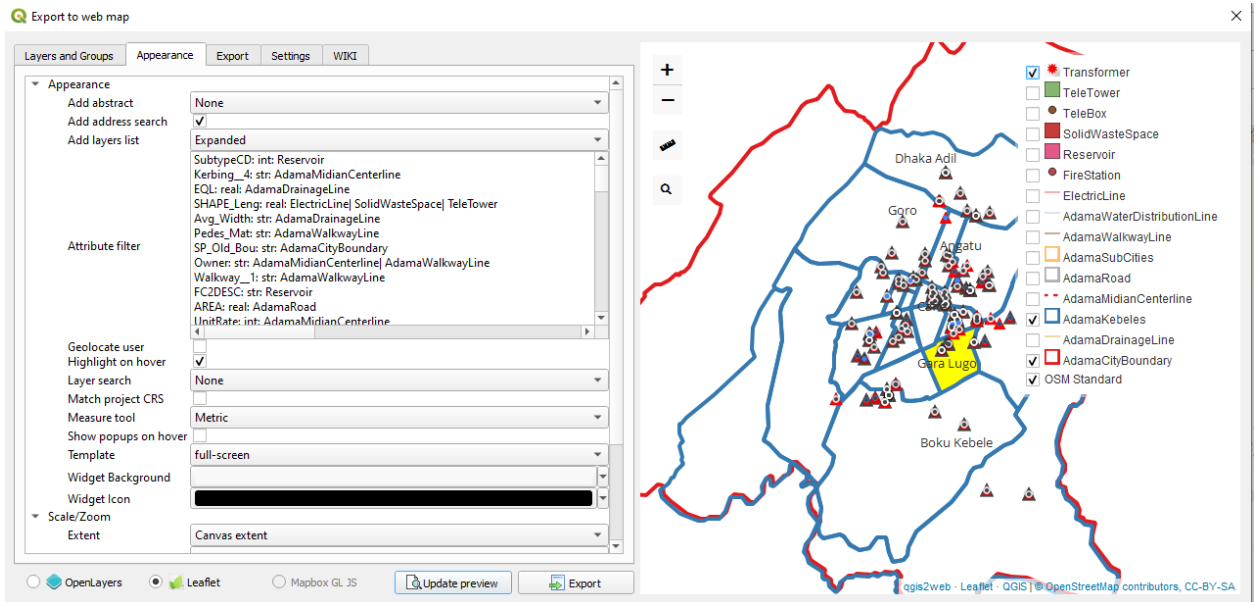


Figure 4.7 Tested functions for web map preparation

In this research result output, the focus is on the customization of specific functions to enhance the functionality and user experience of the web map. The following actions were undertaken:

1. **Layer On/Off Customization:** Customization was performed to enable the toggling of specific layers within the web map. This functionality allows users to turn on or off specific layers based on their preferences or information needs. By providing this capability, users can focus on relevant layers and streamline their exploration of the map.
2. **Layer Labeling Selection:** Another customization involved determining which layers within the web map should be labeled. By selectively choosing which layers to label, the researchers aimed to improve the clarity and readability of the map. This enables users to easily identify and understand the different elements present on the map.
3. **Zoom In, Zoom Out, and Measure Functions:** The web map was enhanced with additional functionalities, such as zoom in, zoom out, and measure functions. These features empower users to closely examine specific areas of interest by zooming in or obtain a broader view by zooming out. Additionally, the measure function enables users to calculate distances or areas on the map, facilitating precise analysis or planning activities.

By customizing these functions within the web map, the researchers aimed to optimize the map's usability and provide users with enhanced control and flexibility in exploring and

interacting with the data. This customization step adds value to the web map by incorporating user-friendly features that improve the overall user experience and facilitate efficient data exploration.

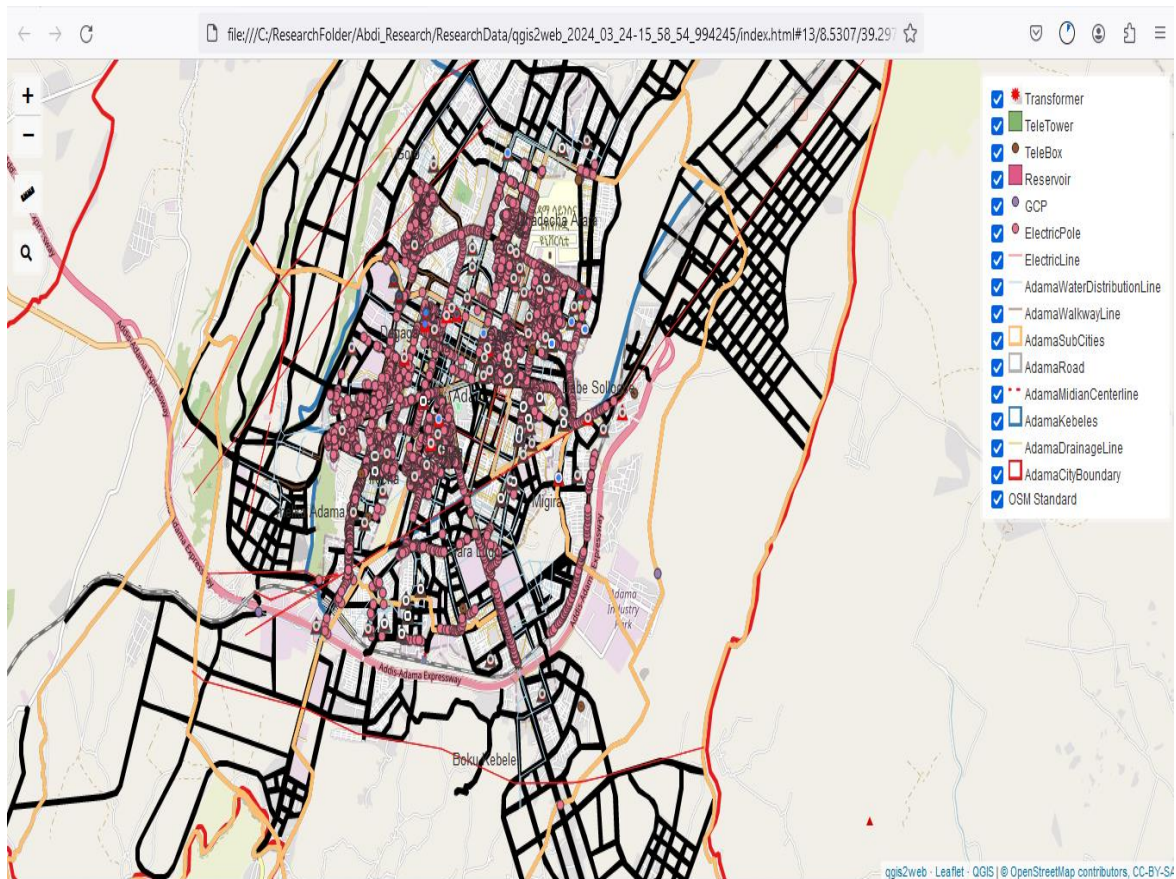


Figure 4.8 Web GIS implementation on local server

Figure 4.8 presented showcases a web GIS application designed specifically to facilitate the sharing of infrastructure asset information with targeted users through the web. This application aims to provide comprehensive data concerning various elements such as roads, walkways, drainage lines, water distribution lines, and medians. The information encompasses spatial locations, length, width, and the condition of these assets.

The researcher responsible for this study employed open-source software tools, specifically Leaflet and PostgreSQL, to develop the aforementioned web GIS application. By harnessing the capabilities of these tools, the researcher successfully created a platform that is both user-friendly and interactive, enabling easy access to infrastructure information.

The significance of this research result lies in its potential to offer a wide range of users, including experts and decision-makers, convenient access to critical infrastructure information. By making this data readily available through the web GIS application, users can gain valuable insights and make well-informed decisions regarding the management and maintenance of infrastructure assets. The accessibility of this information enhances the efficiency and effectiveness of infrastructure planning, monitoring, and decision-making processes, ultimately contributing to the overall improvement of infrastructure management practices.

The web GIS application serves as a valuable resource that empowers users to analyze and visualize infrastructure data, identify trends and patterns, and assess the condition and performance of various assets. This, in turn, enables informed decision-making in areas such as infrastructure investment, maintenance prioritization, and resource allocation. The user-friendly interface and interactive features of the application enhance the usability and adoption of the platform, ensuring that the infrastructure asset information reaches the intended audience effectively.

The effective management of infrastructure assets is a critical component of ensuring the long-term sustainability and resilience of urban centers. In the case of Adama City, Ethiopia, research has revealed significant challenges in the existing infrastructure asset management practices (Tadesse A., 2021; Berhanu T., 2018). These challenges include data fragmentation, limited accessibility, and the need for more comprehensive evaluation and implementation of innovative solutions.

To address these issues, this research explores the development of a spatial geodatabase model and an open-source web-based application to enhance the management of Adama City's infrastructure assets. The geodatabase system consolidates dispersed infrastructure data, enabling better organization, integration, and analysis, ultimately supporting informed decision-making processes (Haas R., 2016; Smith A., 2018).

The web-based application, built using open-source technologies, provide a platform for publishing and sharing infrastructure data with stakeholders and the public (Wondimu G., 2022; Gebremariam S., 2024). This increased transparency and accessibility will foster collaboration, public engagement, and evidence-based decision-making regarding asset maintenance, resource allocation, and infrastructure planning.

The research findings from Adama City will contribute to the broader knowledge base on effective infrastructure asset management practices, providing valuable insights and guidance for other cities facing similar challenges (Tesfaye M., 2019; Seyum D., 2007). By implementing the proposed geodatabase and web-based application, Adama City can enhance its infrastructure asset management capabilities, leading to improved performance, longevity, and sustainability of its critical infrastructure systems.

Overall, this research aims to provide a comprehensive framework for infrastructure asset management in Adama City, Ethiopia, serving as a model for other urban centers facing similar challenges. By bridging the research gap and leveraging innovative technological solutions, this study will contribute to the sustainable and resilient development of Adama City and its infrastructure systems.

## CHAPTER V

### CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

The research findings suggest that there are several areas in the infrastructure asset management systems that require improvement. The assessment results highlight specific aspects such as the inventory system, data storage and management, road condition assessment, decision-making processes, operational planning, maintenance planning, capital works planning, and information systems that need to be addressed for better system performance.

In response to these identified areas of improvement, a geodatabase model was developed as a solution. This model was designed to effectively handle and organize infrastructure and utility information. The model's functionality and efficiency were successfully tested using ArcGIS and Postgresql with Post GIS extension, demonstrating its effectiveness in managing the data related to infrastructure assets.

Furthermore, to enhance accessibility and collaboration, a web GIS application was implemented using the qgis2web plugin of QGIS. This application allowed users to interact with the infrastructure data through a web-based interface. To make the application widely accessible, it was published on GitHub pages, enabling further collaboration and dissemination of the research findings.

Overall, the development of the geodatabase model and the implementation of the web GIS application provide valuable tools for improving the infrastructure asset management system. These tools offer efficient data management and visualization capabilities, facilitating better decision-making and planning processes. The availability of the web GIS application on GitHub pages ensures wider access and promotes collaboration among stakeholders interested in enhancing infrastructure asset management practices.

## **5.2 Recommendation**

Based on the research findings, several recommendations are suggested to enhance the infrastructure asset management system. Firstly, the inventory system should be evaluated and upgraded to ensure comprehensive and precise documentation of infrastructure assets. This may involve adopting advanced data collection techniques like remote sensing or automated inventory management systems. Secondly, exploring advanced database solutions and technologies is advised to improve data storage and management. Considering cloud-based storage options, implementing robust data backup mechanisms, and ensuring data integrity and security are essential steps in this regard.

Furthermore, optimizing the road condition assessment process is crucial by incorporating advanced technologies such as remote sensing, machine learning, or predictive analytics. These tools can provide real-time updates on road conditions, facilitating proactive maintenance and decision-making. Integrating data-driven decision-making and operational planning into the infrastructure asset management system is also recommended. This can be achieved through the implementation of analytical models or decision support systems that consider factors such as asset condition, budget constraints, and performance indicators.

Moreover, refining maintenance and capital works planning requires the implementation of a comprehensive asset management strategy. This strategy should prioritize investments based on asset condition, risk assessment, and long-term infrastructure development goals. Upgrading the information systems within the infrastructure asset management framework is crucial as well. This includes improving data accessibility, integration, and interoperability between different systems. Exploring advanced GIS technologies and integrating them with existing systems can enhance data visualization, analysis, and reporting capabilities.

Additionally, establishing a feedback loop for continuous evaluation and feedback is important. Conducting periodic system audits, collecting user feedback, and incorporating lessons learned will further refine the infrastructure asset management system. Lastly, it is recommended that the responsible body installs the necessary server, database, and software to support the implementation of these improvements.

By implementing these recommendations, it is anticipated that the infrastructure asset management system will experience increased efficiency, accuracy, and effectiveness in supporting informed decision-making and long-term planning.

## REFERENCES

- Alemu Y., & Mekonnen T. 2023.** *Streamlining data management through a spatial database model for infrastructure asset management in Adama city.* . s.l. : Journal of Infrastructure Asset Management, , 2023. 30(4), 268-283..
- Berhanu T., & Alemayehu S. 2018.** *Enhancing transparency and collaboration in infrastructure asset management through open-source tools: Lessons from Adama city.* s.l. : Journal of Infrastructure Development, 2018. 20(3), 145-160. .
- Brown M., et al. 2020.** *Application of open-source tools in integrated infrastructure and utility.* . s.l. : Journal of Infrastructure and Utility Management, 2020.
- Consortium, Adama City Research. 2025.** *Addressing infrastructure asset management challenges in Adama city: Lessons learned and guidance for other cities.* s.l. : Adama, Ethiopia: Adama University Press. , 2025.
- Daulat S., Rokstad M. M., Klein-Paste A., Langeveld, J., & Tscheikner-Gratl F. 2024.** *Challenges of integrated multi-infrastructure asset management: a review of pavement, sewer, and water distribution networks.* s.l. : Structure and Infrastructure Engineering,, 2024. 20(4), 546-565..
- Debela, K. W. 2021.** *Decentralized urban governance and water supply service delivery in Ethiopia: The case of Adama City.* . s.l. : American Journal of Management Science and Engineering, 2021. 6(3), 63-76.
- Fekade W., Tomas. 2000.** *Deficits of formal urban land management and informal responses under rapid urban growth, an international perspective.* s.l. : Habitat International,, 2000. 24(2), 127-150.
- Gebremariam S., & Tsegaye M. 2024.** *Promoting transparency and stakeholder engagement through open-source tools for infrastructure data in Adama city.* s.l. : Proceedings of the International Symposium on Open Data in Urban Systems, 2024. 2024, 80-87.
- Gibson.w, Edison. 2009.** *Capabilities for strategic infrastructure asset management.* s.l. : Queensland University of Technology, 2009.
- Haas R., & Roelofs J. 2016.** *Infrastructure asset management: An introduction.* CRC Press. 2016.
- Halfawy, M. R. 2008.** *Integration of municipal infrastructure asset management processes: challenges and solutions.* *Journal of Computing in Civil Engineering*, 22(3), 216-229.

- Johnson R., & Brown M. 2018.** *Interoperability of spatial data in asset management systems: A review.* s.l. : Journal of Infrastructure Asset Management, 2018. 5(1), 1-13..
- Johnson R., et al. 2018.** *Achieving a holistic approach to integrated infrastructure and utility management: Optimized resource allocation, improved resilience, and enhanced system performance.* . s.l. : Journal of Utility Management, 2018.
- Lemma E., & Asfaw D. 2020.** *Assessing infrastructure asset management practices in Adama city: A research gap analysis.* . s.l. : Proceedings of the International Conference on Infrastructure Asset Management., 2020. 2020, 45-52. .
- SeyumD. 2007.** *Pastoralist Resource Management and Conflict Transformation in the Ethiopian Rift Valley Cases from the Lakes Region.* s.l. : Addis Ababa University., 2007.
- Smith A., & Johnson B. 2018.** *Leveraging technological advancements for efficient infrastructure asset management.* s.l. : Journal of Infrastructure Systems., 2018. 24(3), 04018014..
- Smith J., et al. 2017.** *The role of spatial data management in infrastructure asset management.* s.l. : Journal of Infrastructure Systems, 2017. 23(4), 04017010. .
- Tadesse A., & Bekele D. 2021.** *Challenges of data management in infrastructure asset management: A case study of Adama city.* s.l. : Journal of Civil Infrastructure Systems, 2021. 37(1), 102-115..
- Tesfaye M., & Mengistu B. 2019.** *Designing a spatial database model for efficient infrastructure data management in Adama city.* s.l. : Proceedings of the International Symposium on Spatial Data Handling, 2019. 2019, 112-119..
- UnitedNations. 2019.** *World urbanization prospects: The 2018 revision.* s.l. : Retrieved from <https://population.un.org/wup/>, 2019.
- W., Debela K. 2021.** *Decentralized urban governance and water supply service delivery in Ethiopia: The case of Adama City.* s.l. : American Journal of Management Science and Engineering, 2021.
- . **2021.** *Decentralized urban governance and water supply service delivery in Ethiopia: The case of Adama City.* s.l. : American Journal of Management Science and Engineering,, 2021. 6(3), 63-76.
- W., Fekade. 2000.** *Deficits of formal urban land management and informal.* s.l. : Habitat International, 2000. 24(2), 127-150.

**Wang, X., & Wang, H. 2020.** *Application of proximity analysis in infrastructure asset management. International Journal of Geo-Information, 9(7), 442.*

**Wondimu G., et al. 2022.** *Comprehensive research approach for enhancing infrastructure asset management in Adama city. s.l. : Proceedings of the International Conference on Sustainable Urban Systems., 2022. 2022, 246-253. .*

**Wright, J., & Williams, P. 2017.** *Tailoring infrastructure asset management practices to individual cities. s.l. : Journal of Urban Infrastructure, 2017. 15(2), 78-94. .*

**Xu Y., et al. 2018.** *Application of open-source GIS tools for water infrastructure management. . s.l. : Journal of Water Resources Planning and Management, 2018. 144(8), 04018048. .*

**Zelege G., Alemu B., Hergarten C., & Krauer J. 2008.** *Consultation Workshop on National Spatial Data Infrastructure and Ethio-GIS (2nd Release): Workshop Proceedings. . 2008.*

**Zhang L., et al. 2020.** *Integration of GIS technology with asset management systems for infrastructure maintenance planning. s.l. : Journal of Infrastructure Systems., 2020. 26(1), 04019039..*

**Zhang, L., et al. 2017.** *Framework development for integrated infrastructure and utility management: Methodologies, processes, and decision-making mechanisms. s.l. : Journal of Management Frameworks, 2017.*

## **APPENDIX**

### **Questionnaire**

The following questionnaire is prepared to collect information for conducting a research for a degree of Master of Science in Geoinformatics in the title Enhancing Infrastructure Asset Management in Adama City through Spatial Data Management and WEBGIS

Thanks for your cooperation in filling the questionnaire. Indicate your opinion by putting sign.

Write your level/position in the organization.....

1. Does your agency/organization have a Road Asset Management inventory database or is planning to develop one (please check one)?

- Yes, it already has a road Asset Management inventory.
- No, it does not have a road Asset Management inventory.
- It is planning to develop a road Asset Management inventory.
- Don't know

2, which of the following statements best describes how your agency/organization decides which data (and their related level of detail) will be collected to support the project selection decisions? Check all that applies: Data collection decisions are:

- Based on historical practice and staff experience defined within the agency/organization
- Based on widely accepted data collection standards.
- Based on specific needs of individual or integrated management systems/decision processes to be supported.
- Don't know exactly.

Please list any other consideration(s) that your agency's data collection decisions are based on:

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.....

3, which roadway asset data are most important in your agency's view for the selection between two projects, e.g. between different Road projects (please rate all data types)?

<b>Road Asset Data</b>	<b>Level of Importance</b>				
	<b>Very Important</b>	<b>Somewhat Important</b>	<b>Not very Important</b>	<b>Not at all important</b>	<b>Don't Know</b>
Location					
Attributes/characteristics (i.e., materials, service life, geometry, etc.)					
Structural condition (i.e., how adequate it is for its purpose)					
Functional condition (i.e., how well it can serve the public)					
Initial agency cost (construction/provision)					
Life-cycle costs					
Usage (i.e., how many users utilize it on a specific time basis, e.g., a day)					
Customer/user feedback and/or complaints					

Please list other data attributes that you think are important for your agency/ organization but were not included in the previous table:

.....  
.....  
.....

4, Has your agency/organization identified and/or formally documented any relationship between the roadway data collected to support Project Selection and the decisions made? Please check one:

- Only identified.
- Identified and formally documented.
- Neither identified nor formally documented.
- Don't know.

5 Please specify the decision-making levels that have been explicitly defined in your agency/ organization (check all that apply):

- No explicit definitions for decision making levels
- Strategic level (i.e., concerning policy of decisions for the overall network).
- Programming and budgeting level (i.e., concerning overall resource allocations for design, maintenance and rehabilitation throughout the entire network).
- Project selection level (i.e., selection of individual projects or groups of projects for funding and/or implementation).
- Project (i.e., design of concerning specific treatments or action for the selected projects).
- Don't know what decision levels are defined.

6, please rate the following Road Asset Management decision processes in terms of their relative importance within your agency/organization:

<b>Road Asset Management Decision Processes</b>	<b>Level of Importance</b>				
	<b>Very Important</b>	<b>Somewhat Important</b>	<b>Not very Important</b>	<b>Not at all important</b>	<b>Don't Know</b>
Performance evaluation and monitoring					
Fiscal planning					
Program optimization					
Development of alternatives (for sustaining assets through their life-cycle)					
Impact analysis					
Performance-based budgeting					
Project selection					
Resource allocations					
Program delivery/project implementation					
Audit, reporting and communication					

Please list up other decision processes important for your agency/organization:

.....  
 .....  
 .....

7, please rate the following criteria according to their level of importance for selecting projects that are candidates for funding and implementation within your agency/organization:

Project Selection Criteria	Level of Importance				
	Very Important	Somewhat Important	Not very Important	Not at all important	Don't Know
Available budge					
Project significance					
Usage of the project					
Proximity of the project to major urban areas					
Ease/difficulty of implementation					
Engineering parameters (including asset condition)					
Geographic distribution of					

projects/funds					
Distribution among asset types					
Public demands/user opinion					
Environmental consideration					
User costs/benefits					
Agency costs/benefits					

Please list up other criteria important for project selection within your agency/ organization:

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**Interview Questions**

I wish to thank you for your participation in this research. The interview you are about to answer to questions is regarding a research for a degree of Master of Science in Geoinformatics . This research is being done to investigate road Asset Management and planning Practices of Adama City.

1, How Road inventory is conducted in your organization?

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2, How frequently the inventory is conducted?

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3, How each segment of the road is identified in the network/ Methods of Assigning Unique ID for each Route?

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4, what attribute of a road are collected and with which instruments and techniques?

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5, How does the organization manage its data?

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6, Which condition assessment technique is used in your organization?

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7, How the condition of a road is predicted for the incoming year/which prediction model is used in your organization?

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8, How capital work planning is accomplished for road sector in your organization?

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9, Are the ICT (system) /applications well designed to support the work processes and the business objectives?

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