Development of a GIS-based Street Addressing System for Enhanced Service Delivery in Adama City: A Case of Bole Sub City

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DECLARATION

I hereby declare that this research thesis entitled "Development of a GIS-based Street Addressing System for Enhanced Service Delivery in Adama City: A Case of Bole Sub City." 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.

Zelalem Alemu	________________________	________________
Name of student	Signature	Date

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I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Development of a GIS-based Street Addressing System for Enhanced Service Delivery in Adama City: A Case of Bole Sub City." prepared under my guidance by **Zelalem Alemu** 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.

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Name of Major Advisor	Signature	Date
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Co-advisor	Signature	Date

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I, the advisor of the thesis entitled "Development of a GIS-based Street Addressing System for Enhanced Service Delivery in Adama City: A Case of Bole Sub City "and developed by **Zelalem Alemu** 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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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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LIST OF ACRONYMS

CGIS	Canadian Geographic Information System
DBMS	Database Management System
ESRI	Environmental Science and Research Institute
GIS	Geographic Information System
GPS	Global Positioning System
IFS	International Federation of Surveyors
ISAS	Informal Settlements Addressing System
LIS	Land Information System
OSM	Open Street Map
QGIS	Quantum Geographic Information System
SAS	Seoul Addressing System
SIS	Spatial Information System

ABSTRACT

This research study focuses on the development of a GIS-based street addressing system to address the challenges posed by the lack of a robust and efficient street addressing system in Adama City, which has been exacerbated by rapid urban expansion and population growth. The absence of standardized labeling or coding for roads and parcels hinders effective service delivery and makes it challenging to locate specific addresses. The research objective is to enhance service area analysis in Bole Sub City, Adama, through the development of a GIS- based street addressing system. The methodology involved data collection, street codification, address assignment, GIS geodatabase design, service area identification, and address point placement. The research findings demonstrate the successful implementation of standardized parcel and street codification, routing analysis, geodatabase design and implementation, and address point geocoding techniques. The results highlight the significance of the implemented spatial analysis techniques, including the parcel codification system, GIS-based street addressing system, route analysis, routing analysis, and service area analysis, in improving service delivery, navigation, resource allocation, competitive analysis, and decision-making processes. These findings contribute to the understanding and application of spatial analysis techniques in Adama City's Bole Sub City, addressing the existing gap in research on this topic. Overall, this research study emphasizes the urgent need for a GIS-based street addressing system in Adama City. The outcomes of this study provide valuable insights for urban planners, businesses, and organizations in optimizing service delivery, allocating resources strategically, and improving decision-making processes. The successful implementation of the developed system showcases its potential to enhance service area analysis and contribute to the overall development and efficiency of Adama City's urban landscape.

Key Words: GIS, Geocoding, Route Analysis, Service Area Analysis

CHAPTER ONE

INTRODUCTION

1.1. Background

Streets play a crucial role in the structure of urban areas, serving multiple purposes. They are essential components of cities and towns, providing access to properties and locations, facilitating the movement of people, goods, and services, and offering public spaces for working, resting, and socializing (Porta, 2006). Additionally, streets function as "breathing spaces," helping with ventilation among other roles. Despite these varied functions, the primary role of streets is to enable access to different properties and buildings. The development pace of an urban area is significantly influenced by its streets (Hajisoltani, 2023).

Urbanization is occurring rapidly worldwide, especially in developing countries. According to a World Bank study, 54% of the global population now resides in urban areas. This swift urban transition presents both opportunities and challenges for local planning authorities. Urban areas concentrate a region's physical, financial, and human resources. One strategy for managing the complexities of urbanization is street addressing, which planning authorities in developing countries can use to convert challenges into opportunities. This approach has proven effective in many cities facing rapid development without adequate supporting (WorldBank, 2015)

Street addressing originated in European countries and the United States in the 18th century, initially focused on house numbering to determine property distribution rather than organizational purposes. Over time, this system was adopted globally to assist with administrative tasks and services like postage. Today, street addressing has evolved into a powerful management tool widely used by planning authorities in various developed countries (Farvacque-Vitkovic, 2005)

Currently, street address modeling and implementation methods vary worldwide, utilizing different geocoding techniques and reference points. Nevertheless, their core objectives remain consistent: enabling accessibility and facilitating the delivery of public services. A street address is described as geographical information that represents a particular location on a map, regardless of its purpose, whether urban, commercial, industrial, recreational, or traditional

(Kellison, 2012). An integrated, accurate, and sustainable addressing system plays a crucial role in raising public awareness, enhancing law enforcement capabilities, and ensuring the provision of public, private, and emergency services. It allows organizations and businesses to link their activities with specific land parcels and buildings, influencing nearly every aspect of their operations (Kellison, 2012).

In Ethiopia, the development and application of street address systems have been relatively recent, relying primarily on traditional methods like assigning street names and installing signs along major roads. Although some street address models have been introduced and tested, such as a trial project in the Addis Ababa city administration and an experimental implementation in Mekele town, they have encountered difficulties in establishing comprehensive and easily navigable street address infrastructure with adequate precision (Goldberg, 2011). Consequently, there is a need for research to explore alternative approaches to street address modeling and implementation that consider the country's urban infrastructure, technological advancements, and level of social development.

Street addressing is one of the most effective and systematic methods for managing properties and locating places. (Farvacque-Vitkovic, 2005) describe street addressing as a process that enables the geographical identification of a plot or residence by assigning an address through a system of maps and signs indicating street and building numbers or names. This system is essential for organizing places, forming a fundamental basis for the organized and accountable maintenance and improvement of urban and public affairs. It also serves as a valuable and efficient tool for urban management, aiding in the delivery of goods and services to urban areas and their surroundings.

Advancements in mapping technology have significantly changed our approach to locating places. According to the previously mentioned definition, a technical GIS-based mapping approach to street addressing surpasses simply numbering buildings and the political naming of streets, common in many African developing countries (Slocum et al., 2022). The primary advantage of a street addressing system lies in its foundation on mathematical logic, allowing for automation using GIS technology, especially as technological awareness increases.

Developed countries have successfully implemented street addressing systems to manage revenues, provide public services, and oversee the general management of urban areas.

1.2. Problem Statement

The lack of a robust and efficient street addressing system in Adama City, as a result of rapid expansion and population growth, presents significant challenges in identifying service areas and impairs effective service delivery (Leta et al., 2024). The current situation is characterized by the absence of standardized labeling or coding for roads and parcels, making it difficult to locate specific addresses and hindering the provision of essential services. Furthermore, there is a notable gap in research conducted on this topic specifically within Adama city. Therefore, there is an urgent need to develop a GIS-based Street addressing system that can effectively codify streets, assign addresses to land parcels/plots, and demonstrate its potential in identifying service areas within Adama city. This research aims to address this research problem by designing and implementing a comprehensive GIS-based Street addressing system (Bekele, 2018).

Developing this system will require mapping and codifying existing streets and land parcels, establishing a standardized addressing scheme, and implementing the necessary technological infrastructure (Abebrese,2019). By introducing a GIS-based street addressing system, developing cities can overcome the challenges associated with the current lack of a reliable addressing system (Olayinka, 2020). This system will enable accurate identification and location of addresses, facilitating efficient service delivery and improving accessibility for residents, businesses, and emergency responders.

Furthermore, the research aims to assess the effectiveness of the GIS-based street addressing system in enhancing service area identification and overall service delivery within the Sub city (Kassaw & Asefa, 2020). This assessment will involve examining how the system impacts navigation, emergency response times, urban planning, and social integration. The findings from this study will add to the existing knowledge on street addressing systems in developing countries and offer valuable insights applicable to similar urban contexts worldwide.

The development of a GIS-based street addressing system in Adama city is essential for addressing current challenges stemming from the absence of a robust system. It will improve service accessibility, enhance emergency response capabilities, and contribute significantly to the overall development and efficiency of the city's infrastructure.

1.3. Objectives

1.3.1. General Objective

To develop a GIS-based Street addressing system for enhanced service delivery in Bole sub city Adama.

1.3.2. Specific Objectives

- To map and codify the existing streets and land parcels in Adama Bole sub city.
- To design and implement a comprehensive GIS-based Street addressing system.
- To assess the effectiveness of the GIS-based Street addressing system in improving service area identification.
- To propose Address point geocoding techniques for service area identification.

1.4. Research Questions

- How can the existing streets and land parcels in Adama city be mapped and codified to establish a comprehensive addressing system?
- How can a GIS-based Street addressing system be designed and implemented to effectively assign addresses to streets and land parcels?
- What is the impact of the GIS-based Street addressing system on the identification of service areas in Adama Bole sub city?
- How can Address point Geocoding techniques be applied to enhance the identification of service areas within the GIS-based Street addressing system?

CHAPTER TWO
LITERATURE REVIEW

2.1. What is A Street Addressing System

A street addressing system can be defined as a structured method for identifying and locating properties, buildings, and plots within an urban area (Boeing, 2017). Another definition describes street addressing as a method of locational identification that includes a systematically assigned number, a road identification, and a locality identification (Abebrese, 2019). Researchers typically describe it as a systematic approach that assigns unique identifiers, such as street names and numbers, to specific geographic locations. This system utilizes a combination of maps, signs, and often geocoding technology to ensure that each address is precise and easily navigable.

2.2. Importance of Street Addressing System

Street addressing serves as both a historical and spatial designation. According to Adebanwi, (2012), street naming is a significant cultural and political practice that helps understand socio-political processes.

As mentioned earlier, street addressing offers numerous benefits across various sectors, including the geospatial field. Vuolteenaho, (2017) observed that commemorative street naming functions as both a historical reference and a spatial designation. A property-numbering system simplifies the process of finding unfamiliar places and reduces confusion. In an urban setting, street addressing plays a crucial role for a wide range of users (Muinde, 2017).

A street addressing system is integral to the functioning of modern urban environments. It enhances navigation, supports public service delivery, fosters economic activities, improves governance, and enables technological integration, thereby contributing to the overall development and well-being of society (Bibri, 2017).

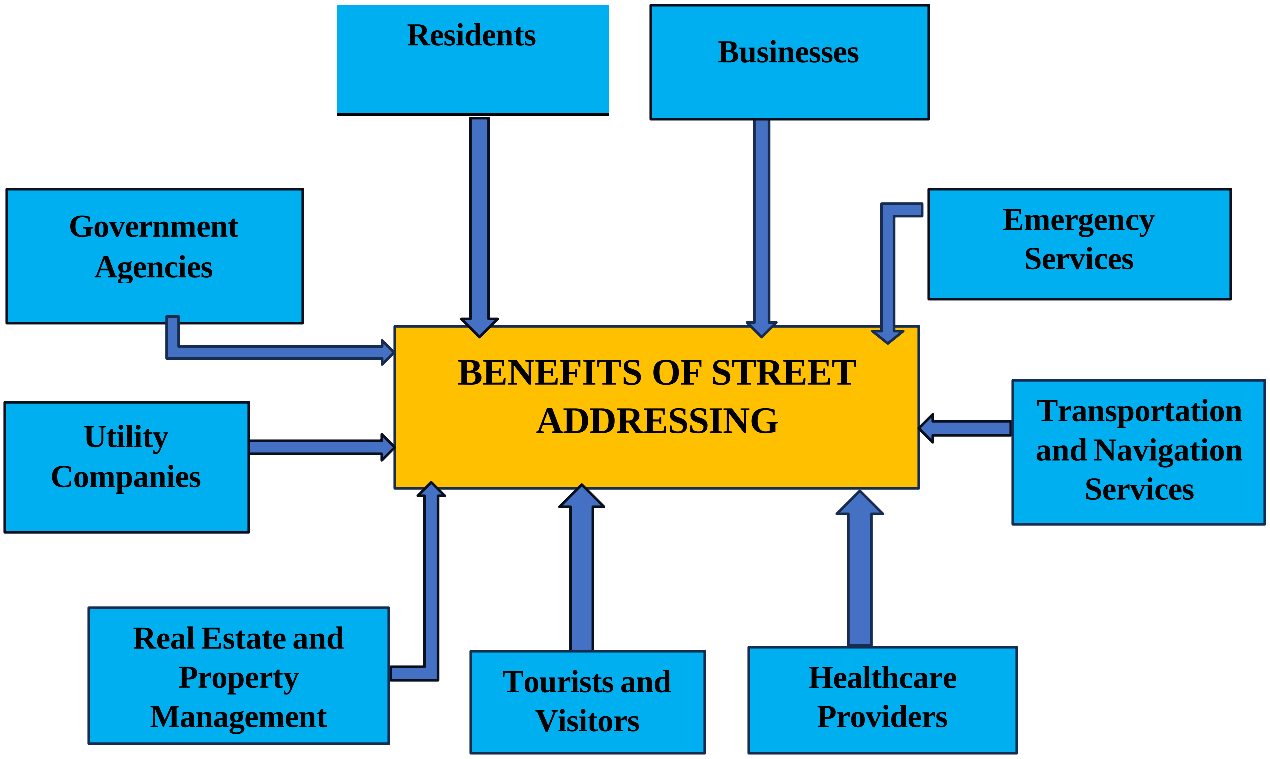

Figure 2.1 Benefits of Street Addressing (Jansson, 2019).

Table 2.1 Significance of Street Addressing to various users (Jansson, 2019).

User Category	Benefits/Significance
1. Residents	Personal Safety: Knowing that emergency services can locate their home quickly provides peace of mind. Mail and Deliveries: Reliable delivery of mail, packages, and other goods is facilitated. Utilities and Services: Easier installation, maintenance, and repair of utilities like electricity, water, and internet.
2. **Businesses**	Logistics and Delivery Companies: Improved route planning and delivery efficiency, reducing costs and improving customer satisfaction. Retailers and Service Providers: Easier to attract and serve customers when locations are clear and precise.
3.Government Agencies	Urban Planning and Development: Better planning and allocation of resources such as public transportation, schools, and healthcare facilities. Tax Collection and Administration: Simplifies property identification and tax collection processes.
4.Em**ergency Services**	Police, Fire, and Ambulance Services: Accurate addresses enable quicker response times in emergencies, potentially saving lives and property. Disaster Response Teams: Efficient coordination and communication during natural disasters or other crises are enhanced.
5.**Public Services and Utilities**	**Infrastructure Maintenance**: Easier identification and access to specific locations for repair and maintenance work. **Service Provision**: More efficient delivery of public services, such as waste collection and street cleaning.
6. Real Estate and Property	**Property Transactions**: Clear addresses facilitate buying, selling, and renting properties.

Management	Property Valuation and Insurance: More accurate property assessments and insurance underwriting.
7.Transportation and Navigation Services	**GPS and Mapping Services**: Enhanced accuracy in navigation systems and online maps, benefiting drivers and pedestrians. Public Transport Users: Clearer directions and route planning.
8.Tourists and Visitors	**Ease of Navigation**: Simplifies finding accommodations, attractions, and services in unfamiliar areas.
9.Healthcare Providers	**Home Visits**: Easier for healthcare professionals to locate patients' homes for house calls or home healthcare services.

2.3. Historical Evolution of Street Addressing

2.3.1. The Origin about 18th Century

Despite the early use of road naming to identify main streets in the 18th century, this practice did not establish comprehensive address networks. Although some primary streets and houses had names, there was no systematic method for naming at the city or national level. Most streets remained unnamed, and houses unnumbered. It wasn't until the 18th century in Western Europe that the official naming of city streets became common. While house names were sometimes used to pinpoint locations, house numbering only began in the early 19th century. Street names evolved from informal references to landmarks to more formalized names, increasingly organizing urban space into neighborhoods and eventually incorporating house numbers. The changing concept of public space, the evolving perception of government responsibilities, and the growing needs of the emerging state necessitated a consistent and formalized system for street naming and house numbering (Peterson, 2003).

2.3.2. Addressing in the Twentieth Century

In the years that followed, cities saw consistent street name identification, which improved spatial organization and laid a better foundation for practical management strategies like tax collection. Over time, the implementation of address networks expanded, moving beyond merely facilitating communication and organization. These networks became essential for social and economic development, especially as cities faced new management challenges due to rapidly increasing urbanization (Rana, 2011).

2.3.3. Addressing in the 21st Century

In the 21st century, street addressing systems have become even more sophisticated and essential. Advances in digital technology, such as GPS and online mapping services, rely heavily on accurate and standardized addresses for navigation, logistics, and location-based services. Modern addressing systems are crucial for emergency services, efficient delivery of goods, and urban planning. They also support the growth of e-commerce by enabling precise delivery locations. Additionally, accurate addresses play a significant role in public health, utilities management, and the overall organization of urban spaces. As urbanization continues to accelerate globally, the need for robust and comprehensive addressing systems has never been greater, ensuring that services and resources can be efficiently allocated and accessed (Huang et al., 2018).

2.3.4. Addressing in the African Continent

Inspired by colonial rulers, French-speaking (francophone) countries were the first to introduce addressing systems in Africa. Countries such as Chad, Burkina Faso, Guinea, Mali, Togo, and Mozambique implemented street addressing in their main cities, while street numbers were assigned in areas surrounding the cities (hinterlands), with most rural areas being neglected. After gaining independence, these colonial systems often fell into disuse. It wasn't until the 1980s that addressing policies began to develop progressively, adopting systems that identified thoroughfares and house numbers (Farvacque-Vitkovic, 2005)

Although Africa's rural areas have traditionally experienced political and physical isolation, they are gradually being integrated into national addressing plans. These plans aim to improve communication, enhance services, and foster national integration. There is a growing awareness across African nations about the importance of addresses. Infrastructure development, including address infrastructure, has become a priority for many African countries and the African Union Commission, which is helping to create guidelines for harmonizing addressing policies among its members (Ondiege et al., 2013).

2.3.5. Street Addressing in Ethiopia

Street addressing in Ethiopia began in Addis Ababa's central area, modeled after European cities, preserving some elements of the pre-independence street layout, including street names and signposts (Legère, & Rosendal, 2019). However, rapid post-independence urban expansion beyond the original fixed urban space led to the growth of unplanned residential developments, lacking official street naming and house numbering. While major roads were named, many residents remained unaware of these names due to the absence of signposts.

Recognizing the necessity for a comprehensive addressing system, the Ethiopian government established an inter-ministerial National Addressing System task force (Gebeyehu et al., 2017). This task force, led by the Ministry of Information, Communication, and Technology, was responsible for expediting the development and implementation of an integrated national addressing system. The primary goal of this system was to enable fire, police, ambulance, and public utility services to locate properties and residences efficiently, ensuring a rapid emergency response. In 2016, the government launched several street addressing projects in Addis Ababa and other major towns (Ayele et al., 2021), with funding from international organizations such as the (World Bank, 2015)

2.3.6. Street Addressing Applications

Street addressing, when integrated with Land Information Systems (LIS), has numerous potential applications (Catheine-Farvacque, 2005). Street addresses play a crucial role in various fields such as management, emergency response, investigation, marketing, mapping, GIS, routing navigation, and more.

However, due to their evolution over time under the control of different local jurisdictions and varying record and database formats, street addresses present complex challenges for geoprocessing and modeling (Authority, 2010). To address this issue, government institutions have attempted to consolidate large and critical address files into master address repositories.

According to Nam & Pardo (2011), the primary and most common application of street addressing is its connection to civic identity, which is essential for achieving social integration within a city. This application involves three dimensions:

1. Relationships among people, which are at the core of any system and can only exist with a functioning street addressing system.
2. Relationships between citizens and government authorities, enabling individual and economic actions to be situated for fiscal and political purposes.
3. Control of urban space, where street addressing serves as the initial step in developing management tools to ensure gradual urban development.

There are also practical applications that explore the links between street addressing and urban information systems, support for municipal services, tax systems, land tenure issues, upgrading informal neighborhoods, and economic development. Additionally, street addressing provides an excellent opportunity to gather land-related baseline information for a city. The creation of databases and maps through such initiatives allows for the development of a simplified Geographic Information System (GIS) that can be integrated with other urban management tools. Maintaining this reference tool facilitates progressive updates as new information becomes available (Nour, 2011).

2.3.7. The Process of Street Addressing

The development of a street addressing system typically involves three key stages (Muinde, 2017):

1. Creating an up-to-date base map;
2. Codifying streets; and,
3. Assigning addresses to physical properties

2.3.8. Up to date Base Map development

Creating an up-to-date base map involves developing a comprehensive map of the designated area. Key components of a street addressing base map include (Shakir et al., 2022):

a) Centerlines of all streets and roads, along with associated attributes within the area of interest.

b) Cadastral layer polygons and attributes detailing all plots within the designated area.

c) Current information on all buildings and properties within the area.

d) Zoning details that designate addressing localities within the area.

To create a current base map, one needs an ortho-rectified image, high-resolution aerial imagery, and cadastral sheets specific to the area of interest. These resources are utilized to generate shapefiles in ESRI format for the mentioned features.

Street codification is the process of organizing and assigning identifiers to streets within an urban area. The layout and development pattern of the area often influence how streets are identified. In areas with little planning and organic development, such as sprawling regions, this task can be particularly challenging. However, in well-organized urban areas, like those with a grid system, the process is simpler (Long & Liu, 2017).

2.3.9. Street Codification

The general principle is that streets typically align in a North-South (N-S) or West-East (W-E) direction (Muinde, 2017). Therefore, when codifying streets, there are three basic steps to follow:

1. The first step involves establishing a reference point within the area, known as point zero, from which street numbering gradually increases. The start and end points of each street must also be defined, with the correct orientation from the reference point.
2. The second step is to categorize the developed road centerlines based on their North-South (N-S) or West-East (W-E) orientation.
3. The third step involves assigning unique identifiers, or codes, to the streets. Typically, Odd numbers are assigned to N-S streets, while Even numbers are assigned to W-E streets, in accordance with the point zero and addressing locality zone limits. In expansive towns with multiple zones, street codes may also incorporate zone codes or abbreviations by combining attributes from both layers.

2.3.10. Guidelines for Street Addressing Methodology

Derived from a street addressing methodology outlined by the World Bank, the following guidelines are recommended:

a) Street Naming: This method is the most straightforward for street identification and is commonly used due to its adaptability to various street layouts (Southworth, & Ben-Joseph, 2013). However, selecting appropriate names can present challenges that may prolong the implementation process. This approach is most effective in cities where development occurs gradually, allowing municipal authorities sufficient time for naming decisions.

b) Street Numbering in Urban Areas with a Grid Layout: This system offers a more standardized approach that is easier for the public to comprehend. Streets are arranged in a grid-like pattern, and addressing is carried out numerically or alphabetically from a designated reference point, often referred to as "point zero."

c) Street Numbering in Urban Areas with an Organic (Irregular) Layout: This approach is commonly employed in anticipation of gradual street naming. To simplify the process of establishing street coordinates, streets are grouped into neighborhoods or zones and assigned sequential numbers with a prefix indicating the respective neighborhood or zone. Many street addressing initiatives referenced in this publication have adopted such a system (Vuolteenaho, 2012).

d) Unidentified Streets: Street addressing initiatives are not exclusive to developing cities; they also address the issue of unidentified streets in high-density housing projects and other residential development (Dave, 2010). These projects often exacerbate the information gap by disregarding surrounding street layouts, introducing private streets, and identifying buildings using numbers or letters instead of street coordinates (Farvacque-Vitkovic, 2005).

Addressing Physical Properties

This phase involves the methodical assignment of numbers to properties and buildings to provide them with a distinct identifier within a straightforward and easily comprehensible numbering system. As outlined in a manual by the World Bank on street addressing systems, after determining the starting point of a street, properties and buildings on the right side are allocated even numbers, while those on the left side receive odd numbers (Demir et al., 2018). This system is universally adopted as the fundamental approach

There are three primary property addressing systems commonly employed in street addressing initiatives:

i) Sequential numbering: This method involves assigning numbers to existing properties in a continuous sequence, such as 2, 4, 6 on the right side and 1, 3, 5 on the left side (Golomb, 2017). While sequential numbering is relatively straightforward to implement, it can present challenges and confusion if properties are subdivided or multiple buildings are constructed on the same plot in the future. To address this, newly developed buildings between existing plots or subdivisions after numbering are assigned a suffix based on the original plot number, followed by sub-numbers (e.g., 365/1, 365/2, 365/3... or 365/A, 365/B, 365/C).

ii) Metric numbering: Properties are numbered based on their distance from the starting point of the street, with distances rounded to the nearest even or odd figure depending on the side of the street (Khan et al., 2010). This system is straightforward and easily understandable, as it relies on distance from a known point on the street. Metric numbering offers advantages over the sequential system, particularly in organic, informal, and unplanned urban areas. It also provides a solution for future challenges such as plot amalgamations or subdivisions without requiring suffixes for split numbering.

iii) Decametric numbering: This approach combines elements of sequential and metric numbering by assigning even and odd numbers to 10-meter-long sections of the street (Mansfield, 2012). This system offers the benefits of both simplicity and clarity in predictable distance numbering.

Segment	Distance (m)	No. left side	No. right side
1	0 - 10	1	2
2	10 - 20	3	4
3	20 - 30	5	6
4	30 - 40	7	8
5	40 - 50	9	10
6	50 - 60	11	12
7	60 - 70	13	14
8	70 - 80	15	16
9	80 - 90	17	18
10	90 - 100	19	20
11	100 - 110	21	22

Table 2.2 Decametric Numbering System

2.3.11. Building or Parcel Codification

The building codification shall be unique at the national level. Such unique codes are used to locate places without any confusion/ duplication in the country (Benson, 2012).

2.3.12. Assumption of Building/Parcel Codification

1. All buildings/neighborhoods shall have a unique ID;
2. The codification of the buildings shall be treated separately from road codification;
3. In the codification process of open spaces, under construction, merging and subdividing buildings shall be considered;
4. Should be both human-friendly and suitable for use in computer systems (Ranjbari et al.,2023).

2.4. Building/Parcel Codification Guidelines

The global addressing trends show that addressing man-made and natural features demands unique, consistent, high precision and accuracy at centimeter and millimeter levels (Gao et al., 2017). Accordingly, the national digital addressing shall be established as a national-level uniform and consistent building unique ID and accommodate the minimum lot sizes of the given household unit. Thus, the addressing of the buildings shall be formulated using a grid and Ad hoc codification system. The details are described below:

1. Shall divide the country into 99 grids which is 9 rows *11 columns (1.1 degree * 1.1-degree grid);
2. The 1st level grids represent two digits 01 to 99 numbers

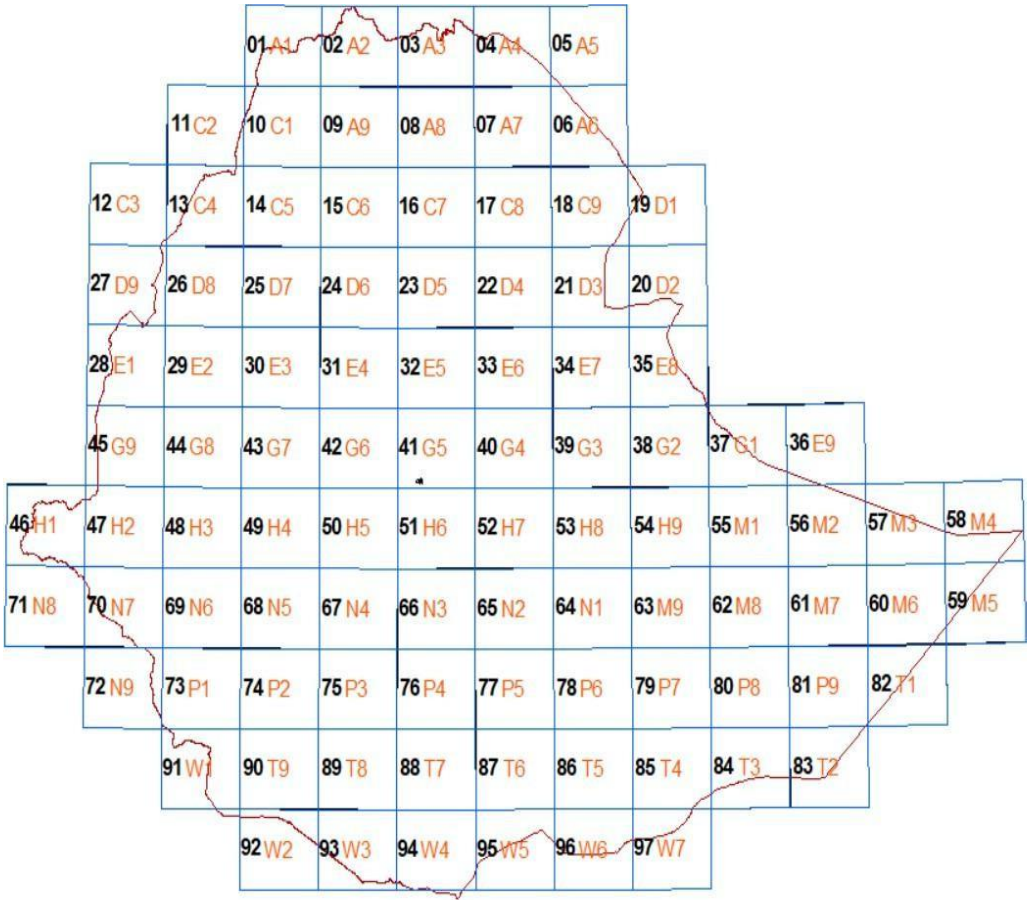

Figure: 2.2 National Addressing grid classifications (Source: National Digital Addressing Standard).

3. When a building is divided by a grid, the neighborhood division code shall be determined in the largest area it falls.
4. The neighborhood delineation shall be made based on the actual situation of the block on the ground. It might use roads, block patterns, orientations, natural boundaries (river, lake, etc.), administrative boundaries, etc. In the case of rural areas, neighborhood size will depend on the geographic and natural position and aspects of the area.
5. The codification of each grid (neighborhoods) shall start from the NW to NE in a clockwise and zig-zag approach

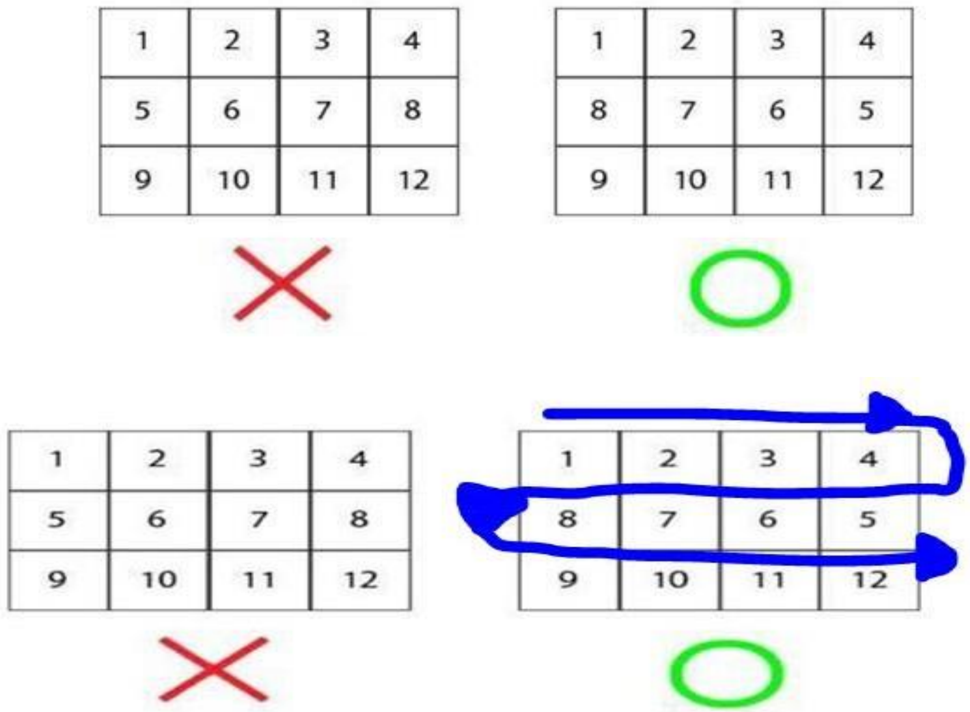

Figure 2.3 Codification of each grid (neighborhoods), Source: (National Digital Addressing Standard).

6. The codification of buildings shall be a zig-zag approach.
7. The unique codes of the building are based on the block and building arrangements/patterns of the area and shall be assigned odd numbers to buildings found West and South of the road. Whereas even numbers to buildings are found East and North of the road. Any building within or neighborhood block from the top view shall keep its odd and even pattern consistently.

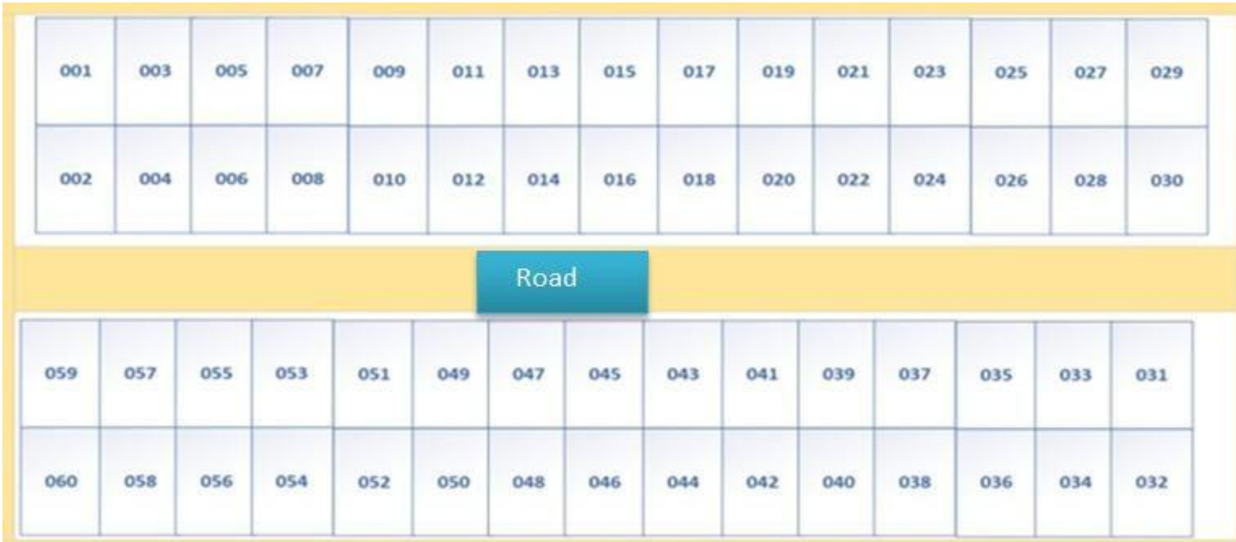

Figure 2.4 Building/Parcel Codification along Road

8. Direction - Unique codes for buildings in the area will be assigned odd numbers to the South/West and even numbers to the North/East based on the block and building arrangements, with consideration for the initial reference point (Abebrese, 2019).

- North: - Even
- South: - Odd
- East: - Even
- West: - Odd

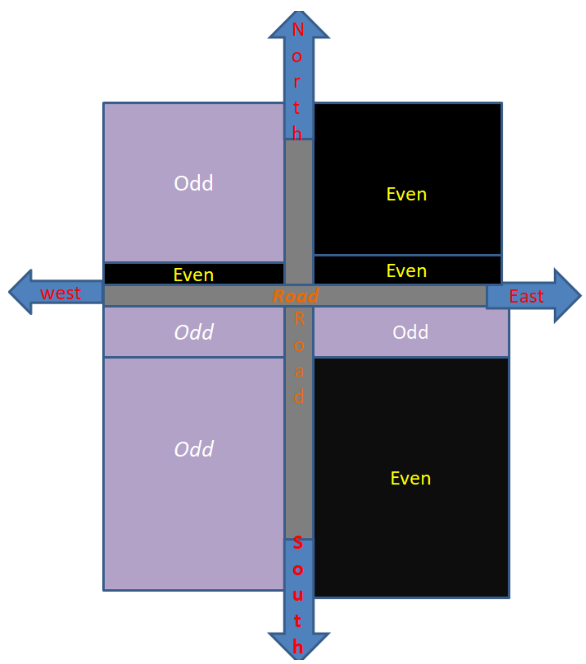

Figure: 2.5 Direction - Unique codes for buildings (National Digital Addressing Standard).

9. Patterns - The unique ID assigning pattern will be a Zig-zag approach. This approach is simple and easy to assign code to Parcel. If the number is assigned sequentially in order, it is easy to plan a sign pole in each corner of the block (Koc et al., 2022).

Figure: 2.6 The unique ID assigning a Zig-zag approach (National Digital Addressing Standard).

2.4.1. Street Addressing System and Service Delivery

Street addressing can be applied in various areas to enhance the service delivery system (Barakabitze & Walshe, 2022). Here are key areas where effective street addressing plays a critical role:

1. Emergency Response Services

Application: Police, Fire, and Medical Services: Quick and accurate location identification for emergency calls

Disaster Management: Efficient coordination and resource allocation during natural disasters. (Lohokare et al., 2017).

2. Postal and Courier Services

Application:

Mail Delivery: Accurate delivery of letters and packages.

E-commerce Deliveries: Efficient and timely delivery of goods purchased online.

3. Utility Services

Application:

Electricity and Gas: Installation, maintenance, and emergency repairs.

Water Supply and Sewage: Infrastructure management and fault repairs.

Telecommunications: Installation and maintenance of telecom lines and services.

4. Health Services

Application:

Home Healthcare: Delivery of medical services and supplies to patient homes.

Ambulance Services: Quick dispatch and navigation to emergency locations.

Public Health Campaigns: Targeted health interventions and outreach programs.

5. Municipal Services

Application:

Garbage Collection: Optimized routes and schedules for waste management.

Street Cleaning and Maintenance: Regular and efficient street upkeep.

Public Works and Infrastructure: Planning and executing infrastructure projects like road repairs and upgrades.

6. Education Services

Application:

School Transportation: Efficient routing of school buses.

Community Outreach Programs: Identifying and reaching target populations for educational initiatives.

7. Law Enforcement and Public Safety

Application:

Patrol Services: Effective planning of police patrol routes.

Crime Analysis and Prevention: Data-driven approaches to identifying and addressing crime hotspots.

8. Commercial and Business Services

Application:

Service Deliveries: Accurate location for services such as food delivery, maintenance services, and home installations.

Customer Reach: Businesses can target and reach customers more effectively for marketing and delivery purposes.

9. Tourism and Navigation

Application:

Tourist Services: Improved navigation and access to tourist attractions.

Local Navigation: Enhanced use of GPS and mapping services for residents and visitors.

10. Social Services

Application:

Welfare Programs: Identifying and serving recipients of social welfare programs.

Community Services: Effective delivery of community-based services and support programs.

11. Urban Planning and Development

Application:

Zoning and Land Use: Precise identification of zones for residential, commercial, and industrial use.

Infrastructure Development: Planning and execution of new infrastructure projects, such as roads, parks, and public buildings.

12. Environmental Management

Application:

Resource Management: Efficient management of natural resources within specific areas.

Environmental Monitoring: Identifying and addressing environmental concerns, such as pollution control and green space maintenance.

13. Transport and Logistics

Application:

Public Transport: Planning routes and stops for buses, trams, and trains.

Freight and Logistics: Efficient routing for the transportation of goods.

14. Civic Engagement and Participation

Application:

Voting and Elections: Accurate voter registration and polling station assignment.

Public Consultations: Effective engagement with residents on local issues and developments.

Effective street addressing is fundamental to improving service delivery across these areas (Yildirim et al., 2014). It enables precise location identification, efficient resource allocation, and improved coordination among various service providers. By implementing a robust street addressing system, municipalities can ensure that services are delivered promptly and effectively, enhancing the quality of life for residents and fostering sustainable urban development.

2.5. Geographic Information System (GIS)

Initially developed to aid in the management of natural resources and environmental conservation, Geographic Information System (GIS) technology has evolved into a versatile tool utilized across numerous fields at local, regional, and global levels. Its applications include street addressing, place location, land use planning, suitability analysis, urban utility management, disaster management, monitoring and evaluation, among other areas. GIS is a powerful tool used for computerized that has replaced most of cartographical works such as mapping and spatial analysis. A system provides spatial data entry, management, and retrieval, analysis, and visualization functions. The potential for applying GIS technologies and other related technologies is growing by the day. GIS applications have quickly grown from mere map-making to providing real world solutions for the numerous and very often complex problems facing our communities on day-to-day basis. This ideally means that GIS is no longer a monopoly of scientists (cartographers, surveyors and ecologists), but is now increasingly being applied in other industries such as health, crime, marketing, real estate, aviation, insurance among others (Tao, 2013).

GIS applications focused heavily on the traditional areas of its applications such as land use/land cover mapping, census mapping, urban mapping, environmental planning and management, disaster/hazard risk management, among numerous others. Even within these traditional areas of GIS application, the emphasis remained on macro level mapping where interest was on mapping expansive entities such as natural resources, urban areas, and population. However, with the rapid evolution of digital technology, and more specifically,

GIS, the horizon of GIS applications has tremendously broadened.GIS now utilizes sophisticated database systems, allows easy overlay of data in different projection systems, fully integrates raster data and allows internet mapping.

GIS is therefore not only becoming more powerful but more relevant (Khamala and Karimi, 2004).

2.5.1. Historical Evolution of GIS

Before 1960 – Paper Map Predominance (Before computers): All mapping work was done manually on paper. Globally, the computer mapping technology was not developed. Maps were mainly used for way finding and locating of new/unfamiliar places (Kerski, 2022).

After 1960 to 1980's, computers were invented and initial steps of GIS Development were made: Early rapid urbanization trends were being experienced. Most technological milestones were made during this period as countries embarked on development agendas. It is in this period that the discovery of second generation of computers (with programming languages, storage memory and operating system) totally changed the face of mapping and development of GIS technology. GIS development credits are given to Roger Tomlinson, collaboration with Canadian Government, initiated, planned and directed the development of the Canadian Geographic System (CGIS) in late 1960's (Castron, 2022). This was a historical milestone in GIS development since CGIS is considered as the foundation of GIS development. CGIS implemented a layer approach system to mapping (Steiniger & Hunter, 2013).

1975 to 1990 – Making money from GIS: As major enhancements in computer technologies were being made, planning authorities started to realize the merits of digital cartographic works (Nedović-Budić, 1998). Then, improvement on storage, performance and graphics of computers had a direct impact on quality and efficiency improvement on the mapping world. New cartography products started creeping in the market. This attracted interest in number GIS product vendors in the market around late 1980's. ESRI, a giant GIS software developer was launched with other GIS consortiums starting to come up also. ARC/INFO was first introduced and tested in 1982.

1990 to 2010 – GIS user at the center stage: This period is credited as when GIS made major strides. Application of GIS was being introduced in different fields such as education, entrepreneurship, research, in an endeavor to create visual map analysis (Krygier & Wood, 2016). By this time, computers were much advanced, variety of GIS software options, spatial data availability and advancement of remote sensing technology, streamlined the penetration of GIS to the people.

2010 to Present – The Era of Open Source, Big Spatial Data and Cloud GIS: The invention of open-source technology for GIS in this era makes access and sharing of spatial data possible. With improvement of GIS technology and expansion of geo-spatial industry to other fields, there is so much spatial data generated on daily basis. These spatial datasets accumulate to a point that handled and managed efficiently by common database management systems therefore categorized as big spatial data. Overtime, the demand for storage and effective handling of big spatial data increased resulted to development (Song, & Wu, 2021).

2.5.2 Relationship of GIS and Street addressing System

A theoretical statement by (IFS) International Federation of Surveyors (FIG, 2001)15 claims that nearly 80% of all information generated is based on particular geo-spatial components. Geospatial information is used to making critical decision-making. An integrated approach of merging GIS technology and descriptive addressing system has a vast range of benefits. First, it adds efficiency in way-finding and mapping exercise for the codification of streets and numbering of properties. The created GIS database is useful to a number of users such as the public, business proprietors, city planners among other users. For town and urban planners, a GIS- based street addressing system will make it easy for them to track and maintain public facilities; keep inventories, map location, model scenarios and distribution of services (Tao, 2013). From time to time, the database can be easily updated to keep it in line with the current trends.

GIS technology incorporates common database processes such as querying and statistical analysis with the distinctive visualization and spatial analysis benefits displayed by maps Jovanović, V. (2016)16. These capabilities distinguish GIS from other information systems making it appreciated to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies.

2.5.3 Geodatabase and Design Process

A geodatabase is a specialized type of database designed to store, query, and manage spatial data. Unlike traditional databases that primarily handle alphanumeric data, geodatabases are optimized for managing geographic information system (GIS) data, which includes both spatial (geometric) data and attribute (descriptive) data associated with geographic features Alamouri, & Gerke, (2019).

The primary feature of a geodatabase is its ability to integrate spatial data with attribute data seamlessly, allowing users to store information about geographic features such as points, lines, and polygons alongside descriptive attributes like names, addresses, and classifications. This integration enables sophisticated spatial analysis, visualization, and modeling, which are essential for applications in fields such as urban planning, environmental management, transportation, and natural resource exploration Bajjali, W. (2023).

Geodatabases support a variety of spatial data types, including points, lines, polygons, and raster data (gridded data representing continuous phenomena). They also incorporate spatial indexing techniques that optimize spatial queries for efficient data retrieval. This capability is crucial for tasks such as proximity analysis, spatial joins, and route optimization Reddy, (2018).

Moreover, geodatabases provide tools and functions specifically tailored for geographic data management, such as geocoding (assigning geographic coordinates to addresses), topology rules (defining spatial relationships between features), and network analysis (modeling complex networks like road systems) Unger, (2015).

Overall, geodatabases play a pivotal role in modern GIS applications by providing a structured framework for organizing, analyzing, and visualizing spatial data, thereby facilitating informed decision-making and resource management in diverse fields that rely on geographical information Breunig, Bradley, Jahn, Kuper, Mazroob, Rösch, Jadidi, (2020).

The geodatabase design process involves several key steps to effectively manage spatial data within a database system. First, translating a conceptual model into a logical data model ensures that entities and relationships are accurately represented in a relational database schema. This step establishes tables for entities like Streets, Addresses, Parcels, Service Areas, and Routes, with primary and foreign keys maintaining relational integrity Chesnaux, Lambert, Walter, Fillastre, Hay, Rouleau, Germaneau, (2011).

Next, defining data types and constraints assigns appropriate attributes (e.g., text, number, date, geometry) and constraints (e.g., not null, unique) to ensure consistent data storage and validity. Normalizing the database further optimizes data integrity by minimizing redundancy and eliminating anomalies Albarak, Bahsoon, Ozkaya, & Nord, (2020).

For the physical database design, a GIS Geodatabase is chosen as the Database Management System (DBMS) due to its specialized capabilities in handling spatial data. Storage structures such as tables, indexes, and spatial indexes are selected to enhance query performance, supporting tasks like street addressing, service area analysis, and route analysis Breunig, Bradley, Jahn, Kuper, Mazroob, Rösch, Jadidi, (2020). Loading initial data and implementing mechanisms for ongoing updates, including geocoding and data validation, maintain data accuracy and reliability over time.

Lastly, configuring the database for spatial analysis involves setting up functions and workflows that enable operations like proximity analysis and route planning Scheider, & de Jong, (2022). This systematic approach underscores the importance of structured data organization and leveraging spatial analysis capabilities to support applications in urban planning, transportation management, and other fields dependent on spatial information.

Evaluation Factors for GIS-based Street Addressing System

An ideal Street addressing system for management of revenue should at least fulfil the following basic requirements (Muinde, 2017).

1. Simplicity and clarity: should be developed on a concept that is clear and easily understandable by public.
2. Employ a predictable numbering system that will enable user to envisage places at first instance allowing time saving and accurate locating of places.
3. Improve communication and decision-making.
4. Expandable and updatable: Street addressing must have the capacity to grow the process to neighboring zones stretch to cover even the entire country in a clear and understandable procedure. The developed geo-database should be updatable to spatial changes on land and land use.

Empirical Literature Review

Several studies have been conducted on the implementation and impact of GIS-based addressing systems in various cities around the world. Kim and Kim (2016) implemented the Seoul Addressing System (SAS) in Seoul, which improved service delivery through accurate address information, faster emergency response, and enhanced navigation. Gómez and Conesa (2017) implemented the Spatial Information System (SIO) as part of their Smart City initiatives, leading to improved service delivery, better decision-making, and data integration. Lategan and Coetzee (2017) developed the Informal Settlements Addressing System (ISAS), providing formal addresses to previously unaddressed areas, resulting in improved service delivery and access to government services. Randal and McLean (2019) implemented a GIS- based addressing system that enhanced emergency response, resource coordination, and service delivery.

Other studies focused on specific aspects of GIS-based addressing systems. Smith et al. (2015) evaluated the impact of such a system on emergency response times, emphasizing data accuracy and system integration. Chen and Liu (2018) examined resource allocation and service efficiency, emphasizing the need for proper training and ongoing maintenance. Gonzalez and Martinez (2017) assessed service accessibility, highlighting the role of public awareness campaigns. Wang and Li (2019) investigated the impact on service delivery in rural areas, considering challenges such as limited connectivity. Rodriguez and Gomez (2016) analyzed the impact in a developing country, emphasizing government support and technical capacity building.

These studies collectively emphasize the importance of accurate data, stakeholder collaboration, public awareness, ongoing maintenance, and integration with existing systems in implementing GIS-based addressing systems. While these findings provide valuable insights, further research is needed, especially in developing country cities like Adama, where such systems are lacking.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Description of the Study Area

3.1.1. Location

Adama is Ethiopia's third-largest town, located about 100 kilometers southeast of Addis Ababa on the main road to Harar. At an average altitude of 1620 meters above sea level, it is located between 8°35'00" and 8°36'00" North latitude and 39° 11' 57" to 39° 21'15" East longitude (Fig. 3.1). Adami, which means cactus tree in Afan Oromo, is the general name for a little milky plant Kefale, A. T., & Shebo, H. H. (2019)17.

Adama's founding and location were impacted by a variety of circumstances. The rise and development of the town are dependent on favorable economic, social, and topographical conditions. The Italian occupation of Adama, which lasted from 1936 to 1941, had a significant impact on the town's development. During their stay in town, the Italians completed a number of construction projects, including road, transportation, and communication, all of which aided the town's expansion.

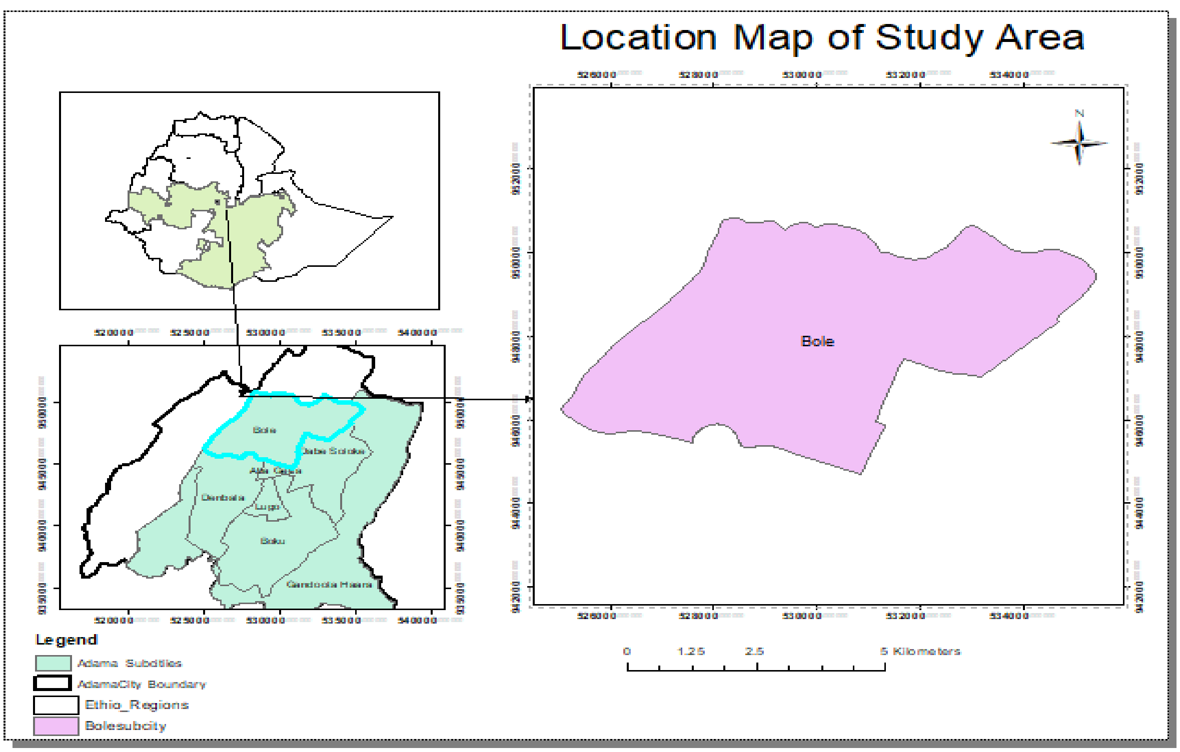

Figure 3.1. Location map of the study area

The developments of infrastructure services and amenities such as education, health, water supply, energy supply, and recreation, as well as the expansion of transportation and communication, have all contributed significantly to the town's development. The town became a major point of communication for passengers after highways were built and improved from Addis Ababa via Adama to Wonji, Assela, and Harar.

Adama's strategic location and suitable climatic conditions have aided the city's rapid growth as an economic, industrial, residential, and recreational hub. The Awash valley, with its economic potential and future expansion, is one of the major elements contributing to the towns and nearby region's growth and development. The town benefited from the development of the Koka Hydro-Electric Power Station in 1958. It boosted the agricultural economy while also meeting the needs of industrial and urban customers in Adama and its environs. Modernization in various disciplines, particularly health, education, and communication, has resulted in the construction of new structures from time to time. Galawdiwos School and Hailemariam Mamo Hospital, for example, were constructed in 1948 and 1964, respectively.

Adama has grown into a large town with a land area of 4320 hectares. Adama has excellent development potential and is expected to play a significant role in the systematic and integrated development of the nearby urban and rural areas due to its strategic location along the railway line that connects the port of Djibouti with Addis Ababa and at the intersection of major routes to Addis Ababa, Arsi, Harar, and other hinterland areas of high economic importance (Tefera, 2010)18.

3.1.2. Topography

In the Great Rift Valley region of east Africa, Adama Town is located in the flat lowland between the mountain peaks Kechema and Kurfagutu. Its physiographic condition is thus primarily the consequence of past volcano-tectonic events. Still, it is partly the result of sediment deposition, primarily of fluvial and lacustrine origin. With a likelihood of 0.99 earthquakes every 100 years, Adama is considered a seismically active place in earthquake hazards. Adama's elevation ranges from 1600 to 1970 meters above sea level. Awash is the only perennial river in the neighborhood of Adama, into which all of the town's streams discharge (Tefera, 2010)18.

3.2. Data and

Software Data Source

The studies were mainly supported by geospatial datasets gathered from different sources.

Table3.1: Data and their Sources

No	Data	Source
1	Cadastral Data (Land Parcel Data)	Adama Bole Sub city
2	Street Data	Adama Municipality
3	Administrative Boundary	Adama Municipality
4	Service Area	Adama Municipality

Software Used

The following software applications were utilized for the Development of a GIS-based Street Addressing System for Enhanced Service Delivery in Adama City: A Case of Bole Sub City.

Table 3.2 Required Software

No.	Software	Purpose
1	ArcGIS 10.8	For Mapping and Analysis
2	QGIS Plugins	For Geocoding
3	Microsoft Excel	For Organizing Data

3.3. Method of Data Analysis

3.3.1 Data Collection

The research methodology involved collecting data on street networks, land parcels/plots, and existing addressing systems within Bole Sub City of Adama City. The purpose of this data collection phase was to gain insights into the current state of addressing systems and establish a foundation for developing a GIS-based Street addressing system. The following steps were undertaken: Initially, digital cadastral maps of Bole Sub City in Adama City were obtained from the Adama Municipality Land Management Office. Additionally, essential spatial information, including street layouts, major landmarks, and other geographical features, was gathered from Google OpenStreetMap (OSM).

To validate and supplement the collected data, field surveys were conducted. This involved physically verifying the information, capturing any additional details, and ensuring the accuracy and reliability of the data. Subsequently, the collected data from various sources were integrated and consolidated into a single dataset. This process entailed combining the digital maps, land records, and existing addressing databases to create a comprehensive and up-to- date dataset. The aim was to have a reliable and unified dataset that could serve as the basis for further analysis and the development of the GIS-based Street addressing system.

3.3.2 Street Codification

In this research methodology step, the development of a standardized coding system for streets in Adama city was carried out. The objective was to assign unique identifiers to each street segment, ensuring precise and consistent addressing. The following activities were undertaken in the past:

Firstly, existing street coding systems used in Adama city, as well as in other relevant cities or countries, were thoroughly reviewed and analyzed. This review provided valuable insights into established practices, conventions, and standards for street codification.

Based on the review and analysis, key coding elements were identified. These elements encompassed street names, types (e.g., avenue, road, boulevard), directions (e.g., north, south), block numbers, and other relevant attributes crucial for uniquely identifying each street segment. subsequently, a coding scheme was developed that incorporated the identified coding elements. This scheme defined the structure, format, and rules for assigning unique identifiers to street segments. It was tailored to accommodate the specific characteristics and requirements of Adama city.

To ensure consistency and uniqueness, the coding scheme was designed meticulously. It guaranteed that no two street segments shared the same identifier, and the coding system followed a logical and standardized pattern that facilitated easy identification and navigation. The assigned street identifiers were then integrated into a comprehensive database, which included the street network and associated attributes. This database served as a reliable reference for accurate addressing and was utilized in the subsequent stages of the development of the GIS-based Street addressing system.

3.3.3 Address Assignment

In this research methodology step, the GIS platform was utilized to assign addresses to individual land parcels/plots within the study area of Adama city. This process involved linking each parcel to its corresponding street segment and assigning a unique address. The following activities were undertaken:

Firstly, the geospatial data of land parcels/plots and the street network were integrated using the GIS platform. This integration established the spatial relationship between the parcels and the streets, laying the foundation for accurate address assignment. Through the application of spatial analysis techniques, each land parcel/plot was linked to its corresponding street segment. This linkage was established based on proximity and spatial overlap, ensuring the correct association between each parcel and its respective street.

Address assignment rules were established to determine the structure and format of the assigned addresses. These rules took into consideration factors such as block numbers, parcel location within the street segment, and any existing addressing conventions or standards. The aim was to ensure the uniqueness, consistency, and logical sequencing of the assigned addresses. Using the GIS platform and the established address assignment rules, a unique address was allocated to each land parcel/plot. The assigned addresses consisted of the necessary components, including the street name, block number, and any additional address elements required for accurate location identification.

The assigned addresses, along with the corresponding land parcel/plot information, were compiled into an address database. This database served as a centralized repository of addresses and associated attributes, enabling efficient access and retrieval of address information as needed.

Overall, this research methodology step involved the utilization of the GIS platform to link land parcels/plots with street segments and assign unique addresses. The process encompassed data integration, spatial analysis, rule-based address assignment, validation, and the creation of an address database. These efforts aimed to establish a reliable and accurate addressing system within the study area of Adama city.

3.3.4 GIS Geo-database Design

In this research methodology step, a comprehensive GIS geo-database was designed to incorporate the street address index, land parcel information, and service area boundaries. The aim was to facilitate efficient retrieval and analysis of address-related data. The following activities were undertaken:

The design of the GIS geo-database began with the development of a data schema. This schema defined the structure and organization of the database, including the tables, fields, and relationships necessary to store address-related data. The design process took into account the specific data elements required for the street address index, land parcel information, and service area boundaries. The street address index, including the assigned addresses and associated attributes, was integrated into the geo-database. A dedicated table or layer was created to store the address data, ensuring proper linkage to the corresponding street segments and land parcels/plots.

Land parcel information, such as parcel boundaries, ownership details, and other relevant attributes, was included in the geo-database. This information was stored in a separate table or layer, establishing the spatial relationship between land parcels and addresses. The boundaries of service areas, such as administrative divisions or specific jurisdictional zones, were also integrated into the geo-database. This integration enabled the association of addresses and land parcels with their respective service areas, facilitating targeted analysis and service provision.

To ensure data integrity and efficient retrieval, relationships were established between the different tables or layers within the geo-database. For example, a relationship could be established between the street address index and land parcel information based on a unique identifier or spatial proximity. These relationships facilitated seamless data integration and retrieval within the GIS environment.

3.3.5 Service Area Identification

In this research methodology step, GIS functionality was utilized to define and identify service areas within Adama city based on the street addressing system. Various GIS techniques, such as proximity analysis, network analysis, and spatial queries, were employed to determine the coverage of specific services. The following activities were undertaken:

The specific services to be analyzed and identified were determined. This involved selecting services such as public utilities, healthcare facilities, educational institutions, or other relevant services that could be delineated based on the street addressing system.

Proximity analysis techniques were used to assess how closely each street segment is located to the desired service location or facility. This analysis took into account the distance or travel time between street segments and service points, facilitating the identification of potential service areas. Network analysis tools within the GIS platform were employed to evaluate the connectivity and accessibility of street segments across Bole sub-city in Adama city. Factors such as road network hierarchy, traffic flow, and transportation infrastructure were considered to pinpoint areas that could be effectively served by specific services. Spatial queries were conducted to identify street segments located within a specified radius or proximity of the desired service location. This process aided in defining the boundaries and extent of each service area based on the street addressing system.

The results of the proximity analysis, network analysis, and spatial queries were integrated into the GIS environment. This involved overlaying the identified service areas on the street addressing system, creating a spatial representation of the coverage areas for the specific services. The identified service areas underwent validation and refinement processes. Stakeholders, such as service providers, local authorities, or community representatives, were consulted to ensure the accuracy and appropriateness of the delineated service areas.

3.3.6 Address Point Placement

In the Address Point Placement methodology step of this research, advanced Geocoding techniques were employed to optimize the placement of address points within the GIS system, aiming to ensure accurate geolocation of addresses and facilitate efficient service delivery. To accomplish this, several activities were undertaken.

Firstly, data preparation was conducted to clean and standardize the address data collected from various sources. This ensured consistency and compatibility with the Geocoding process, and thorough checks were performed to ensure data completeness, accuracy, and uniform formatting.

Next, an appropriate Geocoding algorithm was selected based on the specific project requirements and available data. Different algorithms, such as address matching, spatial interpolation, or address point placement models, were evaluated to determine the most suitable approach for accurate Geocoding.

The prepared address data was then inputted into the chosen Geocoding algorithm, which processed the addresses and assigned spatial coordinates (latitude and longitude) to each address point, effectively geolocating them within the GIS system. Factors such as address components, reference data, and any additional parameters required by the selected algorithm were taken into consideration during the Geocoding process.

To ensure the accuracy and reliability of the Geocoded address points, quality assurance and validation procedures were implemented. This involved comparing the Geocoded results with ground truth data, conducting field verifications, or cross-checking with external reference sources. Any identified discrepancies or errors were corrected to enhance the overall quality of the Geocoded address points.

Finally, the Geocoded address points were integrated into the GIS system, associating each point with its corresponding address and additional attributes or information. This integration facilitated seamless spatial analysis, visualization, and querying of the address points within the GIS environment.

3.3.7 Methodological Flowchart

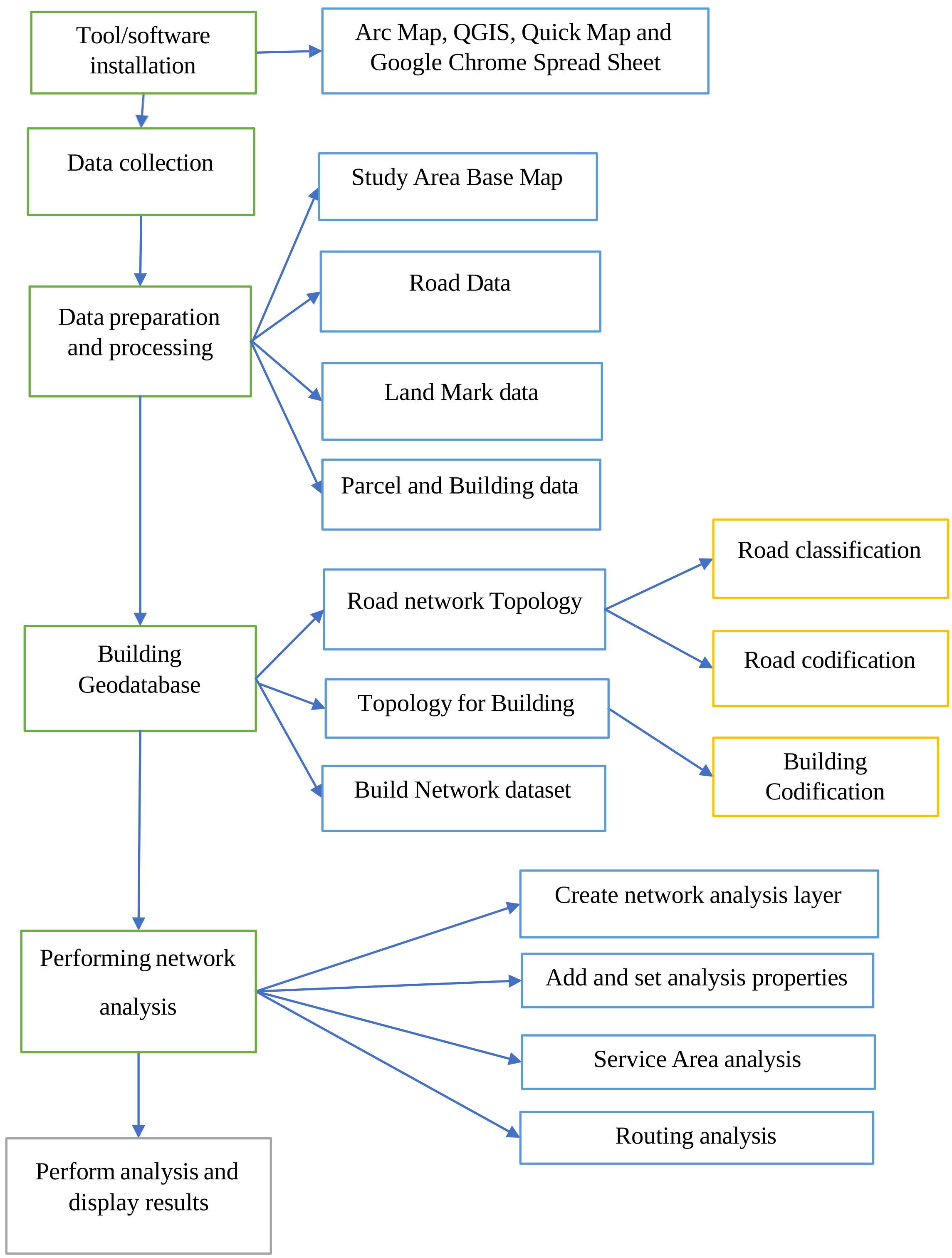

Figure 3.2 Research Methodological Flowchart

CHAPTER FOUR

RESULT AND ANALYSIS

4.1 Parcel Codification

The research findings include a detailed examination of the parcel codification map for a sample parcel located in Bole Sub City. Figure 4.1 visually represents the process and methodology used to assign unique identification codes to individual parcels within the sub city. This system is part of a larger initiative to implement a GIS-based street addressing system aimed at improving service delivery and administrative efficiency in Adama City's Bole Sub City.

The parcel codification map (Figure 4.1) is a critical component of the research, highlighting the benefits of a systematic and unique parcel identification code. This system plays a pivotal role in enhancing property management, service delivery, and administrative efficiency within Bole Sub City. The visual representation provided by the map underscores the practicality and effectiveness of the codification methodology, making it an exemplary model for other regions aiming to implement similar GIS-based systems.

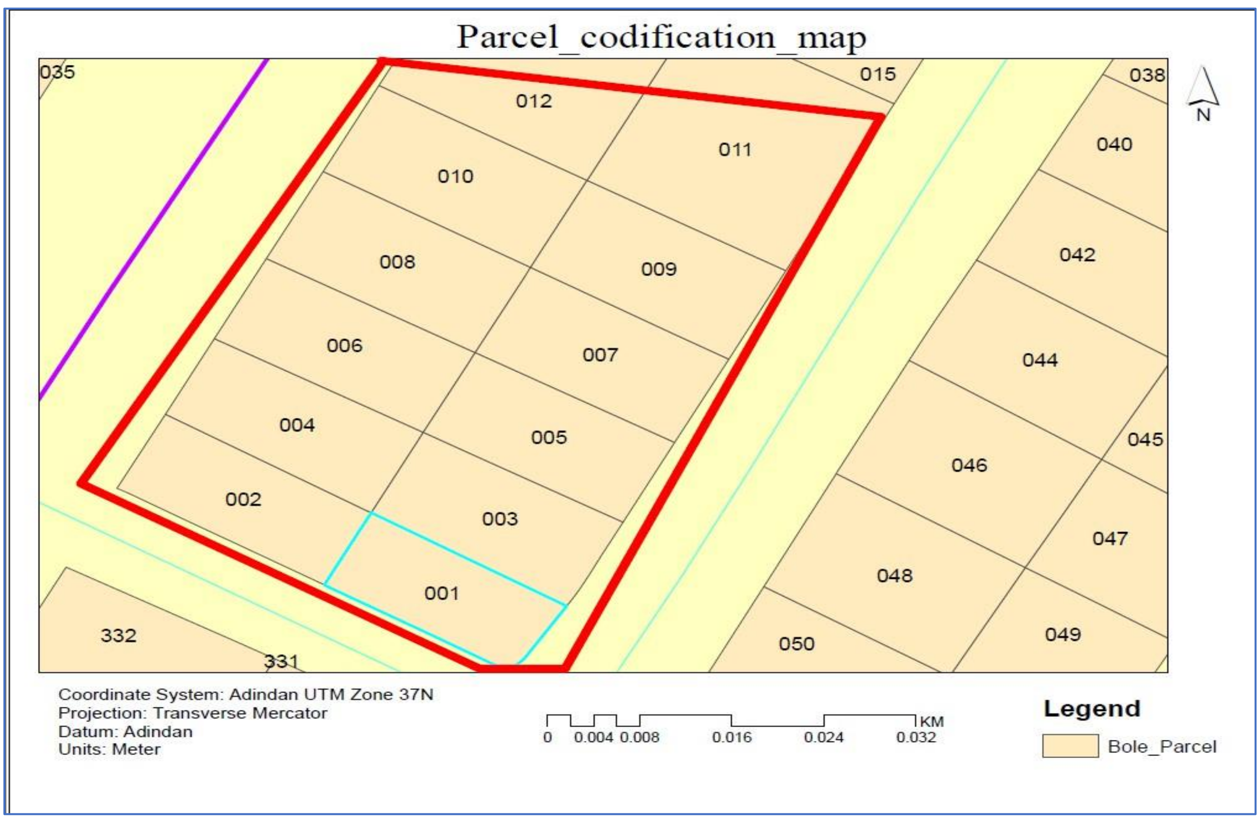

Figure 4.1 Parcel codification map

4.2 Coding visualization for Roads

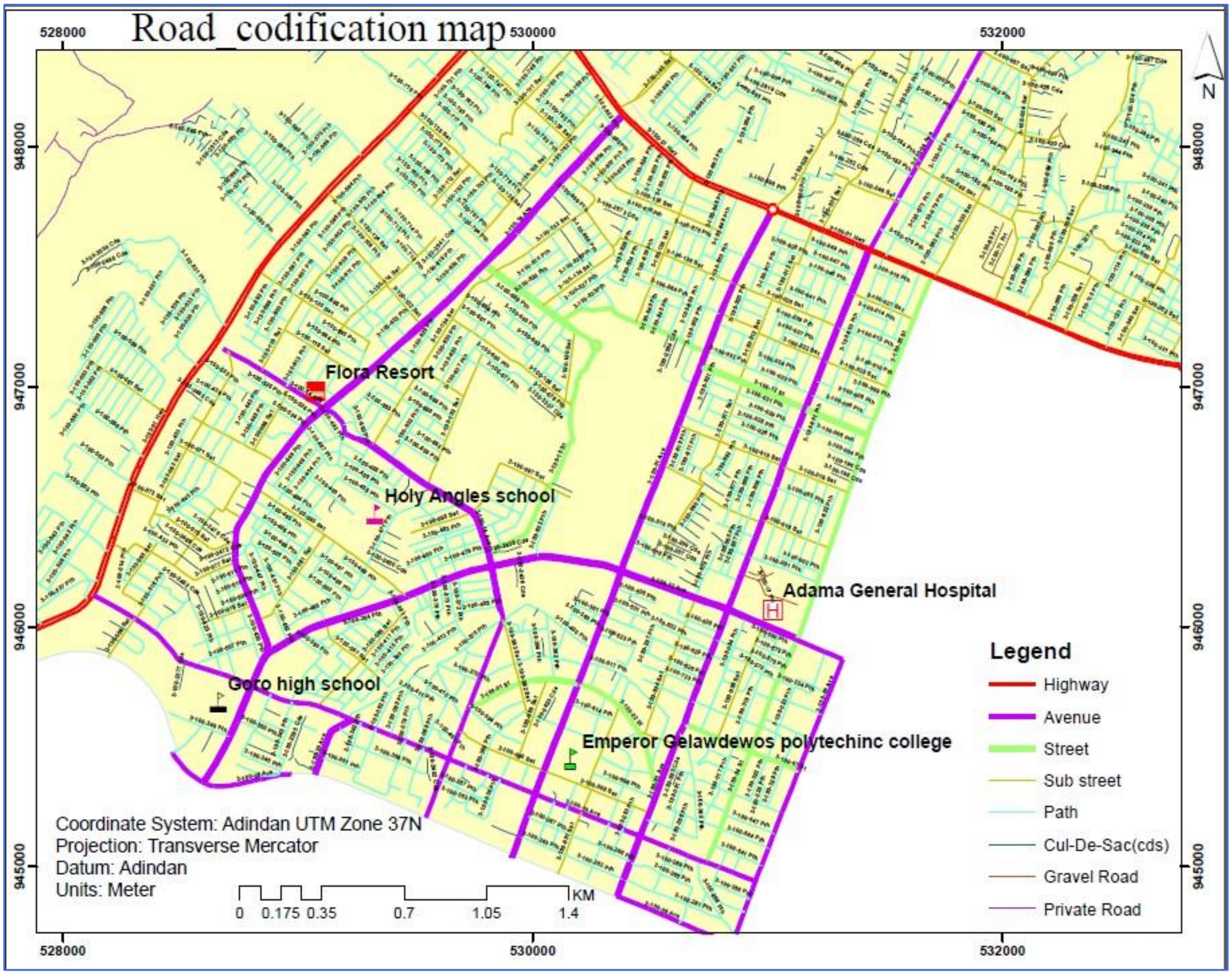

Figure 4.2 Road codification map

The provided research results showcase the road codification map of Bole Sub city and shed light on the coding methodology used.

The findings in Figure 4.2 provide a detailed examination of the road codification map for Bole Sub City, detailing the methodology employed to assign distinct codes to different road segments. This coding system plays a vital role in discerning the importance and role of each road within the transportation network, thereby enhancing navigation efficiency, infrastructure management, and service delivery.

The Principal Arterial Code, specifically "Baseline 3," suggests that the road has been classified based on its significance and function within the transportation network. "Baseline 3" likely represents a specific category within the principal arterial classification system. This classification helps identify the importance and role of the road in the overall transportation infrastructure.

The Distance from Zero Kilometer, labeled as 100, represents how far a specific road segment is from a designated starting point at zero kilometers. This zero-kilometer point acts as a reference for navigation and measurement. Understanding the distance from this reference point simplifies the process of locating and evaluating the respective road segment.

The Road Type code provides information about the type of road and appears to consist of three components. The City Reference component could be a code or abbreviation indicating the location or jurisdiction of the road within the city or urban area. The second component includes various road types such as Highway (Hwy), Avenue (Ave), Street (St), Sub Street (Sst), Path (Pth), and more. Each road type carries its own specific designation, enabling differentiation between different kinds of roads or thoroughfares.

For instance, let's consider the example of the codification for the street location of Adama General Hospital. The codification reveals that Adama serves as the reference or baseline for the path marked as 3. Additionally, the distance from the reference point or from Addis Ababa is measured as 100 units. Consequently, based on this information, we can determine the road class as 3-100-17 Pth and 3-100-12 Ave, indicating the specific characteristics and classification of the road segment associated with Adama General Hospital.

The road codification map (Figure 4.2) of Bole Sub City is a pivotal tool for understanding and managing the urban transportation network. The detailed codification system, including the Principal Arterial Code, Distance from Zero Kilometer, and Road Type Code, provides a comprehensive framework for identifying, navigating, and analyzing road segments. This system exemplifies an effective GIS-based approach to enhance service delivery and infrastructure management in Bole Sub City.

4.3 Designed Geodatabase

The result presented outlines the process of translating a conceptual model into a logical data model and designing a physical database using GIS geodatabase for managing spatial data.

a). Translating the conceptual model into a logical data model:

This step involves converting the entities and relationships from the conceptual model into a relational database schema. Tables are created for each entity, such as Streets, Addresses, Parcels, Service Areas, and Routes. Primary keys are assigned to each table, and foreign keys are used to represent relationships between the tables. This process ensures the logical organization and structure of the data.

b). Defining data types and constraints:

Appropriate data types (e.g., text, number, date, geometry) are assigned to each attribute in the database. Constraints, such as not null, unique, and check constraints, are applied to ensure data integrity and validity. This step ensures that the data is stored in a consistent and standardized manner.

c). Normalizing the database:

Database normalization techniques are applied to minimize data redundancy and optimize data integrity. Normalization helps eliminate data anomalies and ensures efficient storage and retrieval of information.

Physical Database Design:

i). Choosing a GIS Geodatabase as the DBMS:

A GIS Geodatabase is selected as the database management system. Geodatabases are specifically designed to handle spatial data and provide advanced capabilities for managing and analyzing geographic information.

ii). Determining appropriate storage structures:

Tables, indexes, and spatial indexes are selected as the storage structures for the database. These structures optimize query performance for specific use cases, such as street addressing, service area analysis, and route analysis. Indexes and spatial indexes improve the speed of spatial queries, allowing efficient retrieval of data.

iii). Loading and updating the initial data:

The initial data is loaded into the database, and mechanisms are put in place to keep the data up-to-date over time. Tasks like Geocoding (assigning spatial coordinates to addresses), data validation, and data transformation are performed to ensure the accuracy and reliability of the data.

iv). Configuring the database for spatial analysis:

The database is configured to support spatial analysis tasks. This involves setting up spatial analysis functions, tools, and workflows that enable operations such as proximity analysis, service area analysis, and route analysis. Configuring the database appropriately enhances its capabilities for spatial analysis tasks.

By incorporating the concepts of geodatabase design, street addressing, and service area analysis, the research result demonstrates the systematic and comprehensive approach to managing spatial data within a database system. It highlights the importance of organizing spatial data in a structured manner, leveraging appropriate storage structures, and utilizing spatial analysis capabilities to support various applications in urban planning, transportation management, and other fields that rely on spatial information.

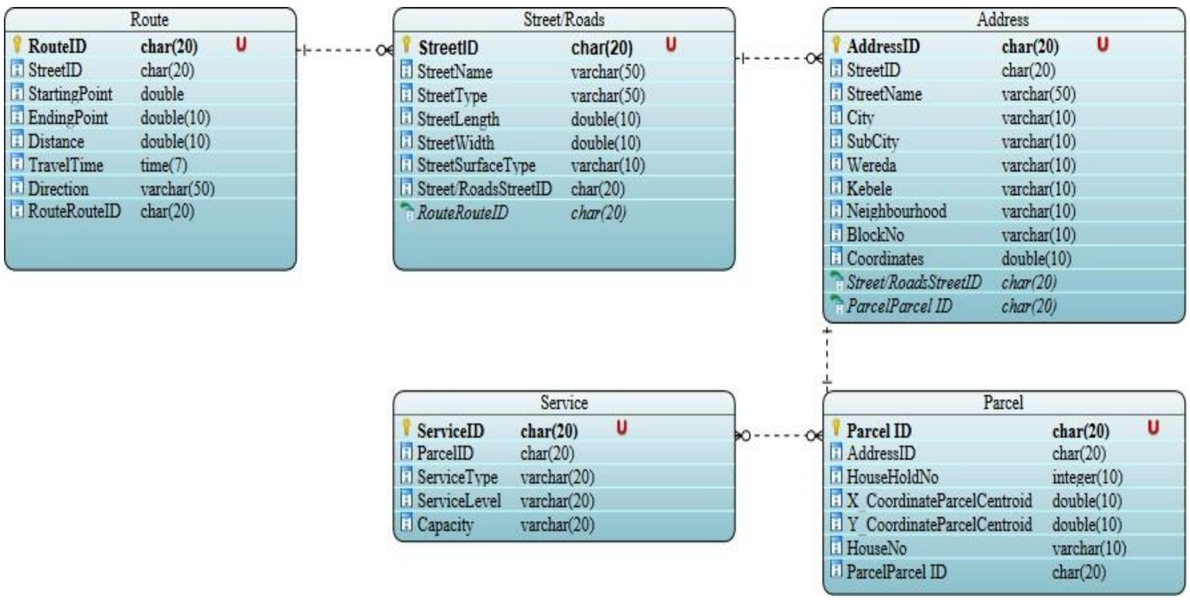

Figure 4.3 Designed Logical Database Model

4.4 Routing Analysis.

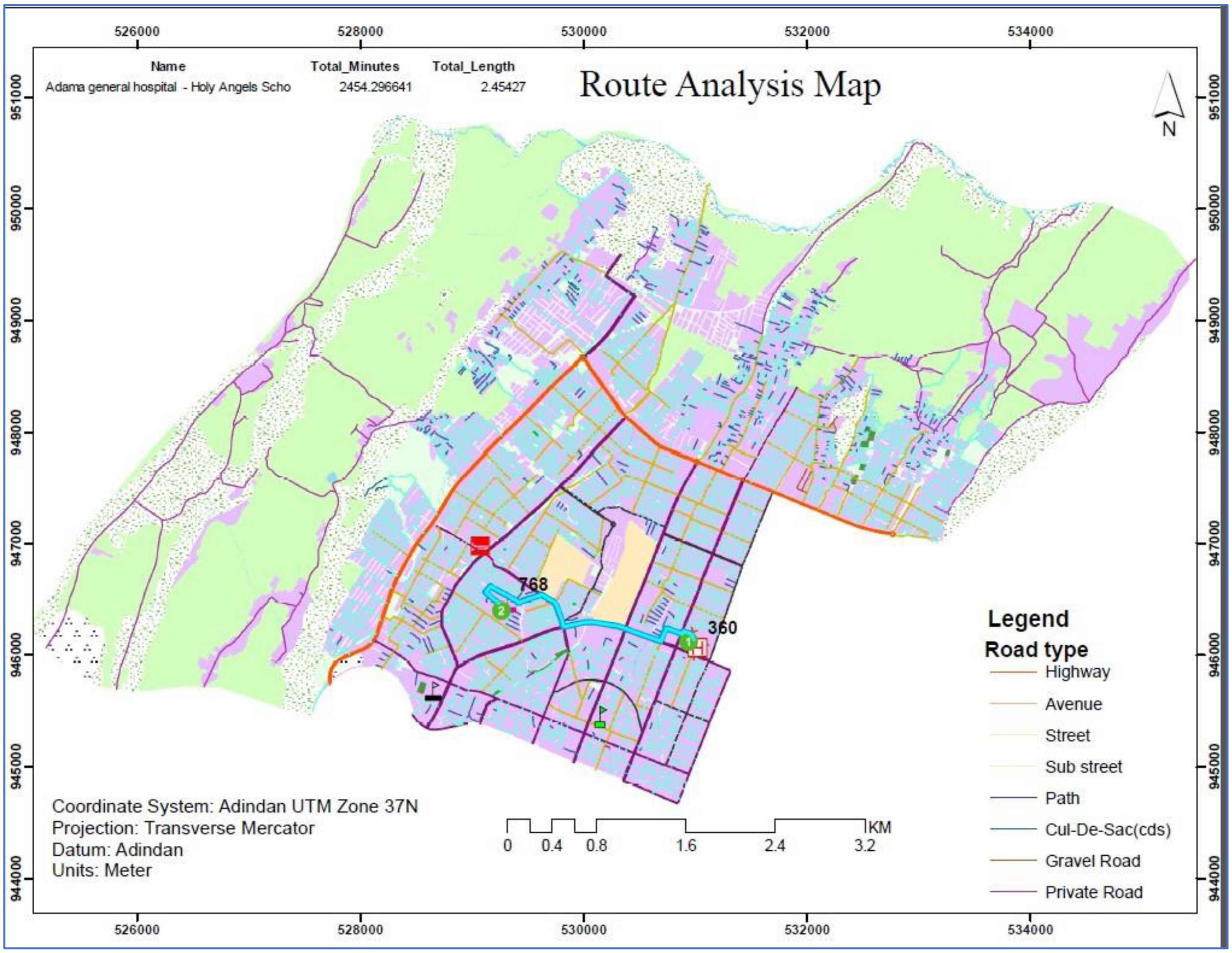

Figure 4.4 Routing analysis map of Adama General Hospital and Holy Angels School.

The research results present a routing analysis map conducted between Adama General Hospital and Holy Angels School. This map was created using ArcGIS, a powerful geographic information system tool, to determine the optimal route between these two reference points. Route analysis in ArcGIS involves evaluating various factors to find the best path for travel, making it an invaluable tool for transportation planning, logistics optimization, and efficient navigation.

Route analysis in ArcGIS refers to the process of evaluating and determining the optimal path or route between two or more locations based on various factors such as distance, travel time, road conditions, and other constraints. It is a valuable tool for analyzing and visualizing transportation networks, planning efficient routes, and optimizing logistics.

In this context, the figure demonstrates the route analysis performed using ArcGIS between Adama General Hospital and Holy Angels School. By utilizing ArcGIS's route analysis capabilities, the map provides valuable insights into the best route or path to navigate between these two reference points.

The route analysis map likely incorporates geographic data, road networks, and spatial analysis techniques to calculate and visualize the most efficient route for travel. It considered factors of distance to determine the optimal path between the two locations.

By conducting route analysis in ArcGIS, researchers can gain valuable information about the distance, travel time, and potential obstacles along the route. This analysis aids in decision-making processes related to transportation planning, logistics optimization, and efficient navigation.

Generally, the routing analysis map (Figure 4.4) of Adama General Hospital and Holy Angels School demonstrates the power of ArcGIS in determining the optimal route between two reference points. By incorporating geographic data, road networks, and spatial analysis techniques, the map provides a clear and efficient path for travel. This analysis is crucial for transportation planning, logistics optimization, and efficient navigation, offering valuable insights into distance, travel time, and potential obstacles. The results highlight the practical applications of route analysis in enhancing decision-making processes related to urban transportation and logistics management.

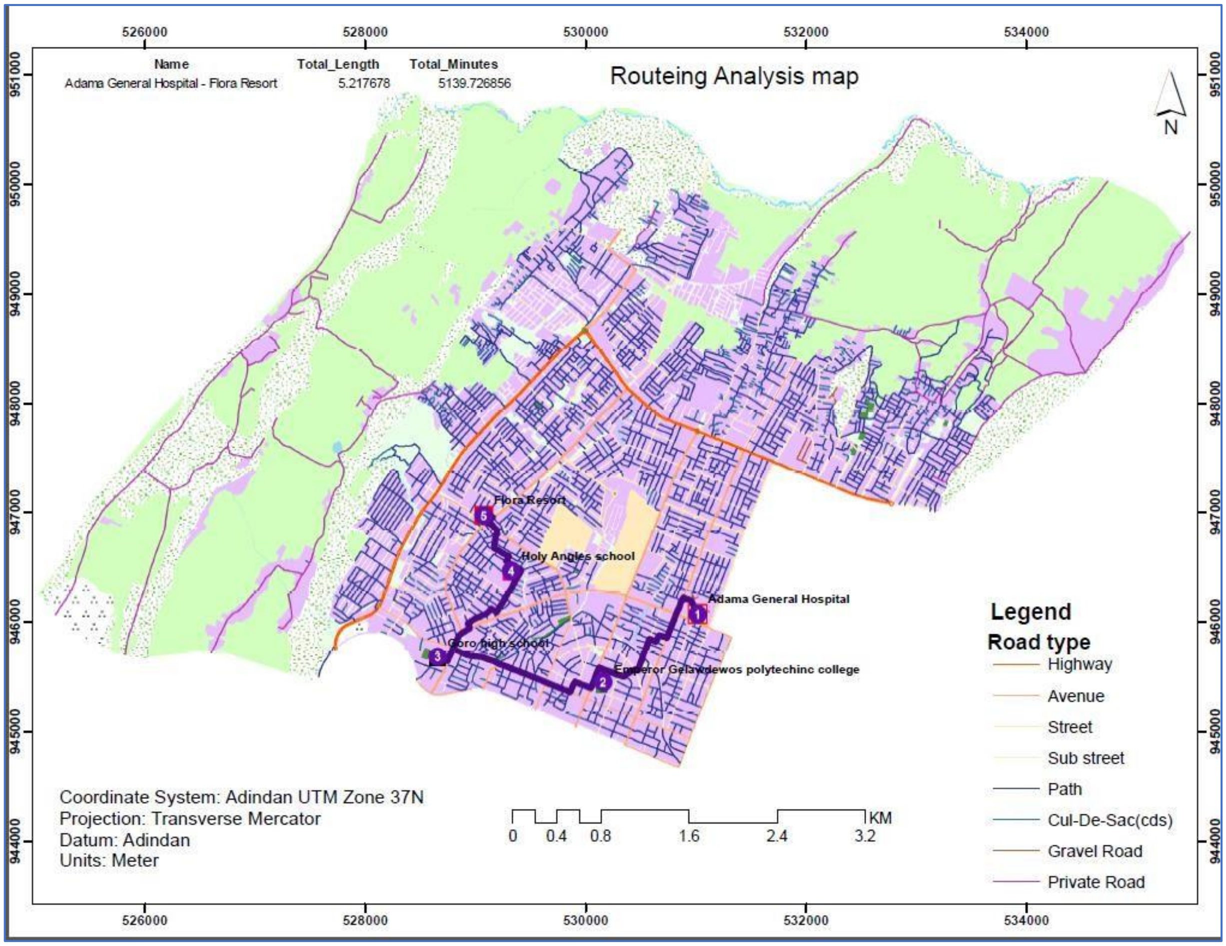

Figure 4.5 Routing analysis map

Figure 4.5 of the research presents a routing analysis map that considers the road surface condition between starting and ending points.

The routing analysis map offers valuable insights into the optimal route for navigation based on the consideration of road surface condition. By incorporating these factors, the map aims to provide users with the most efficient and convenient path from the starting point to the destination. The road surface condition refers to the physical state of the road, including factors such as smoothness, potholes, repairs, and overall quality. By considering the road surface condition in the routing analysis, the map aims to prioritize routes that have better road conditions, ensuring a smoother and more comfortable journey for the travelers.

Overall, the research result depicted in the map (Figure 4.5); offers a valuable depiction of the routing analysis that considers both road surface condition and traffic condition. By providing insights into the optimal route based on these factors, the map aims to enhance the navigation experience and improve overall travel efficiency for users.

4.5 Service Area Analysis.

The provided research result showcases a service area analysis map for Flora Resort located in Adama Bole. The map establishes service areas within specific distance ranges, namely 0-200m, 200-500m, and 500-1000m. Service area analysis is a spatial analysis technique used to determine the coverage or reach of a facility or service within a given area. It helps identify the geographic extent or boundaries within which the services offered by a particular location can effectively serve customers or clients.

The research results also showcase a service area analysis map for Flora Resort located in Adama Bole. This map delineates service areas within specific distance ranges: 0-200m, 200-500m, and 500-1000m. Service area analysis is a spatial technique used to determine the geographic coverage or reach of a facility or service within a given area.

In the context of the research result, the service area analysis map for Flora Resort highlights the zones or areas that fall within different distance ranges from the resort. The distance ranges, such as 0-200m, 200-500m, and 500-1000m, represent concentric circles or buffers around the resort, indicating the varying distances customers are willing to travel to access the services provided by the resort.

The importance of service area analysis lies in its ability to provide valuable insights for businesses or facilities. By understanding the extent of their service areas, establishments like Flora Resort can make informed decisions about marketing strategies, target audience, and resource allocation. It helps them determine the potential customer base and identify areas that might require additional marketing efforts or expansion plans. Service area analysis also aids in assessing competition within specific distance ranges. By analyzing overlapping service areas of competitors, businesses can identify areas where they have a competitive advantage or areas that are underserved, presenting opportunities for growth and market expansion.

Additionally, service area analysis assists in evaluating transportation logistics, infrastructure requirements, and resource allocation. It helps businesses optimize their operations by identifying areas that can be efficiently served and areas that might require additional infrastructure development or transportation considerations.

Overall, the research result depicted in the map demonstrates the service area analysis for Flora Resort, showcasing the coverage of service areas within different distance ranges. By conducting service area analysis, businesses can gain valuable insights into their market reach, competition, and resource allocation, enabling them to make informed decisions and enhance their overall service delivery.

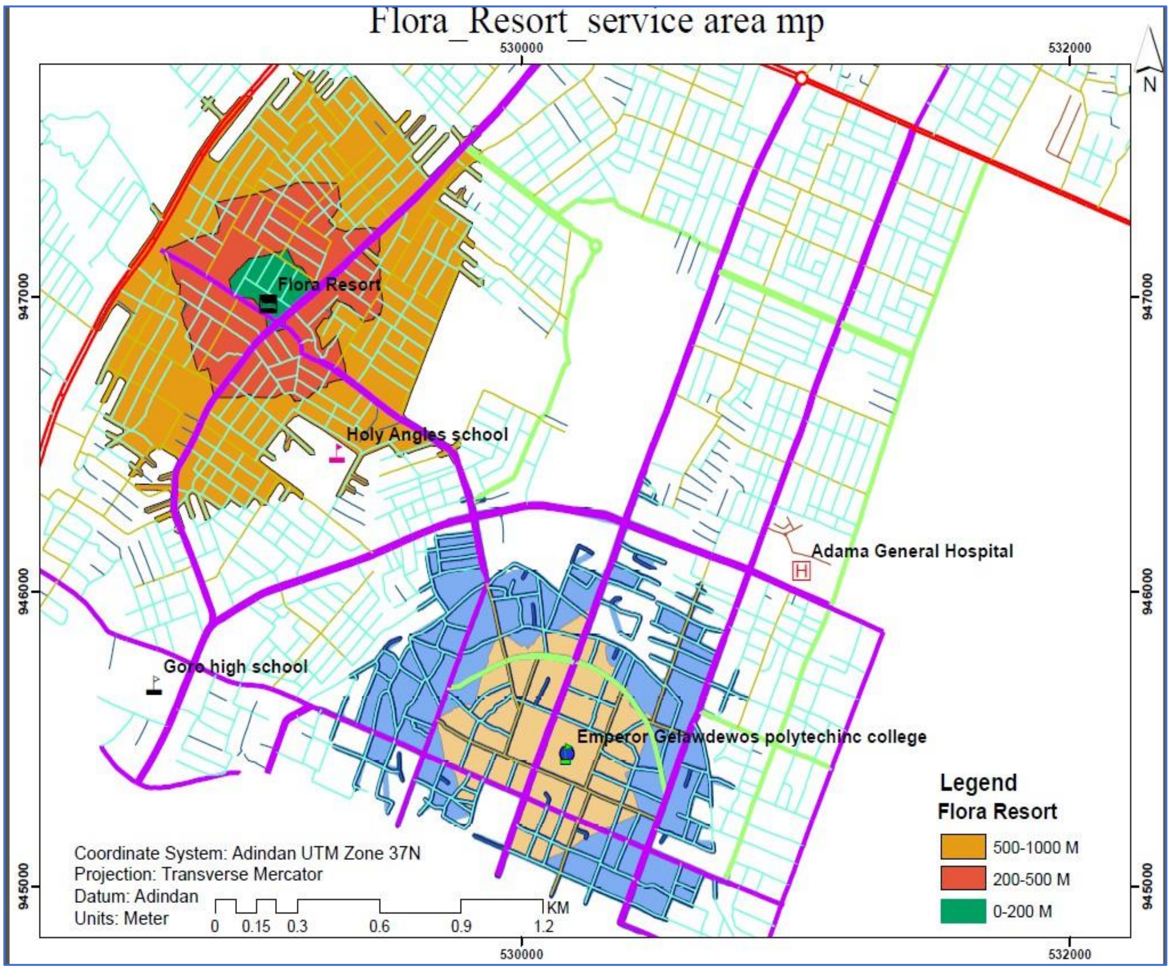

Figure 4.6 Flora Resort Service Area Map

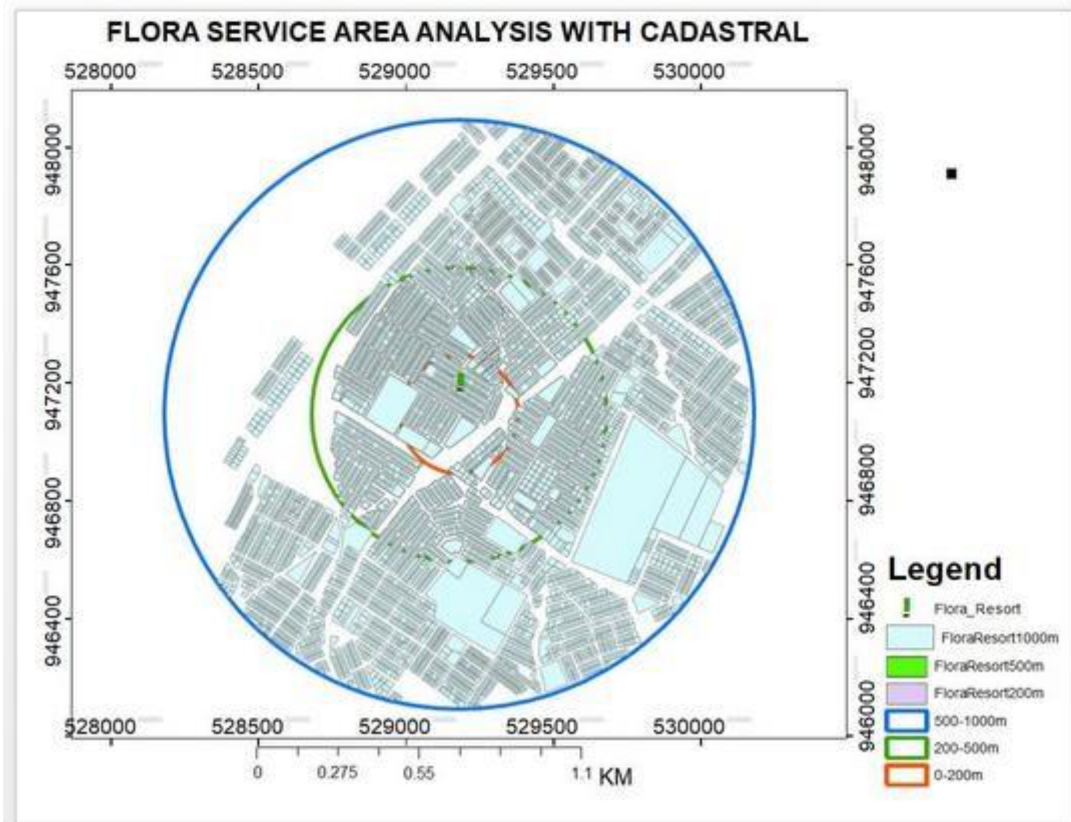

Figure 4.7 Flora Resort Service Analysis Map

The research result presented in the above figures indicates the extent of coverage provided by the Flora resort within different radii. Specifically, the figures show the number of parcels served by the Flora resort within three different radii: 200 meters, 500 meters, and 1000 meters. According to the figures, within a radius of 200 meters, the Flora resort serves a total of 276 parcels. This means that the resort is located in close proximity to these parcels, allowing easy access and potential utilization of its facilities and services by the residents or owners of those parcels.

Expanding the radius to 500 meters, the Flora resort serves a significantly larger number of parcels, with a total of 2036 parcels falling within this range. This indicates that the coverage area of the resort extends further, encompassing a larger portion of the surrounding region. Further increasing the radius to 1000 meters, the Flora resort serves an even greater number of parcels, with a total of 6286 parcels falling within this range. This suggests that the coverage area of the resort expands significantly, reaching out to a larger population and potentially attracting visitors or customers from a wider area.

The research result highlights the spatial distribution and coverage of the Flora resort within different radii. It demonstrates the influence and reach of the resort in terms of its accessibility and potential customer base. The figures provide valuable information for stakeholders and decision-makers interested in understanding the resort's market potential, catchment area, and potential demand.

It is important to note that the research result considers only the number of parcels served within each radius and does not provide information about the specific characteristics or demographics of the parcels or the level of utilization by the parcel owners or residents. Further analysis and research could be conducted to explore additional factors such as the socioeconomic profile of the served parcels, customer preferences, or the impact of the resort's presence on the surrounding area in terms of economic development or property values.

The research result presented in the figures can be further elaborated by considering service area analysis and the concept of street addressing.

Service area analysis is a spatial analysis technique that examines the extent to which a particular facility or service can reach and serve a given area. In the context of the Flora resort, the figures indicate the number of parcels served within different radii. This information can be used to assess the effectiveness and coverage of the resort's service area. By analyzing the distribution of served parcels, it becomes possible to identify areas that may be underserved or areas where the resort has a strong presence.

In relation to street addressing, the concept plays a crucial role in understanding the research result. Street addressing is a system that assigns unique addresses to buildings or parcels based on their location within a street network. It provides a standardized way of identifying and referencing specific locations. In the research result, the number of parcels served by the Flora resort within different radii can be attributed to the proximity of these parcels to the resort's location as determined by the street addressing system. The addresses associated with each parcel help establish the relationship between the parcels and the resort.

Additionally, street addressing facilitates efficient service area analysis. By leveraging the street network, it becomes possible to calculate distances and travel times between different locations, which are essential for defining service areas. The figures presented in the research result, such as the number of parcels served within specific radii, rely on the underlying street addressing system to determine the proximity of each parcel to the resort.

Analyzing the research result in conjunction with service area analysis and the concept of street addressing allows for a more comprehensive understanding of the spatial relationship between the Flora resort and the surrounding parcels. It helps identify the reach and coverage of the resort's services based on its proximity to different areas within the defined radii. Furthermore, it highlights the importance of a well-established street addressing system in accurately assessing service areas and conducting spatial analyses.

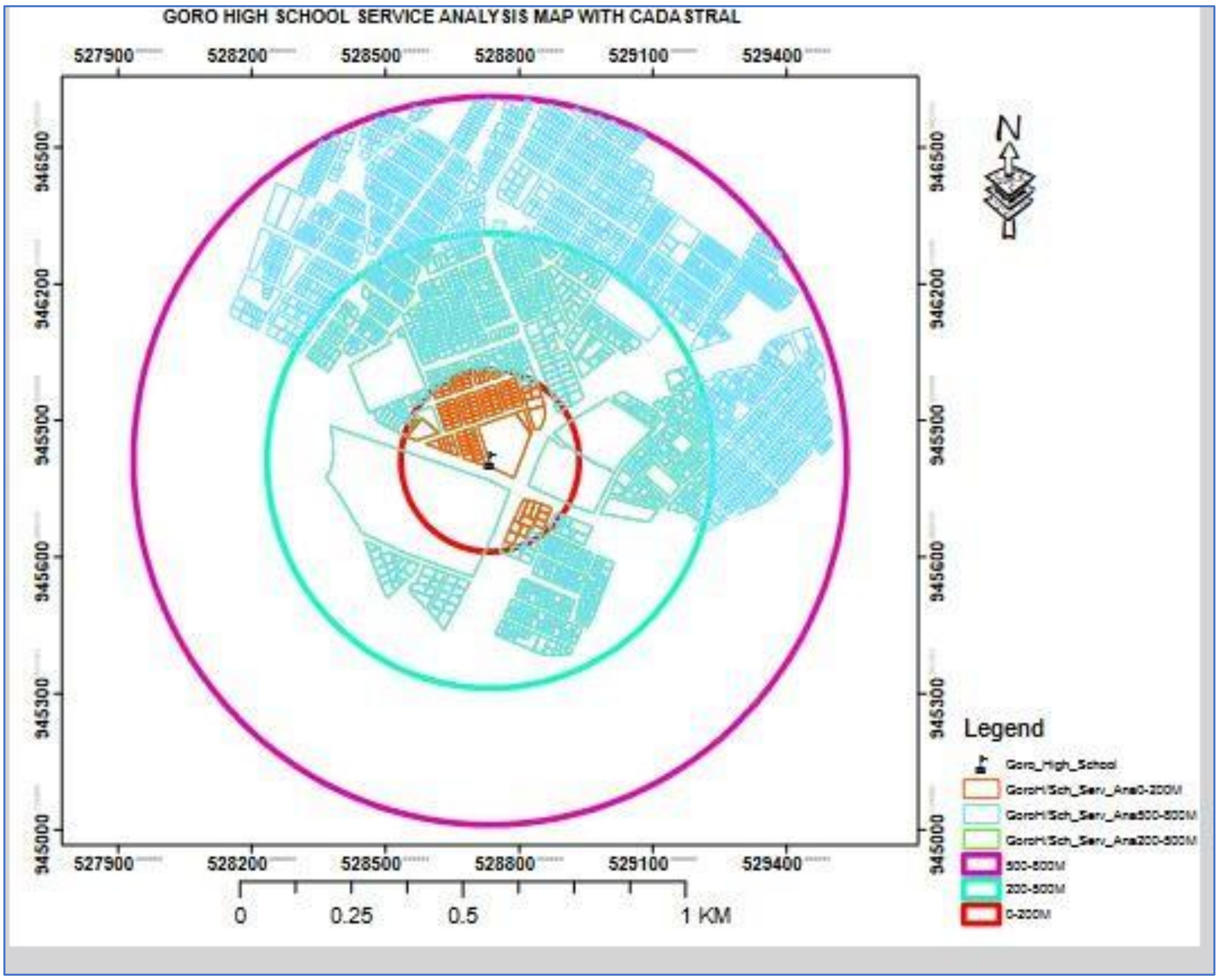

Figure 4.8 Goro High School Service Analysis Map

The research result presented in the figures illustrates the coverage provided by Goro High School within different radii. The figures display the number of parcels served by the school within three specific radii: 200 meters, 500 meters, and 800 meters.

According to the figures, within a radius of 200 meters, Goro High School serves a total of 99 parcels. This indicates that the school is in close proximity to these parcels, allowing students living in these areas easy access to the school. The small number of parcels served within this radius suggests that the school primarily caters to students residing in the immediate vicinity. Expanding the radius to 500 meters, the coverage area of Goro High School increases significantly, encompassing a larger number of parcels. Within this radius, the school serves a total of 929 parcels. This implies that the school's influence extends beyond its immediate surroundings, attracting students from a broader area within a reasonable distance.

Further expanding the radius to 800 meters, Goro High School serves a larger number of parcels, with a total of 2342 falling within this range. This suggests that the school has a wider catchment area and draws students from a more extensive region. The larger coverage area within this radius indicates that students from various neighborhoods or residential areas attend Goro High School. The research result highlights the spatial distribution and reach of Goro High School within different radii. It provides insights into the school's accessibility and potential student population. By analyzing the number of parcels served, stakeholders and decision-makers can assess the school's capacity, demand, and potential need for expansion or resource allocation.

It is important to note that the research result focuses solely on the number of parcels served within each radius and does not provide information on the specific characteristics of the served parcels or the demographics of the students attending the school. Further analysis could be conducted to explore factors such as the socioeconomic profiles of the served areas, student enrollment patterns, or the impact of the school's presence on the surrounding community.

This information can be used to assess the effectiveness and coverage of the school's service area. By analyzing the distribution of served parcels, one can identify areas that may have limited access to the school and areas where the school has a strong presence. In the research result, the number of parcels served by Goro High School within different radii can be attributed to the proximity of these parcels to the school's location as determined by the street addressing system. The addresses associated with each parcel help establish the relationship between the parcels and the school. Additionally, street addressing facilitates efficient service area analysis. By leveraging the street network, it becomes possible to calculate distances and travel times between different locations, which are essential for defining service areas. The figures presented in the research result, such as the number of parcels served within specific radii, rely on the underlying street addressing system to determine the proximity of each parcel to the school.

Analyzing the research result in conjunction with service area analysis and the concept of street addressing allows for a more comprehensive understanding of the spatial relationship between Goro High School and the surrounding parcels. It helps identify the reach and coverage of the school's services based on its proximity to different areas within the defined radii. Furthermore, it highlights the importance of a well-established street addressing system in accurately assessing service areas and conducting spatial analyses.

By considering service area analysis and street addressing, stakeholders and decision-makers can gain insights into the accessibility of Goro High School and its potential impact on the surrounding community. This information can inform educational planning, transportation infrastructure, and resource allocation to ensure that the school adequately serves the needs of the student population within its service area. Overall, the research result, when considered in conjunction with other relevant data, can provide valuable insights for educational planning, resource allocation, and understanding the school's role within the community.

4.6 Address Point Geocoding

Table 4.1 Geocode Data

S. No.	Name	Country	State	City	Full Address	Latitude	Longitude
1	Adama General Hospital	Ethiopia	Oromia	Adama	Adama General Hospital Ethiopia Oromia Adama	8.5615235	39.282495
2	Emperor Gelawdewos Poly Technique College	Ethiopia	Oromia	Adama	Emperor Gelawdewos polytechnic college Ethiopia Oromia Adama	8.555132	39.2745509
3	Goro high school	Ethiopia	Oromia	Adama	Goro high school Ethiopia Oromia Adama	8.5571127	39.2611139
4	Holy Angles school	Ethiopia	Oromia	Adama	Holy Angles school Ethiopia Oromia Adama	8.5263486	39.2583293
5	Flora Resort	Ethiopia	Oromia	Adama	Flora Resort Ethiopia Oromia Adama	8.5686951	39.2651755

Figure 4.9 Address Point Geocoding of Adama General Hospital, Holy Angels School and Flora Resort.

The above figure shows address point Geocoding methods implemented in QGIS with a base map of quick map services. Address point Geocoding is a critical component in service area analysis, as it provides precise and accurate location information for addresses within a research study. This research output highlights the importance of address point Geocoding in various aspects of service area analysis. By accurately determining service area boundaries and mapping customer locations, businesses can efficiently allocate resources, tailor marketing strategies, optimize routing and navigation, and gain insights for competitive analysis and expansion planning. The integration of geocoded address points with other spatial datasets enhances the depth of analysis and enables informed decision-making based on geographic factors. This research output emphasizes the significance of address point geocoding in enhancing the precision, efficiency, and effectiveness of service area analysis for businesses and organizations.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In summary, this research study provides a comprehensive understanding of several spatial analysis techniques employed in Adama City's Bole Sub City, including the parcel codification system, GIS-based street addressing system, route analysis, routing analysis, and service area analysis. These techniques have been successfully developed and implemented, demonstrating their significance in improving various aspects of service delivery, navigation, resource allocation, competitive analysis, and decision-making processes.

One of the key findings of this research is the importance of accurate and precise geocoding. Geocoding plays a crucial role in assigning unique identification codes to parcels and addresses, enabling efficient tracking, management, and referencing of property information. By accurately geocoding addresses and integrating them with other spatial datasets, businesses, organizations, and urban planning authorities can enhance the precision, efficiency, and effectiveness of service area analysis.

Furthermore, the research highlights the successful development of a spatial geodatabase. This geodatabase serves as a centralized repository for storing and managing the parcel codification system, street addressing system, and their relationships. The geodatabase facilitates the integration and analysis of spatial data, enabling researchers and practitioners to make informed decisions based on geographic factors.

The practical implications of these research findings are significant. Businesses and organizations can optimize their operations by utilizing the insights gained from service area analysis. By understanding the reach and coverage of their services, they can strategically allocate resources, tailor marketing strategies, and identify opportunities for expansion. Urban planning authorities can leverage these findings to enhance service delivery, infrastructure planning, and transportation logistics within the city.

In conclusion, this research study contributes to the knowledge and understanding of spatial analysis techniques in Adama City's Bole Sub City. The successful implementation of the parcel codification system, GIS-based street addressing system, route analysis, routing analysis, and service area analysis underscores their importance in improving service delivery, navigation, resource allocation, competitive analysis, and decision-making processes. The development of a spatial geodatabase further enhances the efficiency and effectiveness of these techniques. These findings have practical implications for businesses, organizations, and urban planning authorities, enabling them to optimize operations, allocate resources strategically, and cater to the needs of their target audience more effectively.

5.2 Recommendation

Based on the research findings and conclusion, several recommendations emerge for future studies and practical applications. Firstly, it is important to conduct further research on Geocoding techniques, exploring alternative algorithms and machine learning approaches to enhance the accuracy and precision of address point Geocoding. Secondly, integrating real- time data into routing and service area analysis should be a focus, as it can provide more up- to-date and reliable results. Thirdly, regular validation exercises and quality assurance checks are necessary to maintain the accuracy and reliability of the parcel codification system, street addressing system, and geocoded address points.

Additionally, scalability and adaptability should be considered, ensuring the spatial analysis techniques can accommodate urban growth and changes in road networks. User-friendly interfaces and visualization tools should be developed to enhance accessibility and usability, while comparative studies can identify best practices and guide practitioners in selecting suitable techniques. Lastly, stakeholder engagement and collaboration should be encouraged to align the techniques with specific needs and requirements. By addressing these recommendations, future research can advance the field of spatial analysis and improve the practical applications of these techniques in urban planning, transportation, and service delivery.

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