



**ADDIS ABABA UNIVERSITY
INSTITUTE OF TECHNOLOGY**

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

**MODELING OF STREET ADDRESS USING MULTIPLE REFERENCE
GEOCODING AND ADDRESS POINT TECHNIQUE. A CASE STUDY OF
YEKA SUB CITY, ADDIS ABABA, ETHIOPIA;**

By: Worku Mammo G/Yohannes

A thesis submitted to the school of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in Geodesy and Geomatics (Specialization in Geomatics Stream)

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Addis Ababa

Ethiopia

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DECLARATION

I declare that this thesis, which I submit to School of Civil and Environmental Engineering of Addis Ababa University Institute of Technology in partial fulfillment of the requirement of degree of Master of Science in Geodesy and Geomatics (Specialization in Geomatics Stream), is my own personal effort. The thesis has not been submitted previously, in whole or in part, to qualify for any other academic award. Furthermore, I took reasonable care to ensure that the work is original, and, to the best of my knowledge, does not breach copyright law, and has not been taken from other sources except where such work has been cited and acknowledged within the text.

Worku Mammo Gebreyohannes

February 2019

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ACRONYMS

AACRA	Addis Ababa Construction and Road Authority
ACORD	Association for Cooperative Operations Research and Development
ARF	Address Reference File
AU	African Union
CSA	Central Statistics Agency
CSV	Comma Separated Values
GIS	Geographical Information Systems
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICT	Information communication technology
INSA	Ethiopia's Information Network Security Agency
KML	Keyhole Markup Language
LIS	Land Information System
MSI	Mobile Spatial Interaction
NCHRP	National Cooperative Highway Research Program
OAU	Organization of African Union
QGIS	Quantum Geographic Information System (software)
TIGER	Topologically Integrated Geographic Encoding and Referencing
SDI	Spatial Data Infrastructure
UPIC	Unique Parcel Identification Code
ZIP	Zone Improvement Plan

Abstract

Addresses are the essential means by which people tried to conceptualize geographical position features using streets and accessibility is the ultimate goal of street address. Poor street address results in a serious challenge in terms of substantial loss of accessibility, less aware for usage, and impracticable for services deliberation to achieve social integration. This comes true for under implementation of street address as pilot project in Addis Ababa City. The aim of this research was made on the street address modeling based on multiple reference geocoding and address point technique. Focused group discussion and field survey was conducted on the identified factors and spatial document analysis was applied to generate street address model. The model geocoding involves entity relation and physical diagram analysis, roundabouts Euclidian and street analysis, and codification of address elements. In addition, Four algorithms were explored, evaluated and integrated with address point analysis. Also, comparison and conceptual framework analysis for party-centric data usage were made. Results indicated that reference points, streets, entrances, parcels, buildings, floors, and floor sections are the basic street address elements which can be linked with the owners. Based on the indicator and Euclidian analysis of four roundabouts, CMC roundabout has the highest proximity result for the study area. Street network infrastructure rates 24.9% while built-up, non-built-up and others occupy with a sum of 75.1% in the landscape of the study area. Among those streets, 29.1% of them are classified as sub-streets while 1.2% of them were classified under the path. The analysis made on the exploration of centroid algorithm revealed that, of the total four algorithms, the biggest inscribed circle method has a 97.5% match rate and the centroid was fit 100% inside the polygon. The comparison results depict that the new model was more user-friendly, comprehensive, and navigable than existing one. This is to mean that the new model is integrated with the address point to simplify the address geocoding, and supports a conceptual framework model of an improved navigation system which is analyzed under this research.

Keywords: Multiple reference point, Address point, Geocoding, Polygon centroid, Euclidian analysis

CHAPTER ONE

1. Introduction

1.1. Study Background

The history of street address modeling and implementation was beginning with references to local place names and shop signs in France since around 17th century (Catherine et al., 2005). Then gradually many countries implement street address by modeling as per countries context and their real ground. When we come to our continent, the history begins to the first street addressing initiatives in sub-Saharan Africa were implemented against the backdrop of the spread of nonexistent tax revenues as a result of embracing urbanization and decentralization in the early 1990s. Next, the addressing activities were undertaken between 1989 and 2004 include projects in 52 cities in 15 countries of Africa with an overall budget of US\$6,800,000, (Catherine et al., 2005). This indicates that a street address project takes an enormous cost.

Now a day street address modeling and its implementation schemes are quite different worldwide in terms of geocoding techniques and references were the address is started. But the final goals are accessibility and provide service to the public in general. A street address is mainly defined as a piece of land irrespective of its urban, commercial, industrial, entertainment or traditional purposes, and it is the locational information of a geographical detail on the map (Kellison, 2012). A unified, accurate and sustainable address system makes citizens more aware for implementation of the law, improves services in public, private and emergencies to operate effectively in that almost every aspect of the interaction of organizations and business can be associated with a land parcel and building (Kellison, 2012). Street addressing operation enables people to locate a plot of land or a dwelling by means of a system of maps and street signs representing the numbers or names of references, streets, and buildings. At the same time, it is a way to relate a person to a place.

Although address itself cannot be legal or illegal, there must be linkage with the other urban land information system like cadaster. Because the land is described by parcel (an aerial geospatial feature) while structures are referenced by address (a pseudo-spatial text string) (Michael, 2012).

Addressing must be given a high priority during the modeling and development review process to assure consistency. A good address system should be easy to implement, use, and integrated with other LIS infrastructures and predictable. This can only be realized if an accurate street address infrastructure is designed. (Boquieu et al, 2010; Zandbergen, 2010; Coetzee et al., 2008 and Coetzee and Bishop, 2009) indicates that, a street address is required for three basic functions. In modern information technology systems, street address information is recorded to obviously identify the real property, citizen, business or any utility entity in question. In addition, it's a mechanism to merge or link information from different sources like cadaster, banks, and postal service. Last but not least, addresses are used every day by peoples, businesses, and government as an understandable description of the location of a specific piece of information. However, because SDI's are extremely important for data processes and in international descriptions, street address is the one type significant in terms of establishing national and international information infrastructures and determining spatial location features (Boquieu et al., 2010; Coetzee and Bishop, 2009; Coetzee and Cooper, 2007; Coetzee et al., 2008; Henry and Boscoe, 2008; Lind, 2008; Zandbergen, 2008a; Zandbergen, 2010).

According to the international experience, various types of techniques are implemented to model the street address. But, most countries of the world are tried to choose the geocoding technique based on the urban infrastructure they have, the purpose of a street address and technological advancement level. Now a day, the increase in processing power of electronic devices has enabled a new generation of MSI (Carswell et al., 2010) allowing users to interact more easily with relevant digital information in their surrounding environment.

Street address modeling and implementation experience in Ethiopia and the cities have experienced short history with traditional assigning of street names and set apart signage plantation along main roads. Then, some street address model was prepared and implemented including under implementation of street address infrastructure in Addis Ababa city administration as a pilot project and the trial and now stopped implementation of Mekele town. But, still, it's not applicable as it's expected. Because the most challenging issue in street address modeling and implementation was to model comprehensive and navigable with an approximate accuracy of street address infrastructure (Goldberg 2011). Therefore, there is a need to explore a research on different street address modeling and implementation approach by considering our countries urban infrastructure, technological advancement and social development level of the public. Under this research, an improved approach street address model was introduced by the integrating of multiple references with street network centerline and address point that can be simple to access, integrate to others spatial data and positional location. Generally, a logical and consistent addressing system, therefore, can tangibly improve the quality of life in a community.

1.2. Problem Statement

The ultimate goal of implementing street address infrastructure is to provide a clear accessibility of services for the dwellers, local communities and others. According to Catherine et al., (2005), although many cities and towns in countries in Africa, East Asia, Europe and western region has experienced, some cities and towns of developing countries in African including Ethiopia have a limitation in the developments and operation of sound street address. Modeling and implementing of street address as per the country's urban centers context in terms of urban infrastructure, social development and technological progress is a very serious challenge. The most pressing problem of this challenge is a substantial loss of accessibility by the public less aware of usage, impracticable for services deliberation and emergencies to operate effectively and reduce conceptualize location to achieve social integration. Most cities and towns of developing

countries especially in Ethiopia are emerged and urbanized haphazardly following roads, electricity and other infrastructures. Streets and blocks are created without a plan so that the road network pattern and block standard become destitute. This makes the urban street network infrastructure become under standard and more complex.

Recently, the existing street address was now implemented in Addis Ababa city start with the concept of address geocode system using reference point and baseline technique which requires a well-defined road pattern with visible and clear baselines. However, as per our county context, the city of Addis Ababa has a low capacity, less standardized, and worsening pavement condition street network. (Yonas 2014) depicts that despite a large volume of pedestrians, walkways are not existing over a large length (63%) of the roadway network. These imply the irregularity of road pattern that makes too difficult to choose the baselines and access the street address. The existence of unfriendly street address infrastructure makes confusion and needs to spend a lot of time looking around due to the factor of distance and complexity of the street pattern.

Previously, limited researchers have been worked empirically on address geocoding using reference point and baseline system and address point techniques to reduce such complexities and provide precise address location (like Catherine et al., 2005, Coetzee et al., 2008, Zandbergen and Paul 2008, Hinton et al., 2009, Boquiet et al., 2010, Zandbergen 2010, Michael 2012 and Jimmy 2015). Among them, (Zandbergen and Paul 2008) compared parcel, street centerline, and address point geocoding techniques. He concluded that “Address points seem very promising as an address data model for geocoding. They provide additional validation of the address input data since it is less likely a false positive will be introduced”. To date, the integration of street centerline address geocodes using multiple reference techniques with the address point system were not adequately assessed. These provide an improved address system for those cities or towns with complex, less standard street networks and blocks like a city of Addis Ababa.

Lastly, Accuracy in a digitization environment is affected by the characterization of positional error contributed by the operator or media type (Bolstad et al. 1990). This problem reduces the actual representation of parcel location and the opportunity to access a web-based navigation system of LIS infrastructure. In electronic digital navigation, positional accuracy is the key point and require investigation to improve the accuracy for better accessibility of street address. Therefore, Parcel-based Positional centroid coordinate needs the application of a mathematical algorithm rather than manually digitalized. All the above-mentioned issues forced to make a model that will improve the existing street address model.

1.3. Objective

1.3.1. General Objective

The main objective of this study was to model address geocode that will improve the existing street address using multiple references geocoding technique and address point system that allows to integrally feasible with different geospatial infrastructures and improve the accessibility by the dwellers, local communities and others.

1.3.2. Specific Objectives

The following are some of the specific objectives of the paper:

- To investigate zoning based geocoding techniques through the integration of multiple references geocode and address point techniques.
- To determine the complex centroid of polygons using algorithms and compare their result based on the suitable representation of parcel based centroid address point.
- To compare the accessibility, visibility and comprehensiveness of address geocode between existing and newly improved street address model.
- To Produce conceptual framework for party-centric data usage in the industry of application domains and the application of web mapping for electronics navigation using centroid positional information of street address.

1.4. Research Questions

Three research questions were posed to guide this study. These questions were in turn guided by the research objectives.

1. What factors influencing the accessibility and practicability of existing street address model in Addis Ababa city?
2. How an alternative street address model can be developed?
3. How street address can be modeled using point feature and integrated with manual and electronic positional navigation?

1.5. Significance of the Study

One of the major impacts of modeling and implementing inaccessible street address are less user-friendly by the public, takes unanticipated cost and integrally not practicable with different geospatial LIS databases. Therefore, studies on different techniques of street address geocoding are important to provide a better accessible street address. This study could provide information relevant to contribute to the implementation of modern street address accesses plans and improve the existing model of a street address. It is also expected to:

- Provide an improved model of street address that can be more accessible to the inhabitants, public and others.
- Provide a baseline conceptual framework for the application of Web mapping and online electronics navigation using the 2D parcel centroid positional information of street address.
- Assist the street address implementers and decision makers to consider the potentials and usage of an online electronics navigation system for modern urban centers.
- Provide elements for long-term benchmark implementation of the parcel based national urban LIS infrastructure related to the integration of street address.

1.6. Limitation of the Study

The limitation of this research lies in the following unavoidable issues. First, due to expensiveness and unavailability of photogrammetric imageries with the finest resolution like <20cm spatial resolution, this research was conducted using a coarse spatial resolution of 20cm photogrammetric imageries. Therefore, the difficulty to discern each feature on each land parcels has resulted in the positional accuracy in one to another. To reduce this problem, field-collected parcel-based cadaster of vector data having similar spatial resolution with the source image was taken as an input and verify the positional location which in turn incurred the researcher both time and energy expenditures.

Secondly, Due to the complexity and dynamicity of the urbanization phenomenon, there must have been included than what has been incorporated in this study. This is because it was not possible to get a detail urban transport infrastructure data to add more equally important change drivers (e.g. lack of reliable and complete socio-economic dataset). Therefore, the manner in which the conceptual map of online navigation of street address and web mapping application is analyzed within the study area based mostly on existing urban infrastructure and physiographic factors. These leaves a room for further research to consider all these limitations and incorporate other Spatial and socio-economic variables that would exhibit the accessibility and acceptability of street address model and online navigation system development using street address geo database infrastructure in a given area.

1.7. Organization of the thesis

The research paper is organized into five major parts. The first part contains the overall introduction in which clear information to the readers has been provided. The second part is devoted to different worlds' approaches, methods, and mechanisms of modeling street address studies, which have assisted the researcher to produce different arguments on the selected topic. In the third part, it starts with the description of the study area followed by the methods employed including data types and sources, software and instruments utilized to carry out the research. While the fourth part is dedicated to the results and discussion components of the thesis. The conclusion and recommendations are the fifth and the last part of the study.

CHAPTER TWO

2. Literature Review

2.1. Street Address Infrastructure and Urban Land Information System

Street address infrastructure is a particular type of SDI which provides the location identifiers most widely used by state and local government and the public (Catherine et al., 2005). According to Fathul 2015, SDI is an information infrastructure specifically geared to geographic information that provides access to and interoperability of cadastral, street address, land inventory and other land and land holding related information's. (Fathul 2015) argue that SDI is seen as a basic infrastructure, like roads, railways, and electricity distribution that enhance sustainable economic, environmental and social development. It is an evolving concept, essentially consisting of policies, institutional arrangements, GIS, databases, networks, Web services, and portals to facilitate and coordinate the availability, exchange, and sharing of geospatial data and services between stakeholders from different levels (COOPER, A.K. 2013).

On the other hand, a land administration system infrastructure provides for the implementation of land and land-related management policies and strategies. It includes legal frameworks, processes, standards, technologies, and people required to support and control the use of this infrastructure. When these infrastructures are integrated with SDI's based on modern ICT, the land administration system could be described as LIS (Fathul 2015).

According to (Catherine et al., 2005 and Mothibi, 2003), LIS is a tool for land administration, enabling among other things better land use planning, property tax, utility service, emergency service, environmental planning and management which is consists of a database containing spatially referenced land and land-related data for a defined area or parcel. (Mothibi, 2003 and Fathul 2015) argues that, LIS is a parcel-based information system that includes procedures and techniques for the systematic collection, updating, processing, and distribution of

that data. That is why many countries are viewed as a new instrument for land administration and started to implement LIS as a tool to improve land administration sector information.

To date, in different parts of the world experience shows that, a web-based integrated spatial data and urban LIS infrastructures development at city or town, regional and national level should be implemented gradually thereby applying different geo-database infrastructures like cadaster, street address, land inventory and others which are capable of integrating together to provide urban social, economic and political services (Samuel G et al., 2015). It requires a long-term intervention and a holistic vision, clear strategy and systematic approach and to do so long-term political, administrative and financial support is prerequisite of the success in advanced LIS growth. Lessons and experience of LIS implementation are important for understanding the complexity and the ways forward. LIS to be efficient for land administration services improvement, there should have a unified database ensuring data integrity. To make the data integrity, national and city or town based geospatial standard, basic entities with the key relationship and attribute fields' standards are very crucial.

In Principle, any parcel based spatial information must have a unique positional location which is defined by coordinates. In LIS, the geodatabase provided by different SDI's like cadaster and street address should have a UPIC that is defined by positional coordinates. The owners of each land parcel must have a unique parcel identification code provided by different SDI's. These provide for the owner to have a single UPIC and be familiar with his/her code used for any purpose (Catherine et al., 2005). UPIC's are important to create a linkage mechanism digitally in GIS and web-based environment and build an integrated city or town, regional and national LIS center. In addition to these, the challenge of the dynamic nature of land records and parcel maps are constantly changing with new subdivisions, annexations, corrections, and other routine modifications processes are done ones when each individual spatial data infrastructure (street address,

cadaster, inventory, and others) are linked in to a land information center. These reduce the future updating cost, time and capacity of the individual SDI.

2.2. The Street Address and Geocoding Concepts

Addresses are one of the essential means by which people tried to conceptualize geographical position features in the modern world (Paul A. Zandbergen, 2010) and the necessary terms of establishing national and international information infrastructures. (Boquiet et al., 2010). It's a collection of information used for describing the location of a building, apartment and a plot of land using references. (Michael 2012) argues that the most commonly used manner for locating a specific property is the assigned premise address which is used daily by private inhabitants, post offices, delivery vehicles, utility corporations, police sectors, fire & rescue services to locate specific places. Timothy C. Hart and Paul A. Zandbergen, 2013 described that addresses consist of multiple components (i.e. house numbers, name, type and direction of street, city, state, and postal code) used to express a location on the earth's surface.

The development of a street addressing system should not be viewed as a one-off activity, but as a process to be long-drawn-out and progressive over time to address a range of needs. It must be given a high priority during the development and review process to assure uniformity, consistency and positional accuracy that will enhance the user-friendly, easy to use and predictability (Catherine et al., 2005). The application, implementation, and accessibility of street address infrastructures are depending on the accuracy of site address which is a key attribute of digital parcel geodata and a critical part of emergency or package delivery system.

When we come to the address geocoding concept, it's the processes of creating the positional location of an address (i.e., associating an address record with a point on a map) using X and Y coordinates. The address data is useful only if it is transformed into location information having a latitude and longitude that can be viewed on a map, used in distance calculations, or processed in other similar ways.

This conversion process is called geocoding and if the address is a UPIC address, the process is usually called geo-locating (Darrell Massengill and Ed Odom, 2010). Geocoding is a necessary first step when utilizing point data available with addresses. However, geocoding methodology varies substantially across studies and can be fraught with problems, including providing inaccurate geographic coordinates (Drummond, 1995). According to D.W. Goldberg, et al 2007, geocoding involves two basic processes: feature matching and feature interpolation. Feature matching is a process to identify a geographic feature in the reference data set corresponding to the input data that will be used to produce the final geocoding result. It can be performed using an interactive algorithm (when the process of feature matching failed, users can correct input data) and non-interactive algorithm (when the process is done automatically without involvement of an operator). The next geocoding process is feature interpolation that involves obtaining or retrieving the data output coming from geographic feature data obtained during features matching process. Interpolation is the process of generating geographical features from the reference feature, for example produces a point along the street or centroid plots of parcels or buildings.

The geocoding process is contingent on having key lookup data with the relevant information to make a conversion from the address to the location. Addresses routinely change with new building and roads being added, postal codes being split and changed. The older your lookup data, the more likely it is that some address matches might be inappropriate or missed completely. (Darrell Massengill and Ed Odom, 2010).

2.3. Street Address Geocoding Techniques

Techniques in the geocoding process are able to borrow the scheme from various academic fields, In most conspicuously, decision theory, information theory, probability theory, and phonetics. While geocoding applications are varied and extend many types of applications, there are numerous shared problems related with the geocoding process that impact the quality of geocoded data and subsequent spatial analyses (Goldberg et al., 2007). Access to good reference data

represents one of the most fundamental challenges to producing accurate geocoded information; and good reference data requires a sturdy address model that allows the components of the reference data to be organized in a logical, maintainable, and site-specific way.

World experience shows that street address geocoding techniques can be categorized based on different measurement indicators. According to (Zandbergen, 2008a) macro- and micro-level address models exist. The macro-level models utilize large geographic units such as postal codes, counties, cities, census enumeration areas, or any other geographic units while micro-level models utilize limited geographic units. In the macro level geocoding process, the location of an input address is assigned to a particular polygon (or the polygon centroid) while in micro level geocoding process, street network models are consisting of street line segments that hold street names, ranges of house numbers, and block numbers on each side of the street.

The other category is based on geocoding procedure in that (Darrell Massengill and Ed Odom, 2010) described as to supports six methods of geocoding. These include ZIP code centroid, ZIP+4 center, city center, range geocoding (commonly used as IP address geo-locating), custom geocoding and street-level geocoding. Among them, Street-level geocoding is the most complex of all and returns the location of a particular address on a street. It converts a full street address that includes a house or building number, street name, city, state, and ZIP code to a map location.

In order of most accurate to least accurate, a geocoding technique can also be categorized as point-level matching, centerline matching, street matching, and ZIP code centroid matching. Point-level matching locates the center of the actual building footprint or centroid of a parcel and the most accurate type of geocoding technique. While centerline matching is used together with point-level matching to tie a point-level geocode with its parental street segment. This provides you with additional data about the parent street segment that is not retrievable using only the point-level match. The other is street matching used to identify and determine

the approximate location of an address on evenly spaced street segment based on the range of numbers in the location's street. As a result, it is not as exact as point matching since addresses may not be evenly distributed along a street segment. The final is **ZIP code centroid matching** technique which is a center point of an area defined by a ZIP code or a ZIP + 4 and is the least accurate type of geocoding. Since a ZIP + 4 represent a smaller area than a ZIP code, a ZIP + 4 centroid is more accurate than a ZIP code centroid.



Plate 2.1: Sample street geocoding methods based on accuracy level. Sources: Wikipedia

The other category is based on reference data described by (P.A. Zandbergen 2008a). He argues that there are three commonly used methods in address geocoding and each method uses a different data model, geometry type and format in the representing address. The first one is a line-based reference data or baseline system with a single reference point called the street network method. This concept was first introduced in a data model so-called TIGER developed by the US census bureau (Heri Sutanta et al 2016) and relies on a range of street numbers associated with the center line of the street segment. It's the most widely employed traditional technique among law enforcement agencies (Bichler & Balchak, 2007; Harries, 1999). The second one is a point-based multiple point features reference data called address point method. The point reference data is obtained through national mapping or national land organization that can be constructed from parcels or buildings. The third one is based on putting an address on the area of the polygon using interpolation result of a point feature is known as area-based or parcel geocoding method. The output reflects the centroid of the polygon and results are influenced by the shape of a polygon which needs the use of integrative algorithms to make accurate the result of interpolation.

Even though various methods and techniques of address geocoding are existing worldwide, each of them has its own limitations and accuracy errors based on the context of countries real situation. Street address geocoding model can be developed using the above-listed methods and techniques by considering the level of geocode data quality and practicability as per countries context. Goldberg et al. 2010, dictates a best-match criterion by analyzing comparisons of different geocoding techniques in order to define the choices used by a geocoder and regulate the best output from a set of candidate results. Unlike street geocoding where a match is made against an interpolated line segment, geocoding against parcel data allows one to match against an individual plot of land (or rather, the centroids of those polygons). This approach is particularly useful in areas where parcels are not regularly addressed (such as on roads with mixed parity) or those parcels that may be quite a distance from the centerline. Research has demonstrated that parcel or area-based geocoding typically results in a lower match rate in part because a single parcel can be associated with many addresses (Zandbergen, 2008a). Despite these lower match rates, parcel geocoding is considered more spatially accurate and is now becoming extensive given the development of parcel-level databases by various cities and counties in the USA (Rushton et al., 2006) as “street geocoding” and has become the most widely used form of geocoding.

For example, street geocoding, address point and multiple (integration of the two) can be modeled in one of the three systems:

- The reference point and baseline system (quadrant system): usually applied in cities/towns with regular street networks/patterns.
- Grid system: applied in cities/town with a well-planned and regular grid street networks/patterns.
- Multiple reference systems: usually recommended in cities/town with irregular street patterns.

Address point and multiple techniques that are less practiced than Address geocoding technique (Catherine et al., 2005). Address geocoding use street center lines and different administrative division to provide an address for each owner

while Address point is locating the precise location of the structure using the 2D coordinates of the feature in which the address is assigned. It results in the accurate representation of addresses at the Civic Centers (Hinton et al., 2009). Therefore, the integration of address geocodes and address point techniques are established with complex and irregular street network infrastructures by establishing multiple references.

Table 2.1: Literature summary on a comparison of different address geocoding techniques

Comparison elements	Address geocodes and implementation modeling procedures					
	City center geo-code	Street level geo-code	Custom point geo-code	Range geocode	ZIP+4 center geo-code	ZIP code geo-code
Address model	Macro level	Micro level	Macro level	Micro level	Macro level	Macro level
Return the location of particular address on street	Complex	Most complex	Less complex	Less complex	Simple	Simple
Positional accuracy	Accurate	More accurate	Most accurate	Accurate	Less accurate	Least accurate
Positional accuracy method used	Point level, centerline and street matching	Street matching	Point level and centerline matching	Street matching	ZIP Code centroid matching	ZIP Code centroid matching
Street classification needed	Broad	Broad-based on function and orientation	Detail based on hierarchy, capacity, character and clear connection	Broad-based on function and hierarchy	Broad	Broad
Signage distribution	Dense	Spaced	Dense	Less Dense	Optional	Optional
Reference	Single	Single	Multiple	-----	-----	-----
Geometry type	Point base	Street network base	Point base	Area/point base	Area /point base	Area/point base
Application complexity	Complex	Very complex	Less complex	Less complex	Simple	Simple

2.4. Geocoding Quality

Unfortunately, address attributes presently found in many countries of their parcel databases are often inaccurate in its format and stored in many ways. The National Research Council 2007, briefly expressed that, the absenteeism of reliable standards for data content and data quality can lead to serious difficulty. Any

sound data management program must adhere to accepted data management practices to deal with positional attribute data's, a period of proprietorships, consistent PINs, missing parcels, related rights, easements, and bad survey data. The elements of simple address standard are described by Thompson (2011) as the ACORD. The elements of those address quality are remarkably contract among researchers agreed on the approach that question describes the same five core element. These are attributed to accuracy, logical consistency, completeness, positional accuracy, and lineage. But any geocoding result can be characterized by the following three elements of address quality. These are:

- **Completeness:** mean that the percentage of records that can reliably be geocoded, also referred to as the match rate.
- **Positional accuracy:** indicates how close each geocoded point is to the 'true' location of the address.
- **Repeatability:** indicates how sensitive the geocoding results are to variations in the street network reference data, the matching algorithms of the geocoding software, and the skills and interpretation of the analyst.

Geocoding results of high quality are complete, spatially accurate and repeatable. The simplest measure of geocoding quality is the match rate or the percentage of records that produce a reliable match. Different types of addresses result in different match rates (Drummond 1995, Cayo and Talbot 2003, Kravets and Hadden 2007). For example, higher match rates are typically obtained for residential addresses relative to commercial addresses (Zandbergen 2008a). Match rates also vary greatly with the address data model employed. Street geocoding is by far the most widely employed method and match rates typically vary between 70 and 95%, although both lower and higher match rates are sometimes reported. Geocoding against parcel boundaries is more spatially accurate but consequences in lower match rates, typically between 40 and 75% (Dearwent et al. 2001, Zandbergen 2008a). Geocoding against address points has received much less attention, but the limited research so far indicates that match rates are very similar to those of street geocoding for the same address input data. But the positional accuracy of address point geocoding is far superior (Zandbergen, 2008a, b).

2.5. Street Addressing Applications

Street addressing is one of SDI that can be integrated with LIS has many potential applications (Catherine et al., 2005). Street addresses are critical information for managers, emergency reply, investigation, marketing, mapping, GIS, routing navigation, and many other purposes. Because they have evolved over various periods under the control of many local jurisdictions in different record and database formats. This serves numerous purposes so that dissimilar address formats and types pose a number of multifaceted Geo-processing and modeling issues. As a consequence, government institutions tried to integrate large and mission-critical files into master address repositories. Catherine et al., 2005, claims that the first and most general application involves the connection between street addressing and civic identity. It is just one of the many requirements that will help a city achieve social integration. In this case, it involves three dimensions:

- Relations between peoples, which are at the center of any system and can exist only with a street addressing system;
- Relations between citizens and government authorities, by which individual and economic action can be situated for both fiscal and political purposes;
- Control of urban space, for which street addressing is the first in a series of applications intended to ensure the gradual development of management tools.

Other more practical applications explore links between street addressing and urban information systems, support for municipal services, tax systems, the land tenure issue, upgrading of an informal neighborhood, and economic development. In addition, street addressing offers an exceptional opportunity to gather land and land-related baseline information on a city. (Catherine et al., 2005) argue that the database and maps created through such an initiative make it possible to change into a simplified GIS that can be coordinated with other urban management tools. The process of maintaining this reference tool provides an opportunity for progressive updates as new information becomes available.

2.6. Application of GIS In Address Geocode and Its Operation

2.6.1. Application of GIS Tools in Address Geocode

According to the researchers like Fathul Wahid, 2015, Mothibi, 2003 and Boquiet et al., 2010, Arc GIS software environment can be a central part of the Geo-database infrastructure at specific and LIS at large. Many GIS applications by law enforcement agencies include the use of address geocoding. The use of geocoding has become widespread, and it is arguably one of the most successful applications of GIS. Recent reviews of geocoding have been provided by Goldberg et al. (2007) and Zandbergen (2009) in that the determination of a geographic position from a descriptive address is called geocoding and geocoding tools are important components of the urban GIS. It's a powerful GIS tool that provides an economical, although not entirely accurate, way to apply GIS technology to municipal operations (Hart and Zandbergen, 2012).

As with other techniques used to create spatial data, there is some uncertainty associated with the results of geocoding, which may affect its usefulness. Uncertainty in geospatial information is a fundamental issue that continues to attract attention as a research challenge (Couclelis, 2003; MacEachren et al., 2005; Zhang & Goodchild, 2002). Although uncertainty in geospatial information has many components (Chrisman, 1991), completeness and positional error are of particular interest in the case of geocoding.

2.6.2. Address Geocoding Operation Using GIS Tools

In GIS, the geocoding operation involves decomposing street networks into thousands of street segments that connect to form a unified street network. Each street segment contains a starting and ending address range for the left and right sides of a street block (Bichler and Balchak, 2007; Wey et al., 2009; Zandbergen, 2008, 2009). It needs numerous procedures and calculations to take contextual information and reconcile with the reference information to produce GIS features for uses in the application of computer mapping (Jimmy 2015).

The Esri ArcGIS geocoder suggests diverse types of address locator styles that can be configured by the user. Address locator is the key tool for geocoding in Esri's ArcGIS software; it converts stylistic descriptions of information into geographic features (Esri 2013). On the other hand, the locator style is the basics of the address locator which determine the types of addresses that can be geocoded, connect with the reference dataset, and governs the output information (Esri 2013).

In a street range geocoder, the point-based locator information is geocoded based on the reference datasets and it's often a guesstimate of the physical location. (Davis Jr. and Fonseca 2007, Brosowsky and Ekdahl 2012). For a reliable geocoder, a recurrent update to the address range dataset is obligatory. The user also needs to deliver the information precisely, such as filling of address data completely without any grammatical errors, correct spelling of a street name, the abbreviation of a street type automatically, and avoid formatting errors (Yildirim et al. 2013).

2.7. Global Trends in Street Address Geocoding Models

Hansa Luftbild Consulting International GmbH (2011) describe that addresses vary from country to country because they are closely associated with the geographical location, culture, race, religion, and language. There are more than 130 addresses and 36 name formats in more than 240 countries and territories. Although countries like Australia, Canada, and the UK have already developed national address point databases and made these reference files available for geocoding; currently, address point geocoding is not very widespread in the USA. However, some home-grown governments have started to make address point databases and some commercial geocoding companies provide address point geocoding for selected urban areas. Furthermore, the proposed addressing system is not considered unique since similar systems have been implemented in Conakry (Guinea), Ouagadougou (Burkina Faso), N'djaména (Chad) and in cities and towns in Senegal, Niger, Togo, and many other African countries.

2.8. National Trends in Address Geocoding Models

In 2003, the AACRA being consulted by Michael Maiwald, a German urban planner and consultant, developed the concept and the method for the implementation of the land information, addressing and street naming system for the city of Addis Ababa. The concept set the priority of addressing to the land before the buildings. This meant that combining the existing streets names or codes with new street names or codes the corresponding signposting and the new parcel numbers aligned to the newly defined streets made the orientation and address location possible. In 2004 the Addis Ababa city government accepted the concept which was proposed by that authority.

The first fully operational GIS-database based on ArcView 3.3 software and MapInfo 6.5 was handed over to the Addis Ababa city government in August 2005. More than 3000 streets have been newly defined through a number code. This code gives the common basis for attached, newly numbered parcels, stating that the plot number has priority over the house numbers being a more stable element in the city's development, neutral to changes in usage and construction. Addis Ababa has at the moment according to AACRA a number of approximately more than 7,400 public road segments suitable for vehicle traffic, including paved and gravel roads. These have codes (numbers) but less than 200 have been allocated a name.

Nationally, the establishments of street address standards are being applied in Addis Ababa city by (Hansa Luftbild 2011) in collaboration with Addis Ababa city administration. Different from that solution (Hansa Luftbild 2011) proposes the replacement of the current street numbering concept by a concept considering the administrative structure of Addis Ababa, and the installation of a metric house numbering system. This modification will not cause a major change to the existing situation because the current street and house numbering concept has not been established as such and can be adapted for the new concept.

The basic concept of this model is first starting from the establishment of a single reference point and two baselines are drawn east-west and north-south that will

provide as a reference for the entire of land parcels and houses in Addis Ababa. These are what we are going the experience nationally related to the establishment of address standards, models and implementation. That is why the implementation was limited to the capital city rather than widely applied in different cities and towns of the regions.

2.9. Centroid Polygons Algorithm for Street Address

The definition of centroid is varying in different disciplines. The description ranges to any object in n-dimensional space: For instance, in mathematics and physics, the centroid is the arithmetic mean position of all the points in all of the coordinate directions of the shape. While in geometry the term "barycenter" is a synonym for "centroid". There are various methods, theories and practices to determine the centroid of any simple to complex polygons shapes and most of them consider as the centroid is a geometric property of a shape, somewhat related to the center of mass. But their perspectives are quite different (Nedim Vardar, 2015). Some of the methods are plumb line method, balancing method, geometric decomposition, sharply geometry method, integral formula, the vertex of the polygon and biggest inscribed circle methods. Based on these methods, different software's includes different centroid algorithm packages like in GIS, QGIS and others. While MATLAB, C++, and Python programming language also support to determine the centroid of polygons.

According to Nedim Vardar, 2015, the center of mass of a region is the point in which the region (for this research, the parcel) will be perfectly balanced horizontally if suspended from that point. It can be determined by taking to consider the shape of the parcel in regular and irregular form (Stroud A. H, 1971). Based on this method, the software's like Arc GIS and QGIS has a package. But Arc GIS environment has not guaranteed for complex polygons which will lie outside the polygon. Another method is based on the radius of the biggest inscribed circle of a set of points. This means the encircle is designed to fit a circle of maximum radius inside the convex hull of polygon data based on Euclidian distance

transform with a circle on it and then provide the center of that circle represents the centroid of a polygon (Oscar Martinez 2012). Researchers also dictate that the weighted sum of the centroids of the triangles provides the centroid of complex polygon mostly. While others take the concept of the weighted mean coordinate value of the polygon vertex considering the area or length of a polygon. Because of a lot of diverse methods exist; detail algorithm concept was not included in the literature. Centroids are essential in address point geocoding technique because the polygons can be precisely represented with a single point of positional coordinates and important to link with GPS applications, web mapping, and other navigation systems.

2.10. Impacts of Inaccessible Street Address Infrastructure

The effective management of urban areas can only be achieved if an accurate street address infrastructure is formed. Access to good reference data represents one of the most fundamental challenges to producing accurate geocoded information; and good reference data requires a sturdy address model that allows the components of the reference data to be organized in a logical, maintainable, and site-specific way. These create an accessible street address infrastructure.

There are many potential problems related to street geocoding which have been well described in the literature (Goldberg et al., 2007; Harries, 1999; Krieger et al., 2001; Ratcliffe, 2001). Recent research on the quality of geocoding has stressed consideration of completeness, positional accuracy, and repeatability (Whitsel et al., 2004). Collectively, geocoding quality research clearly demonstrates that errors in geocoding can be very significant and needs to be characterized in an expressive way relevant to the use of the geocoding results.

Zandbergen (2009) provides a more thorough review of the effects of geocoding quality on spatial analysis, but a brief summary follows. Errors in geocoded addresses may adversely affect spatiotemporal analyses, but this has not received widespread attention in the literature. Inflation of standard errors of parameters estimates as well as a decrease in the influence to notice such spatial features as

clusters and trends are among the specific effects that geocoding errors may produce. (Jacquez and Waller, 2000; Zimmerman, 2008) demonstrated that even relatively small positional errors can have an impact on local statistics for detecting clusters. However, research on this topic has been mostly limited to the health field. The street geocoded locations of positional error are determined as the Euclidean distance from the street geocoded location to the nearest boundary of the corresponding parcel.

2.11. The Role of Proper Signage in Street Address Implementation

Good signage for roads, houses and other address objects is important for addresses to serve their purpose. It is thus important that signs are designed, placed and maintained in such a manner that the design and placement must be planned carefully. According to the experience of (Norwegian Mapping Authority, 2009), the following rules should be taken to consider during the stage of planning and implementation of the street address. Signage should:

- Be easily visible and readable, also at night
- Not always be placed on the ideal spot and outside the shoulder and pavement
- Consider regarding other traffic signs nearby so that attention is not diverted from these
- Not be blocked by other traffic signs, branches or bushes, billboards etc.
- Be freestanding wherever possible due to space considerations. Freestanding signs should be placed 1.8 – 2 m above ground as long as this does not inconvenience pedestrians or cyclists (higher in areas prone to vandalism).

CHAPTER THREE

3. Material and Methodology

3.1. Description of The Study Area

Addis Ababa is the capital city of Ethiopia located on the central part of our country. Geographically situated at the latitudinal extent of 8° 22" to 9° 30'57" N and longitudinal extent of 38°24" to 39°21" covering an area of 519.52 km². The city was established in 1886 and has experienced several planning changes. As a chartered city, Addis Ababa has the status of both a city and a state. It is where the AU and its predecessor the OAU are based. Addis Ababa enjoys the status of the principal administrative city of Ethiopia, the headquarter of AU, over 115 diplomatic residences and therefore is a hub of a range of governmental organizations, residential, service, educational facilities and also industrial activities. The city is populated by people from different regions of Ethiopia that has as many as 80 nationalities speaking 80 languages and belonging to a wide variety of religious communities. For the purpose of governance and management, the city divided into ten sub cities and each of has on average about 10 woredas under it, and hence the city is divided into more than 116 woredas.

This study was conducted in one of the 10th sub-cities of Addis Ababa named Yeka sub-city of a single woreda and located in the northeastern suburb of the city of Addis Ababa with 9° 2'14.28" N and 38°50'6" coordinates (Figure 3.1.). As to the recent organizational division, Yeka sub-city is divided into 13 woredas and each of them is locally subdivided into section or 'ketana' and neighborhood.

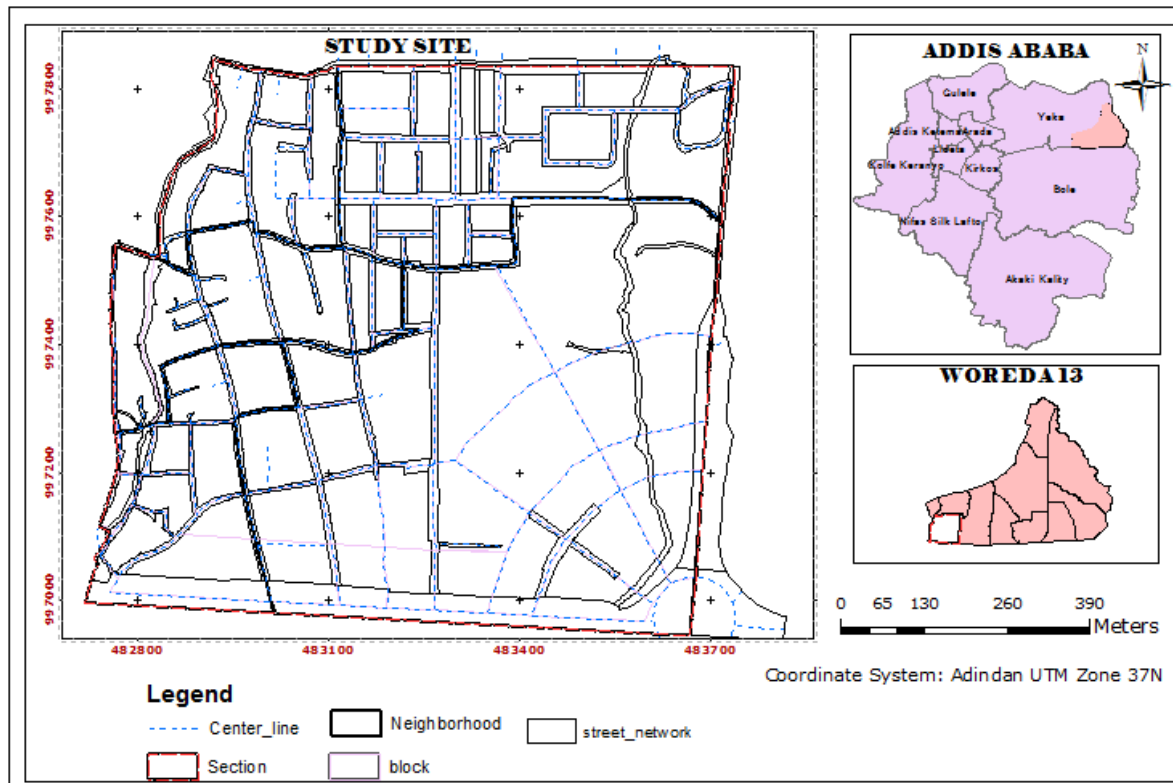


Figure 3.1: Location map of the study area

3.1.1. Physiographic Setting

The main features of the physiography of Addis Ababa are the undulating plain which lies at an altitude of 2,300 meters. The altitude ranges from its lowest point, around Bole International Airport, at 2,326 meters in the southern periphery and rises to over 3,000 meters above sea level in the Entoto mountains to the north. The climate may be defined as tropical and semi-tropical. April is the hottest month with an average temperature of 20°C (68°F) while December is the coldest month at 16°C (61°F) for the same period. The sun is the main temperature source and has almost equal day and night duration of the 24 hours so that it affects the climate of the city.

According to the census of Ethiopia in 1999, Addis Ababa city population growth was reported through successive census during last 60 years; it was noticed that the percentage of Addis Ababa population to that of total Ethiopian population was decreased continuously (from 46.2% in 1950 to that of 22.3% in 2015). This means that its primacy is gradually declining away as a result of a faster growth

rate of the towns in most of the other parts of the country. According to the 2007 census report of CSA, the projected population of Addis Ababa city in 2018 is 3,384,569. Its population increases annually by 4-6 percent which can partly be attributed to the natural population growth of nearly 2.4 percent and the high migration of population from villages and rural areas to the city.

3.2. Data Sources and Sampling Method

3.2.1. Datasets and Sources

To undertake this thesis, both primary and secondary data collection systems were utilized. Focused group discussion, survey data, and reconnaissance survey were used as primary data sources for the comparative assessment of the existing street address accessibility, visibility, comprehensiveness and accuracy of address features and for the evaluation of street and reference points' categories respectively. 50m leather made measuring tape, 8x pixel digital camera and GARMIN 64 model GPS were used for survey data.

The secondary data source which was used under this thesis is referred to as Document analysis. This includes the analysis of a 20cm spatial resolution ortho-rectified aerial photograph covering the entire of yeka sub-city, topographic and line map, cadaster geo-database, recent street, and local road network map of the study area. The remotely sensed ortho-rectified images were used and processed for raster analysis identifying and visualizing major urban landscapes relevant for the contribution of modeling and implementing street address infrastructures like streets, roundabouts, squares, islands, buildings, etc.

Topographic and line map of the study area were taken to update the existing urban landscape which was captured by the photograph passed over 7 years. In addition, recent street and local road network map of yeka sub-city were used to update street and local access roads that are maintained and newly constructed in recent years. Another most important spatial data source is cadaster geo-database of the study site which was used to gather parcel and building based spatial information for geocoding, linking the street address with that of each parcel and

buildings. The overall geospatial analysis and algorithm works were undertaken using ArcGIS 10.3.1, QGIS 2.14.20 and MATLAB R2013a software.

Table 3.1: Characteristics of data types and data sources used as a data input

NO	Lists of Datatype	data sources	data description
1	Ortho-rectified aerial photograph with a spatial resolution of 20cm	INSA	Acquisition date,2011
2	Topo & Line map of yeka sub-city	Yeka sub-city administration	-----
3	Local street & road network map of yeka sub-city	Yeka sub-city administration	updated date is 2018
4	Cadaster geo-database	Yeka sub-city administration	updated in 2017

3.2.2. Sampling Method and Design

This research is a qualitative type of research by which the output street address model is not limited by the area. The research was undertaken at a single Section ('ketana') of the study site in a single woreda. The sample woreda must complete the urban cadaster to provide parcel based geo-database and existing street address implementation to assess comparison analysis with the new street address were seated as a criterion. So, the sample woreda was selected from those woredas of yeka sub city that fulfills the above-mentioned defined criteria by random sampling techniques using QGIS toolset. A sampling procedure for a single section was similarly selected from the sample woreda and then all neighborhood and blocks existing in the sample section were taken as sample neighborhood and blocks respectively. The sample parcels were randomly selected from sample blocks and used in geocoding and centroid calculation for this study.

For qualitative type focused group discussion, purposive sampling methods are common (Cresswell, J. W., & Plano Clark, V. L. 2011) and used for this study. A group of 10 well experienced experts on street address geocoding and related geospatial infrastructure implementation that can provide the best information about the accessibility, integration with other geospatial infrastructure and related issues on the existing street address model representing each woredas of yeka sub city were selected based on purposive homogeneous sampling technique (Ilker Etikan et al., 2015).

Table 3.2: Sample features included in the study site

Sample features	Randomly selected from	Total number of samples
Parcel	Sample Blocks	202
Streets	Sample Ketana	79
Blocks	Sample Neighborhoods	62
Neighborhoods	Sample Ketana	5
Ketana	Sample Woreda	1
Woreda 13	Sample subcity	1

3.3. The Research Methods

There are different kinds of methods, strategies, and techniques to process input data for the required research output in an efficient and sufficient way with desired quality. In fact, the choices of methodology and specific technical arrangements are largely guided by the availability of the desired input data, the quality of available information, the researcher's experience and skill to manipulate the data.

The analysis processes were a geospatial analysis so that ArcGIS 10.3.1 environment were the principal digital processing, geocoding and analysis software used in this study to process and analysis address geocoding and lastly provide the required street address geocode model. In addition to this, QGIS 2.14.20 were also used specifically for analysis of polygon centroid, basic statistics output, and distance matrix. Apart from this, MATLAB R2013a software was deployed to calculate the centroid of polygon based on the biggest inscribed circle algorithm.

Data analysis for this study was started by checking the coordinate system of ortho-rectified images for each GIS data layer thereby ensuring spatial consistency with the demarked study area of yeka sub-city of the sample woreda. Geo-referencing entailed making sure that all spatial data layers used the same coordinates of the map projection. Therefore, all the data sets were projected to Adindan UTM Zone 37N to avoid feature and image distortion and have the same geographic coordinate system. The spatial extent covering the entire yeka sub-city was then extracted from the entire of Addis Ababa ortho-photo using spatial

analyst tool in ArcGIS. All GIS shapefiles were clipped in Arc Map using the study boundary to ensure that all files covered the same area. The detailed analysis methodologies were briefly described as follows:

3.3.1. Street Address Geocoding Methodology and Analysis

A recent aerial photograph taken from an aircraft with the optical axis of the camera nearly vertical as possible with a spatial resolution of 20cm were used for clear identification and verification of administrative divisions, neighborhoods, blocks, parcels, streets, house, and mixed-use buildings in parallel with cadaster geo-database. In addition, the digital topographic map and recent street network map were used to update and prepare the base map of the study site.

Once the street address base map was prepared, the key street address entities and their relationships were identified and diagrammatically notation. This involves building the diagram that describes the identified street address entities in terms of entity and objects, relationships and relationship sets on the identified street address entities and their connection between objects using an entity relationship diagram. Then, the detail physical data model was analyzed that dictates how the model is built in a GIS database. It includes all table structures, including column name, column data type, column constraints, primary key, foreign key, and relationships between tables. This step has a role to clearly analyze and model the operational street address database model in Arc GIS software.

The concept of street address geocoding was started from the technique of multiple reference and address point systems. This method involves the integration of address geocoding of multiple reference point with the positional centroid (address point). The operational database was analyzed based on the conceptual model so that the street address database analysis was procedurally described as follows:

The first step in street address modeling was applied to divide the city in to address zone. The type of subdivision or zoning was based on proximity analysis

of multiple reference points and lower administrative division so that we can say 'Ad hoc Address Zones' system. Because, a variety of characteristics can be combined, such as homogeneous residential areas, administrative boundaries, and natural dividing points; and if administrative boundaries change, the numbering system is not subject to challenge. The identification and selection of multiple reference points in study site were done based on the Euclidian distance, allocation and direction analysis in GIS Euclidian toolset considering the jurisdictional administrative sections and proximity with respect to the study site. Further evaluation was performed based on the standards of key indicator analysis and categories of roundabouts; squares and Iceland's (see appendix A.1 and A.2). In addition to this, those reference points should have started from the known and constructed roundabouts, squares and Iceland's that are capable of addressing at least three main streets in the traffic systems, known to dwellers, community and the public at large that can facilitate the addressing system in the urban center seat. Following this step, street address zone becomes analyzed.

Secondly, once multiple reference points were selected, evaluated and categorized, street address zone was analyzed based on the proximity analysis from the reference point located to the navigational north in the lower administrative section. So, the orientation of providing a three (3) digit (since one city may have more than 100 reference points) sequential numbering system was followed starting from the reference point located to the navigational north and moving clockwise as follows:

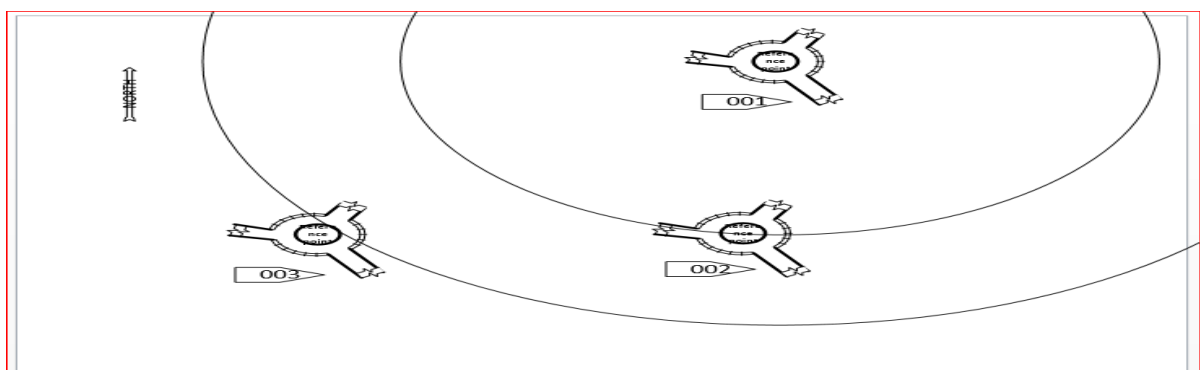


Plate 3.1: Orientation and codification system of reference points

In addition to this, the identification and classification of streets were taken by considering the streets based on both international as well as national key parameters, norms, standards, and experiences. Under this research, a street classification system was undertaken using the province of the American Institute of architects and the province of Ontario alternative street classification scheme (See Appendix B). Because the purpose of street classification is for the street address model in that each class of street should demonstrate a street hierarchy, their capacity, street character, clearer connection between the land use and the multi-purpose role of the streets in the accessibility and navigation of street address.

Third, the orientation of streets was determined based on the navigational northing in a clockwise direction from the selected reference point and centerlines of streets were coded with two (2) digit sequential numbering system (a single reference point can accommodate not more than 100) in each category of street types. After this, the segmentation and codification of streets were based on the ARF method; centerlines and parcel entrance including address locators in geodatabase were performed.

Fourth, Digitization and codification of entrance lines and house number for the identified parcels were followed. Houses are coded with an even number to the right and odd number to left following sequential numbering system. This involves the integration of street centerline address with the entrance and house point using basic attribute fields supported by domain.

Fifth, the signposts location was analyzed based on the physical property, type (i.e. unidirectional and bidirectional) and distribution of address locators (signage). Because, Proper selection of signposts location for streets, houses, and other address objects determine the accessibility, clarity, and effectiveness of signage to serve their purpose. To come up with the above-mentioned function of proper signage, basic attribute fields were created and geo-coded. Lastly, the full address coding system of the above-mentioned results was included in the street address

geo-database. Then, address cleaning and validation were applied to reduce spatial error.

3.3.2. Exploration of Centroid for Parcel Polygon

Under this research, the following four methods, theories, and practices of algorithms were explored on sample parcels to provide a relatively better representative centroid for address point. The only caveat with those algorithms is that the polygon must be non-intersecting. This is often the case, as a self-intersecting polygon doesn't model a physical object in the real world.

3.3.2.1. Based on The Center of Mass and Nonuse Location Contained by Feature

This method considers the shape of the parcel in a regular and irregular manner and the centroid of a parcel can be determined in the form:

Let $\{(x_i, y_i)\}_{i=0}^{N-1} \subset \mathfrak{R}^2$ Be a closed polygon in the 2D plane, and defined by 'n' vertices $(x_0, y_0), (x_1, y_1), (x_2, y_2) \dots \dots \dots (x_n, y_n)$ where the vertices are ordered counter clockwise. Then it is well-known that the polygon encloses the area A becomes:

$$A = \frac{1}{2} \sum_{i=0}^{N-1} (x_i y_{i+1} - x_{i+1} y_i)$$

And its centroid is the point (C_x, C_y) where,

$$A = \frac{1}{6A} \left(\sum_{i=0}^{N-1} (x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i), \sum_{i=0}^{N-1} (y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \right)^T \in \mathfrak{R}^2$$

This is based on the theory of center of mass of the object and was examined using Arc GIS software using the feature to point toolset with nonuse location contained by polygon feature option.

3.3.2.2. Based on The Center of Mass and Use Location Contained by Feature

This method is similar to the above method but the centroid of the polygon is depending on both the center of mass of the polygon and the boundary use location contained by the polygon feature. This means that the algorithm considers the boundary of the polygon feature and forced the centroid to arrive inside the

polygon. This method is examined using Arc GIS software using the feature to point toolset with use location contained by the polygon feature option.

3.3.2.3. Based on the radius of the biggest inscribed circle of a set of points

This concept has the possibility to get the inscribed circle for any shape (Oscar Martinez 2012) including a complex polygon. A circle of maximum radius inside the convex hull of polygon data was designed based on Euclidian distance transform with a circle on it. The algorithm works using vertexes of each polygon which was extracted from QGIS environment as input data and was examined using the MATLAB R2013a software. The computational aim can be written as:

$$(x, y) \text{ maximizes } r = \min_i r_i \text{ where } r_i = \|(x_i, y_i)\| \text{ and } d_i = r_i - r$$

(x_i, y_i) : pairs data points
 $(x,y),r$: pair, scalar circle center and radius

In non-mathematical terms, the concept describes that the center of the largest inscribed circle will lie inside the polygon and the center of such a circle will be furthest from any point on the edges of the polygon. So, we seek for the point that lies inside the polygon and has a maximal distance to the closest edge.

3.3.2.4. Based on the average coordinates of the vertex of a polygon

This algorithm takes the possible number of vertex's coordinate that creates the polygon. At its true that the number of vertices is depended on the distance taken between vertex that builds the polygon and the area of perimeter length of the polygon. Then the mean of the coordinates of a layer starting from a field of the attribute table was calculated as follows:

$$\bar{x} = \frac{\sum_{i=0}^{n-1} x_i}{x_n}, \bar{y} = \frac{\sum_{i=0}^{n-1} y_i}{y_n} \text{ where } x_n \text{ and } y_n \text{ are the vertexes of polygons}$$

Then: $x_centriod = \bar{x}$ and $y_centriod = \bar{y}$

Then, a comparison of the results was done based on distance equivalence to every vertex of the polygon using the distance matrix tool in QGIS. Next, the better representative centroid determination method was selected and the centroid

features become geocoded as an address point with basic attribute field. Following these steps, the integration of the address point geocodes database with that of a multiple reference street address geo-database were followed and the final address map and full address geo-database were developed.

3.3.3. Comparison of the new and existing street address model

Lastly, comparison analysis between the existing street address and the new model was taken based on the following key points.

- Street category and geocoding quality: Based on international standard street category and geocoding quality with key field data,
- The plain metric positional accuracy of centroids related to each polygon and house points,
- The user-friendliness of street address model considering key factors,
- Focused group discussion, assessment result,
- Elements of spatial data quality were analyzed based on the key elements of spatial data quality (Attribute Accuracy, Completeness, Logical Consistency, and Positional Accuracy).

3.3.4. Conceptual model design for street address navigation

Under this thesis, worldwide experience and researches on the street address navigation of party-centric data usage in the industry of application domains using street address were assessed. Then, a conceptual model was proposed using the full address database parcels information and decoding of those street addresses based on the city's urban infrastructure, navigational technology, and social development. This gave an insight into the application of Web mapping for electronics, navigation using the 2D positional information of street address for the future.

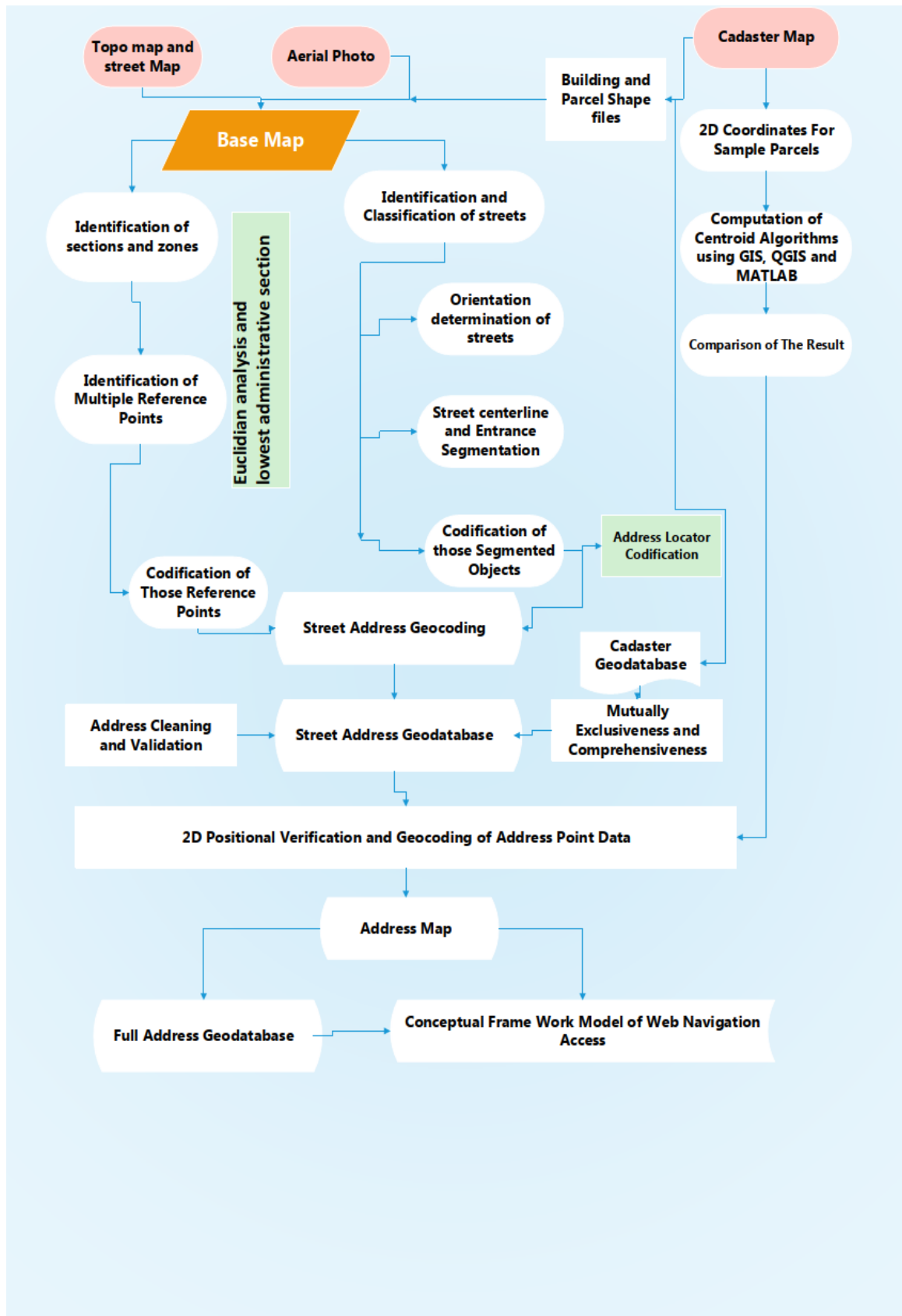


Figure 3.2: A General research methodology flow chart for multiple references and geocoding of street addressing

CHAPTER FOUR

4. Results and Discussion

4.1. Analysis of Street Address Geocoding Procedure

4.1.1. Development of Address Base Map

The street addressing operation is based on preparatory work that should make it possible to establish a precise and up-to-date base map, to show the sectioning(s) (administrative and other) of the city and be clear as to the current status of street addressing. As shown in figure 4.1., street address map of the study area was prepared with basic cartographic elements.

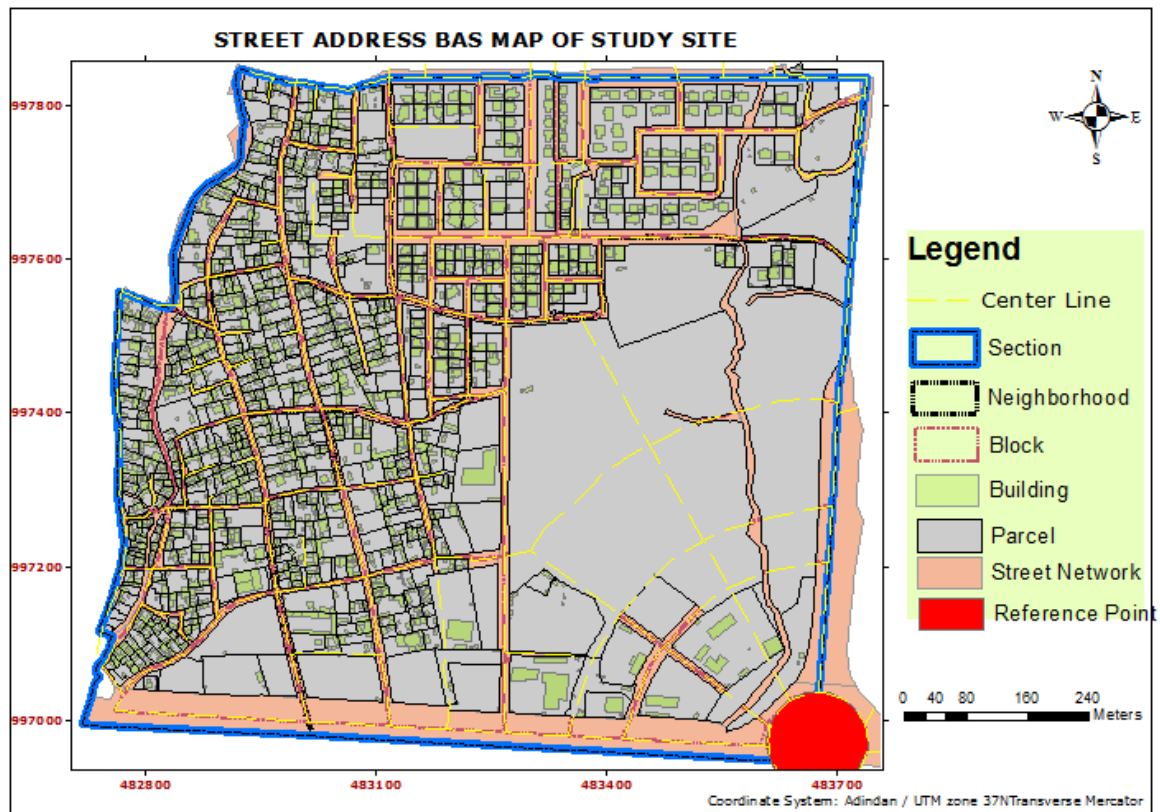


Figure 4.1: A base map for street address

The basic input shapefiles of the study site (Ketana 13, Neighborhoods, Blocks, Sample Parcels, Sample buildings, Road network, Centerlines, and reference points) are included. In addition, aerial photography with a spatial resolution of 20cm was used for the identifying and visualizing major urban landscapes.

4.1.2. Entity Relationship Diagram Analysis of Street Address Model

Entity relation diagram is a high-level and popular conceptual data model used to clearly show the basic entities and their relationships. Under this research, the diagrammatic notation associated with the entity relation model describes data in terms of entity and objects, relationships and relationship set of the identified street address elements and their connection between objects.

As shown in (Figure 4.2), the key street address elements identified are owner, parcel, building, floor, and floor section, entrance, street, and reference point. Each of them is connected based on the address navigation scheme and real-world situation using cardinality constraints (one to one, one to many and many to many entity relationship types).

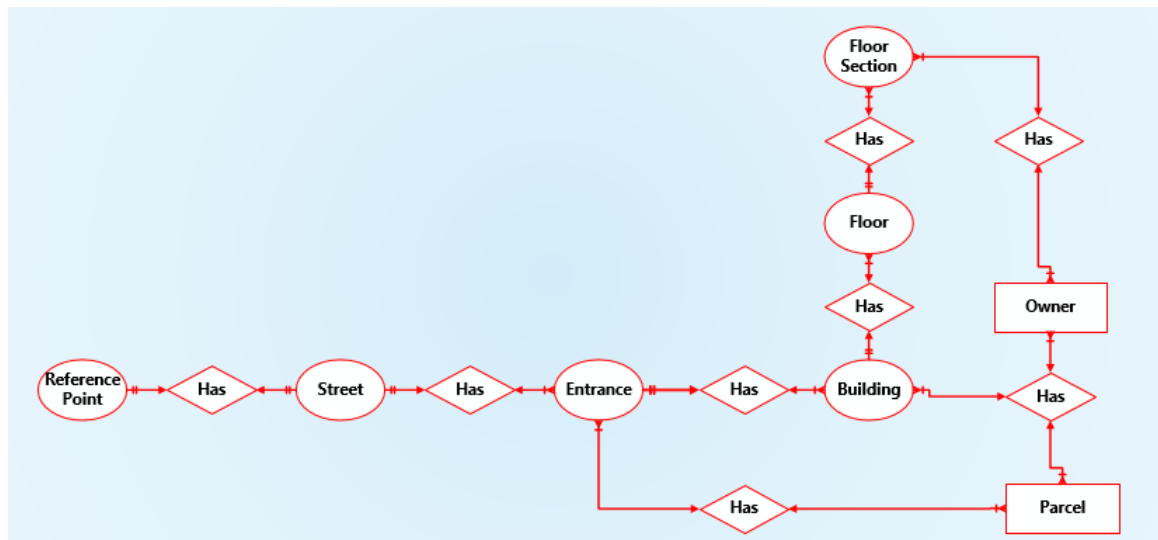


Figure 4.2: Entity relation diagram of basic street address elements

When we try to see the entity relation, an owner may have one or more holdings. In reverse, a single parcel may also have shared by more than one owner. And, a single parcel can accommodate many single-family buildings. Now a day vertical building growth is the key characteristics of urbanization so that a single building can have more than one floor and a single floor can have many floor sections. Due to this, an owner may also have a single or many floor sections in a building or buildings at all. The entrance, street and reference points of floors and floor

sections are made from the building. In another way, any holdings having a building should have one or more entrances that are started from the single or more closed street networks.

According to multiple references geocoding techniques of a street address, a city should have more than one reference. But street networks have a single reference point provided based on proximity analysis. So, a single street should have a single reference. This means that a street and reference point have one to one cardinality constraint. As a result, the owner can have many to many cardinalities with the parcel, building, and floor sections while a building with the floor, floor with floor section, a building with an entrance, entrance with streets and a parcel with entrance have a one to many cardinality constraints.

4.1.3. Physical Diagram Analysis of Street Address Model

Under this analysis, the main intention is how the entities, attributes, and data types are linked in the street address model. A result from the physical diagram analysis (Figure: 4.3) indicates that the entities, relationships, and attributes are shown in (Figure: 4.2) were converted into tables, foreign keys and columns respectively. As shown in (Figure: 4.3), the relations are connected with foreign key and primary key so that the owner is linked with his street address.

In addition, each attribute has necessary information's providing a paramount role in street address accessibility and navigation of the users in general and integrating with another geospatial database in urban settings. It has been noted that navigation needs simple and clear street address infrastructure so that a multiple reference street address data was represented with better-quality positional centroid address point shapefile. The physical diagram shown in (Figure 4.3) describes that the address point key shapefile consists of the overall entities of street address with a navigable positional centroid of x and y coordinates.

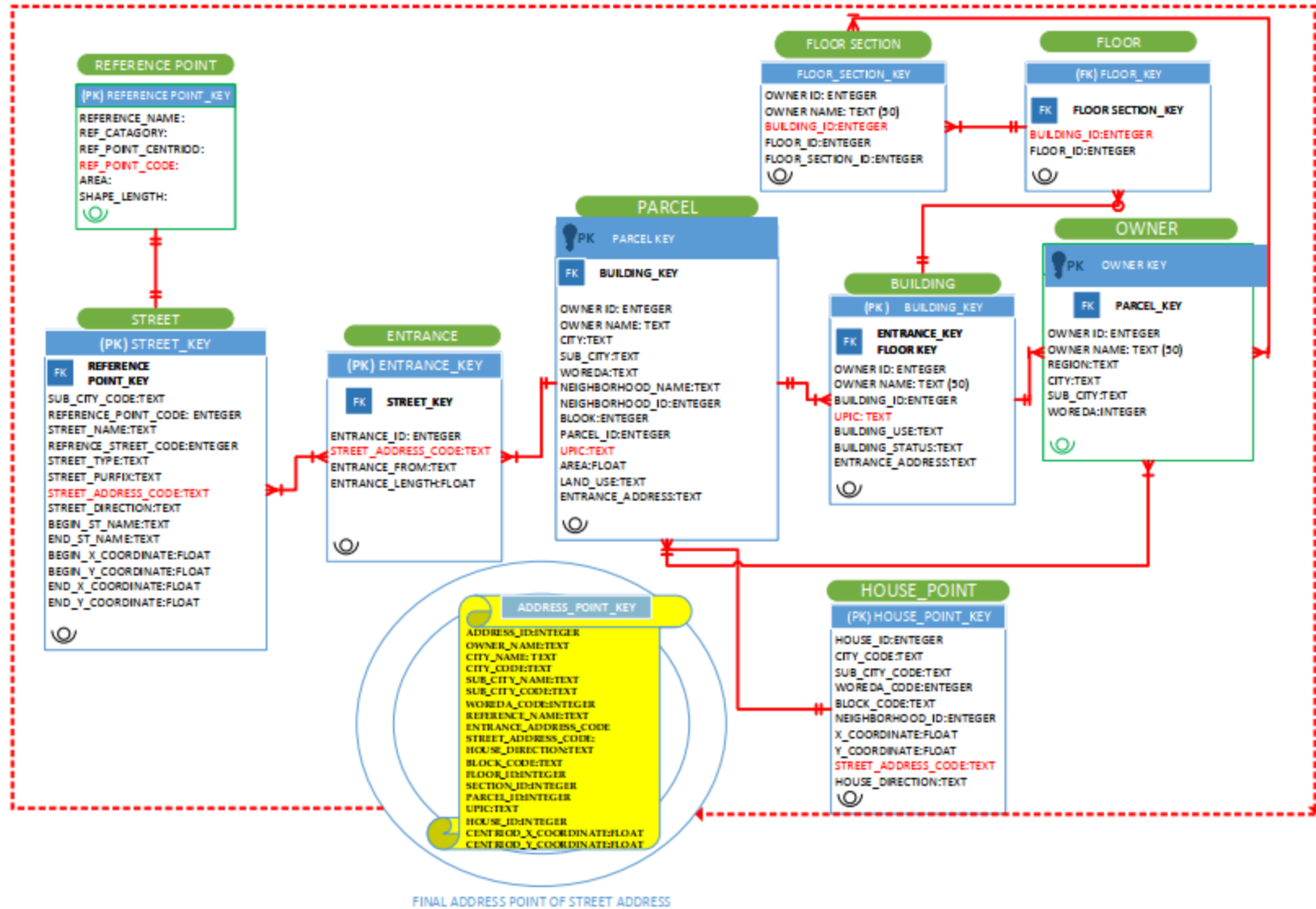


Figure 4.3: Physical diagram analysis of basic street address elements

4.1.4. Selection of Multiple Reference Points

4.1.4.1. Indicator Assessment of Roundabouts

In order to provide useful information about roundabouts to policy makers, decision makers, and the public, there is a need to carefully select indicators. They are helpful as they keep the researcher focused on what to collect and also at which scale the analysis is going to be made. It is good also to be realistic when selecting indicators, taking into consideration the availability, understandability, and usefulness of data in decision-making.

In this assessment, the researcher relied on the information that was readily available in terms of time and resource. The indicators that were used in the identification and evaluation of roundabouts for address reference should be understandable and will make meaning to the street address implementation unit, transport office, and the public. The following questions were practically raised to evaluate and select roundabouts for reference in a street address.

- Is it relevant to the road traffic jam and connect at least three street networks?
- Is it fulfilling the international and national standards of the key features?
- Is it understandable and accessible to the community at large?
- Does it provide a long-term view of service for the community?
- What about the distance, direction and nearest feature to the relative sources?

As a result, reference points were selected there by asking the above questions based on the key indicators or features of roundabouts and Squares which was described in the following table.

Table 4.1: Indicator analysis evaluation of reference points used for street address modeling in the study site

Lists of Reference points	Name of round about	Key feature of indicators								Category of roundabout			Relevancy to the road traffic jam and network			
		Central island	Splitter island	Circulatory roadway	Apron	Entrance line	Accessible pedestrian crossings	Land scape strip (Buffer)	Lane structure	Mini lane	Single lane	Multi lane	Number of streets junction	Road traffic jam condition	Street width vs roundabout ratio	Euclidian distance coverage in km
Reference Point 1	Legetafo roundabout	Nearly 40m Radius, non mountable central island constructed, raised aprone	Green triangular spliter island of West direction and the NS with 40m undeveloped space	A curved path with 3 lane and free space circular traffic	Very small height of 50cm compared to Radius of circle	3 from West and 2 from NS entrance lines	The accessible pedestrian crossing is not clearly outlined	Strips with 20 cm concrete	3 Lane from West and 2 lane from NS direction			yes	3	Good	Good	3.74
Reference Point 2	Ayat roundabout	Nearly 55m Radius non mountable central island constructed, raised aprone	EW direction 8 m with light train line and NS with >30m undeveloped space	A curved path with 3 lane and free space traffic	Very small height of 50cm compared to Radius of circle	2 Entrance lines	With set back from the entrance line and cut of splitter island	Strips with 20 cm concrete	The 3 lane to EW direction and 2 lane to SN direction			yes	4	Good	Good	2.40
Reference Point 3	CMC roundabout	Nearly 55m Radius non mountable central island constructed with center pass of railway line, raised aprone	EW direction 8 m with light train line and NS with green triangular spliter island	A curved path with 2 lane and non space traffic and clear lines	Very small height of 30cm compared to Radius of circle	3 entrance lines in EW and 2 entrance lines in NS	No accessible pedestrain in EW (due to railway line network) and underconstration in NS	Strips are not accessible and constructed using garments plate	The 3 lane to EW direction and 2 lane to SN direction			yes	4	Fair	Problematic	4.27
Reference Point 4	Salitemihret roundabout	Nearly 30m Radius non mountable central island with center pass of railway line, raised aprone	EW direction 8m with light train line and NS with green triangular spliter island	A curved path with 2 lane and non space traffic and clear lines	A 50 cm height concrete but not consider the land scape of the circle	3 entrance lines in EW and NS but not visible	No accessible pedestrain in EW (due to railway line network) and underconstration in NS	Strips are not accessible and constructed	The 3 lane to EW direction and 2 lane to SN direction			yes	4	Fair	Problematic	4.26

The result from indicator analysis shown in table 4.1 indicates that four roundabouts namely Legetafo, Ayat, CMC, and Salitemihret were identified and evaluated based on key feature indicators of the roundabout. Their relevancy for efficient traffic system and categories were also further analyzed. According to the key feature indicator analysis, Legetafo and Ayat roundabouts are most likely constructed with basic feature elements and standards of roundabout than CMC and Salitemihret roundabout. In addition, Legetafo roundabout has three street junctions while Ayat, CMC and Salitemihret roundabouts have four street junctions. But, the junction's street's width with the area of roundabouts and the circulatory roadway in Legetafo and Ayat roundabout relatively shows closer interconnection than CMC and Salitemihret roundabout.

The summary of evaluation dictates that all roundabouts are categorized under multi-lane roundabouts because they have more than two-lane structures and are all of them can be a reference point for the street address.

4.1.4.2. Euclidian Analysis of Reference Points

Results obtained from the cumulative Euclidian distance, direction and allocation analysis for the study area of aerial photography shown in (Figure 4.4), has indicated that all reference points have undergone significant coverage to the whole direction. As it is evident from Figure 4.4 and Table 4.1, the Euclidian distance value of the reference point 1,2,3 and 4 are 2.4, 3.7, 4.3 and 4.3 km respectively. The result is shown in (Figure 4.4) describes that, within the lowest administration section (sample woreda), Legetafo, Ayat and CMC roundabouts have been efficiently satisfying the Euclidian analysis of the raster datasets while Salitemihret roundabouts are outside the sample woreda.

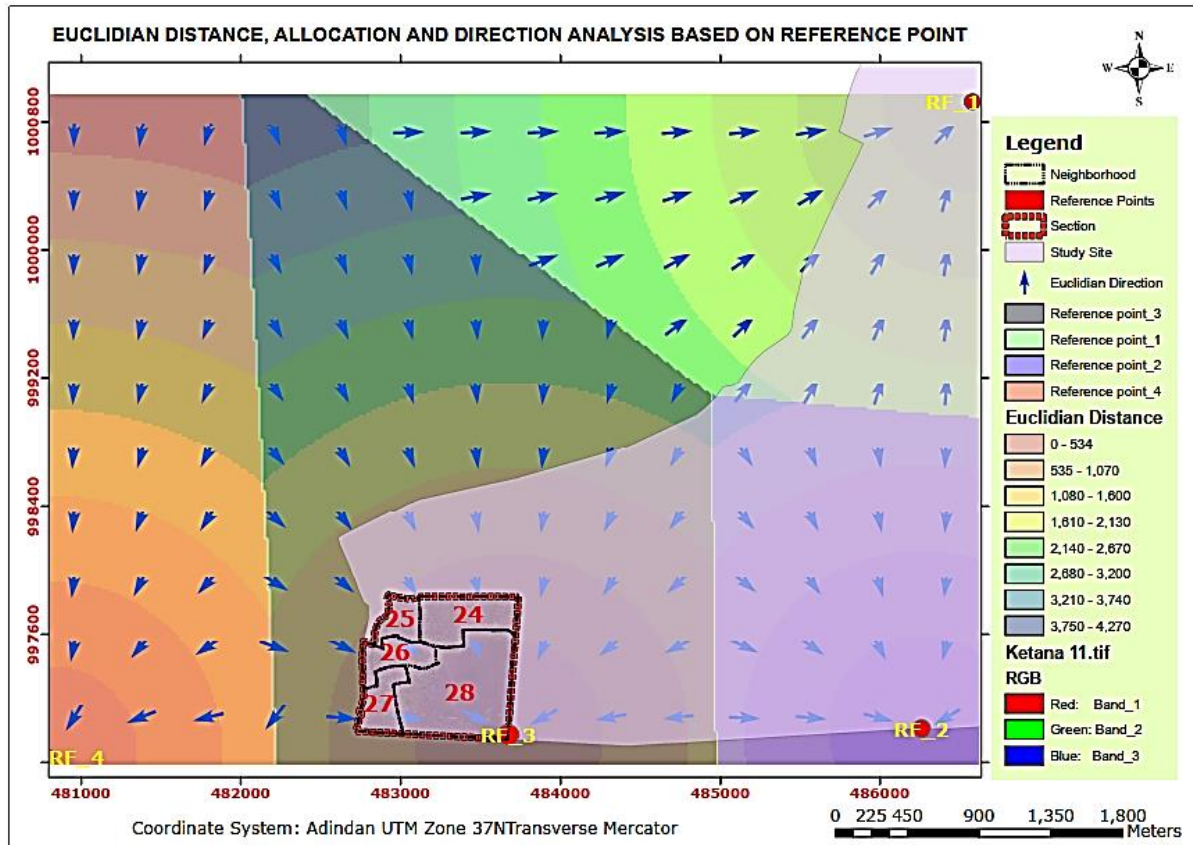


Figure 4.4: Euclidian distance, direction and allocation analysis

The evaluation method of those Euclidian analyses also has their own effect either in a positive or negative way. So, the performance evaluation analysis is important to select which Euclidian analysis method is more preferable for the selection of reference points. The analysis of the result must take into account the fact that analyses do not only evaluate the generated route directions, but also allocation and distance relative to the four reference points. All tests had a positive outcome.

The graph in Figure 4.5 and Figure 4.4 has illustrated that reference point 2 has a first-rate proximity result of the surrounding features while reference point 3 has last rate proximity result. As the sample features or any holding is far and far from the reference point, the accessibility from that reference point becomes reduced.

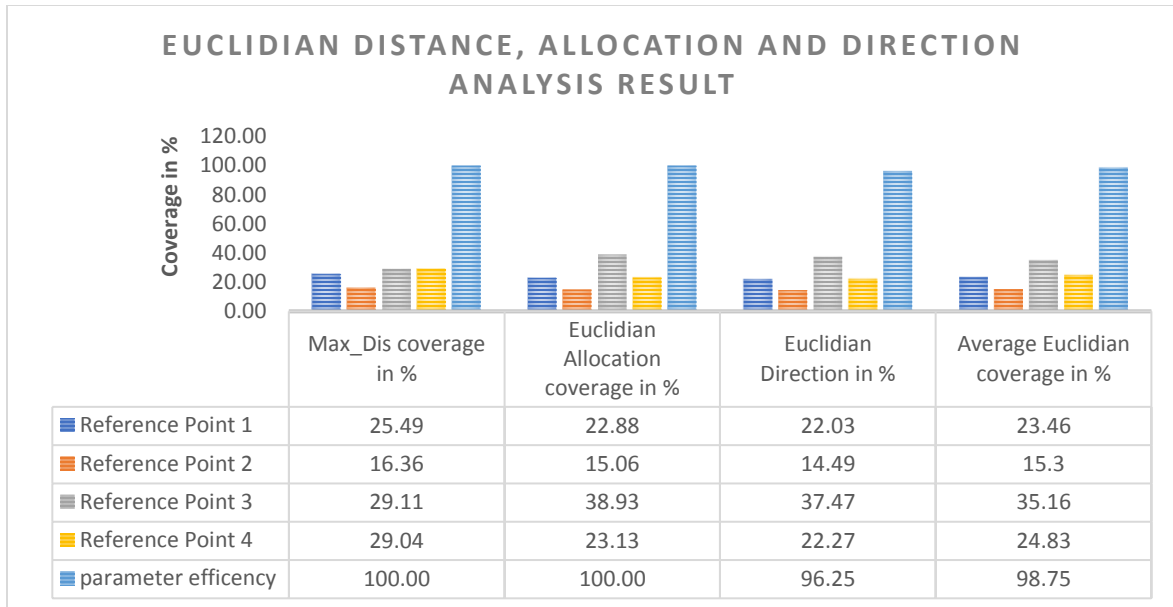


Figure 4.5: Performance evaluation of Euclidian analysis methods for the selection of reference

The Euclidian allocation result is shown in (Figure 4.5) that, 38.9% of the sample area were maximally allocated to reference point 3 while 15.1% were marginally allocated to reference point 2. The Euclidian distance and allocation result also clearly shown the exact way or method of selecting reference points for street address modeling. While the Euclidian direction has been achieving 96.3% accuracy with some outliers in the junctions, outermost distance, and intersections. But the researcher does not jump right to delete them rather assess what might be causing the problem. Probably there might be due to poor distribution of roundabouts and squares with respect to the road traffic network, or perhaps there's some poor bias fixing that is degrading the results.

Selection and design of a roundabout or square, as with any intersection treatment, requires the balancing of competing objectives. These range of transportation-oriented objectives like safety, operational performance, and accessibility for all users to other factors such as street address navigation, economics, land use, aesthetics, and environmental aspects. Sufficient flexibility is provided to encourage independent designs and techniques tailored to particular situations while emphasizing

performance-based evaluation of those designs. This can also happen when the constraints of 400m radius distance set in the command files are too tight.

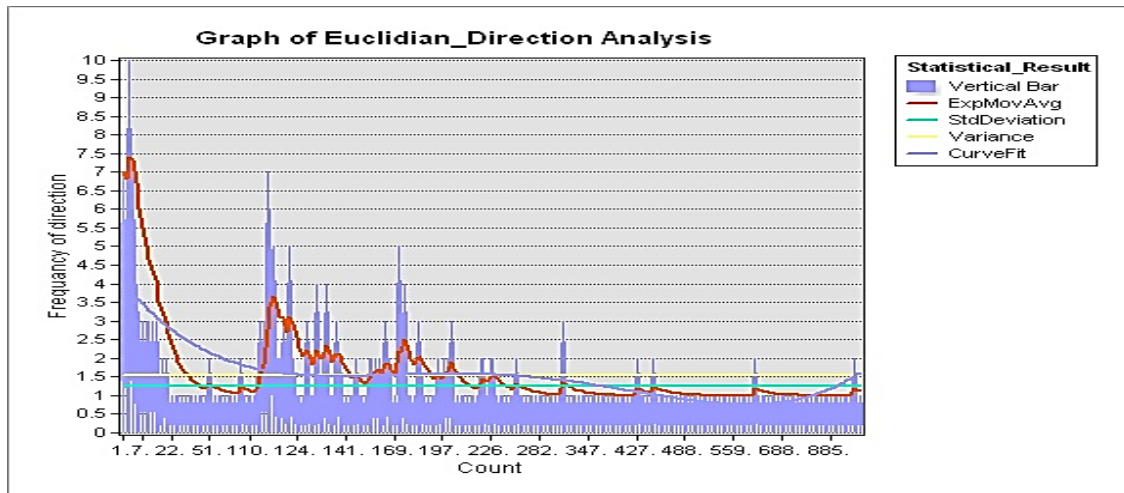


Figure 4.6: Euclidian direction analysis with respect to frequency and count

It can be seen from the graph of Euclidian direction analysis that the statistical analysis of the final results is clearly showing the outliers even though the inclusive rates are very encouraging. Generally, based on the result shown in figure 4.4 due to the proximity to the sample section ('Ketana') reference point 3 is the best reference for the study site.

4.1.5. Identification Analysis of Streets and Parcels

Defining a system for identifying streets is one of operation comprises street addressing. Street identification involves making a census of all streets in the study boundary. Results from the integration of aerial photography, recent road network data and field observation, the analysis indicated in Figure 4.7 that overall 205624.9m² up-to-date street networks were extracted inside the study boundary. From the total street network, the minimum and maximum street area are 50.2 m² and 58264.4 m² respectively. While the mean and standard deviations of a street network are 2741.7 m² and 7241.0 m² respectively. Those streets create a network and are the basic spatial data input for street address modeling. Besides these, other drainage networks were existing which provides as collective tiny gully water and urban drainages which

accounts with a total area of 16739.9 m². The total road length constructed in the study area until 2010 E.C including asphalt, gravel, and cobblestone is 29.0 kilometer.

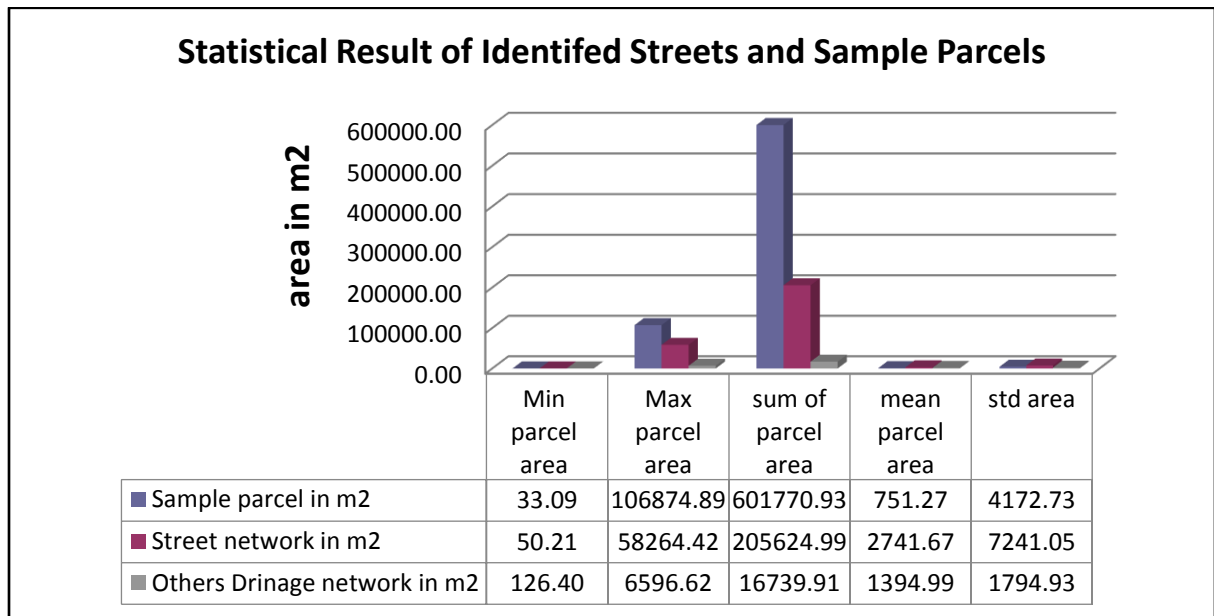


Figure 4.7: Statistical analyses of identified streets and sample parcels

As it true that a good street network infrastructure plays a great role to establish an accessible street address spatial data infrastructure. As shown in Figure 4.8, a street network infrastructure occupies for about 24.9% while other features like built-up, non-built-up and drainages occupy with a sum of 75.0% in the landscape of the study area. As the ratio of the area covered with the road in the study area is increasing which in other words enhancing mobility and accessibility in that study area.

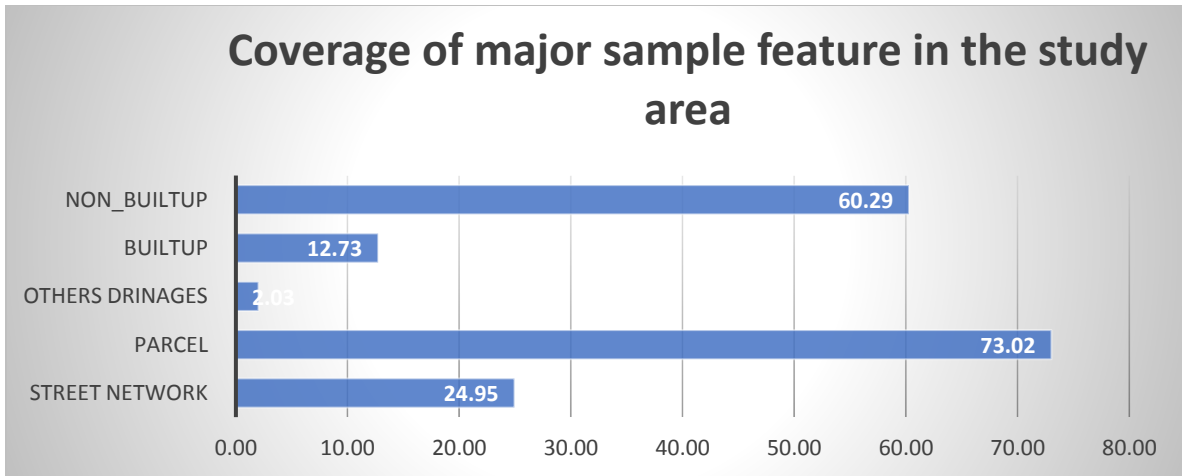


Figure 4.8: Percent coverage of major sample features urban landscape

4.1.6. Classification Analysis of Street Network

Classification of street network centerlines was evaluated based on international as well as national key parameters, norms, standards, and experiences. As shown in (Table 4.2), the identified streets were classified based on the integration of the American Institute of architects and the province of Ontario alternative classification system in line with domestic experience (See Appendix B).

Table 4.2: Classification of streets based on the American Institute of Architects and the Province of Ontario alternative classification system

NO_	International Classifications			Number of streets	Percent coverage (%)
	Name category	Equivalent category	Abbreviation		
1	Highway	-----	Hwy	----	-----
2	Expressway	Limited-Access Highway	Expy	----	-----
3	Boulevard	arterial street	Blvd	2	2.53
4	Avenue	collector street	Ave	4	5.06
5	Street	local street	St	16	20.25
6	sub street	Major street	SSt	23	29.11
7	Minor Street	---	MSt	9	11.39
8	Alley	---	Aly	8	10.12
9	Lane	Way	Ln	3	3.79
10	Passage	Row	Psge	5	6.32
11	Path	----	Pth	1	1.26
12	cul-de-sac	----	Cud	7	8.86
13	Circle	----	Cir	1	1.26
Total number of streets				79	

The result of street classification shown in table 4.2 indicates that from the total of 79 roads in the networks, 23 of them are categorized under sub-streets has the highest coverage with 29.1% while a single street was categorized under path has the least coverage with 1.3%.

4.1.7. Codification Analysis of Street Address Elements

Codification consists of identifying multiple reference points, streets, and numbering entryways. Based on the physical diagram concepts discussed in the previous result, the street address database was created and basic entities with tables and columns with data field formats were first included and restricted in the domain. As shown in Figure 4.9, the major street classification, prefix and street direction result shown in table 4.2, the category of reference points, including sample features of jurisdictional (city, sub city and woreda) and non-jurisdictional (neighborhoods, block and parcels) fields with their code type shown in (Table 4.3), were included in the domain. The criteria which was taken to include those jurisdictional and non-jurisdictional fields in address model are the relation of street address database with others cadaster, inventory, assets, etc. spatial Geo- database which imply the governing factor of likely determines the availability, accessibility and positional integration of those spatial data infrastructures in the study area. These enable to reduce the geocoding error come from manual entries in the attribute table and the uniformity of basic attribute data inputs so that efficient selection and fines queries and navigation can be possible.

Table 4.3: Jurisdictional and non-jurisdictional fields included in address fields

Features_ Category	Feature_ Name	Abbreviation	Code type	No_ digits
City	Addis Ababa	AA	TEXT	2
Sub City	Yeka	YK	TEXT and INTEGER	3
Woreda	Woreda	Woreda	INTEGER	2
Neighborhood	Neighborhood	NHD	INTEGER	2
Block	Block	BLK	INTEGER	2
Parcel	Parcel	PCL	INTEGER	3

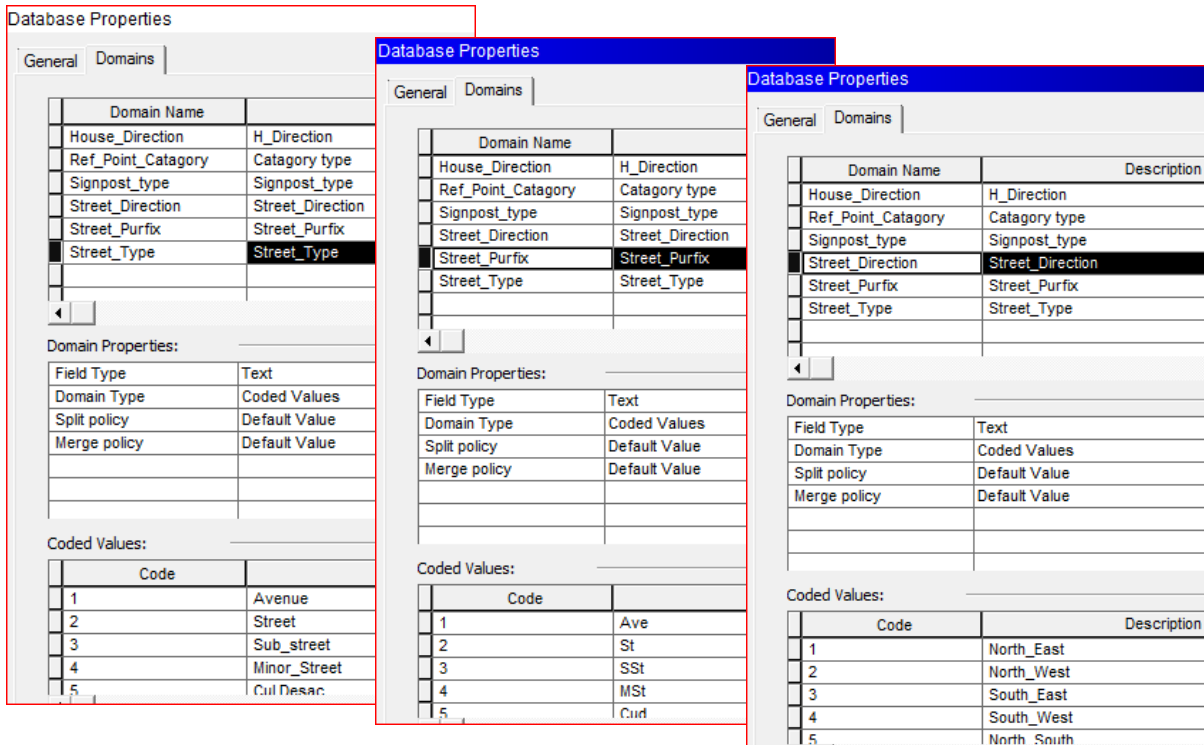


Figure 4.9: Established street address geo database domain for street network geocode

The result obtained from key attribute fields of street centerlines shown in the figure 4.10, indicates that the basic attribute elements of the street network that are included in the physical diagram model were converted into an operational database so that street networks are segmented into 79 centerlines shown in table 4.2 and geocoded based on ARF method.

As shown in (Figure 4.10), streets are represented by their segmented centerlines and each of the segments are composed of the beginning and end of the street address and their location, street names, types of street, abbreviations, bidirectional beginning and ending numbers of the streets information's are populated in the attribute of street dataset. In addition, the street address name codes were geocoded following the relational entities.

[< Sub city> + <Woreda code> + < Reference Code> + < Street Code > == Street type prefix]

STREET CENTERLINE GEOCODE MAP OF THE STUDY SITE

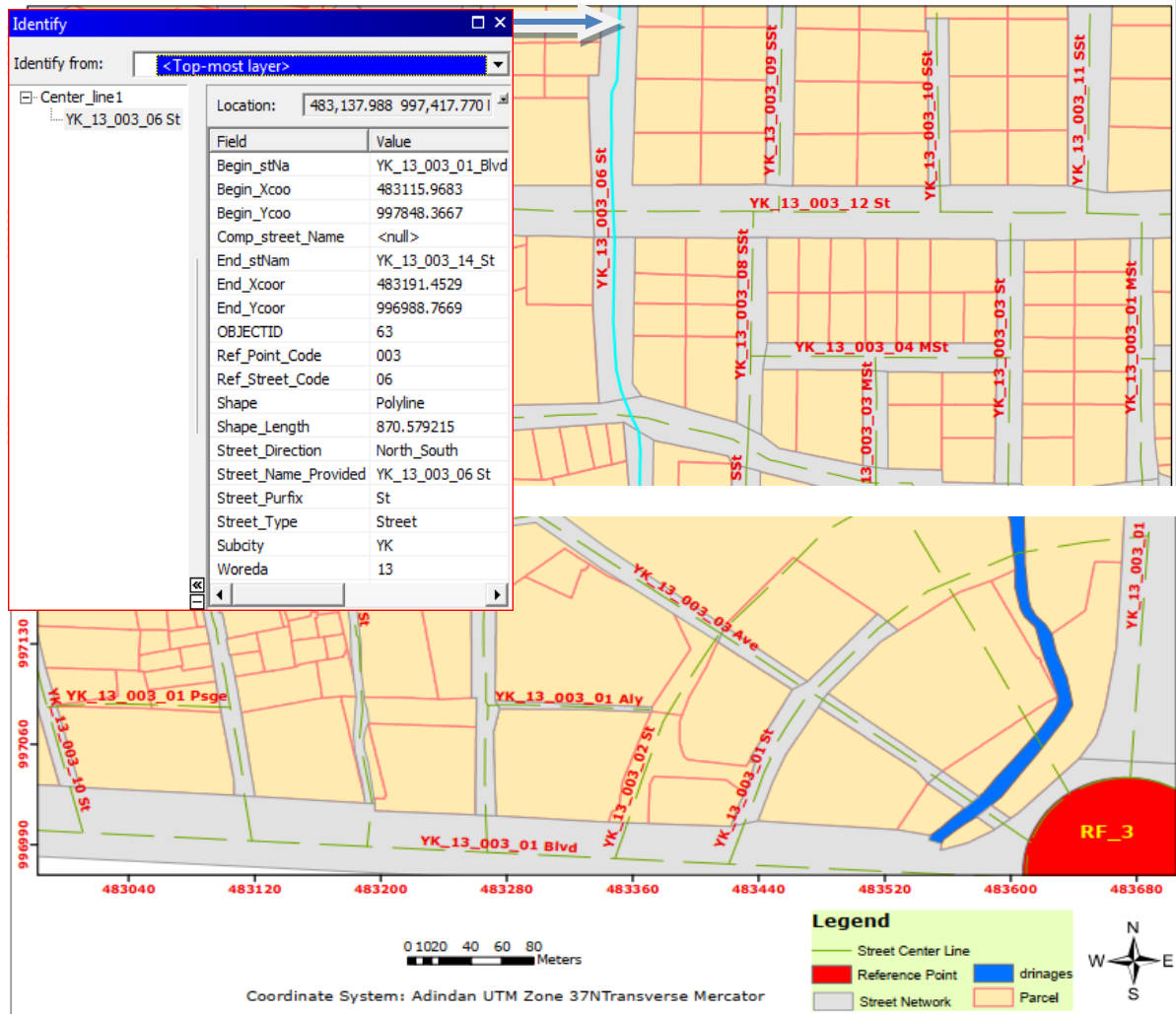


Figure 4.10: Result of street network polygon represented by street centerline geocode and its Key attribute fields

It's clearly shown in the figure 4.10 that a single center line street name code was described as YK_13_003_06 St. this means that YK=> sub city code, 13=>woreda code, 003 reference code, 06=> street code and St=> street prefix that shows the street category. The other important field data is the street direction that describes the street outline during the design. The orientation of streets from where to start and were to end are important to clearly accessible and navigated by the users at all. When we come to the street address map results from multiple reference integration of basic address elements were involved.

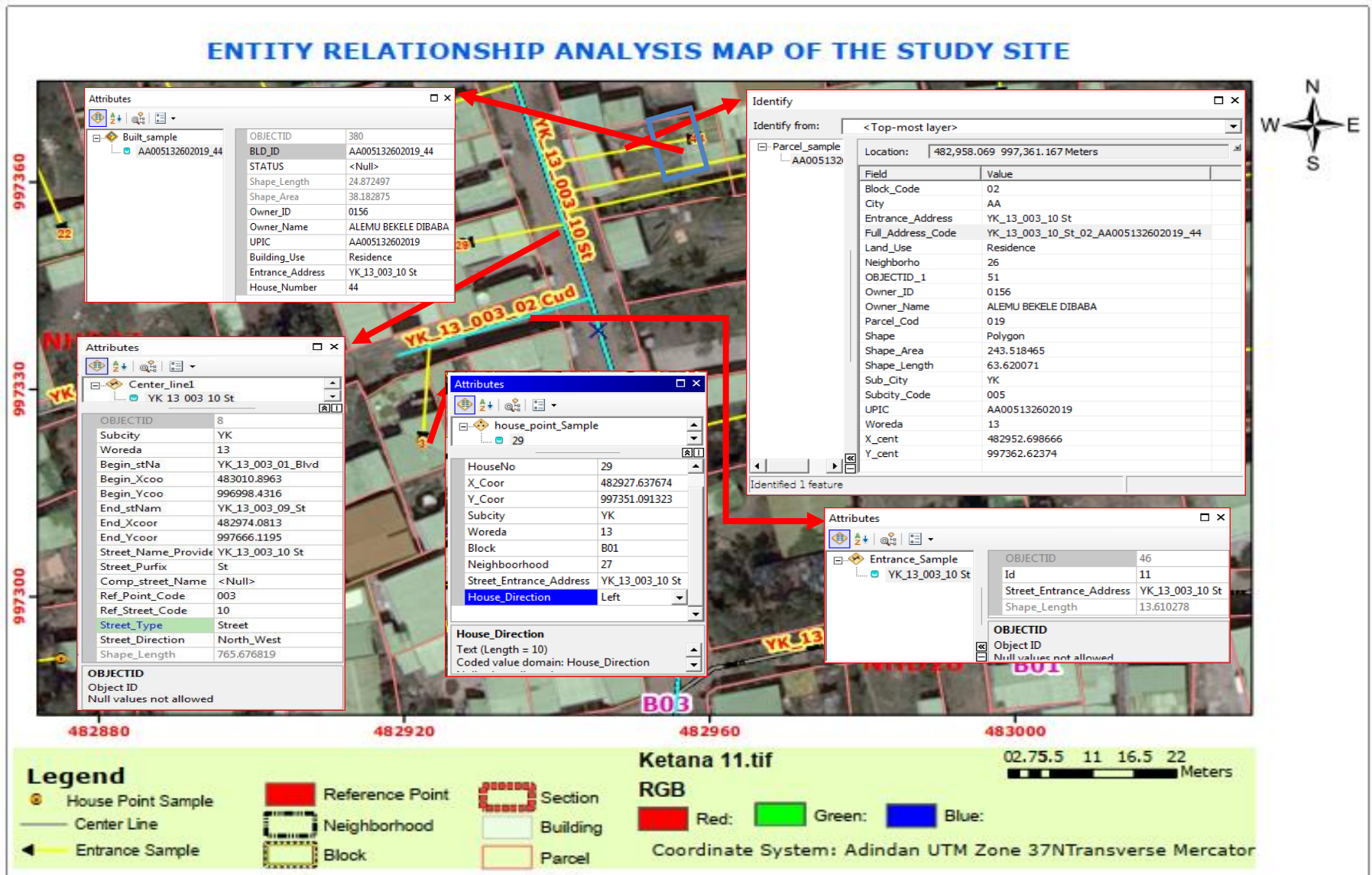


Figure 4.11: Relationships of address elements in street address model

As shown in Figure 4.11, a full address of single residential holdings contains:

- Different jurisdictional administrative sections (City, Sub_city, Woreda)
- Reference Code and Street Code
- Street type and Block Code
- The unique parcel identification code (UPIC) and House Number

For example: YK_13_003_01Ave_10_AA008134310012_06

When we try to see the detail of full address elements from the above example, the following illustration can clearly show how street address code and the unique parcel identification code are integrated into a street address geodatabase. The most important idea in relation to this is to make a relationship and link the address of the owner with its holding parcel. But it doesn't mean that full address codes are used to access and navigate manually or electronically or are displayed on the signage and signposts. Rather, it's used to provide basic address information of the owner with his detail legal issues of land or property holding for street address units and detail address information for cadaster units.

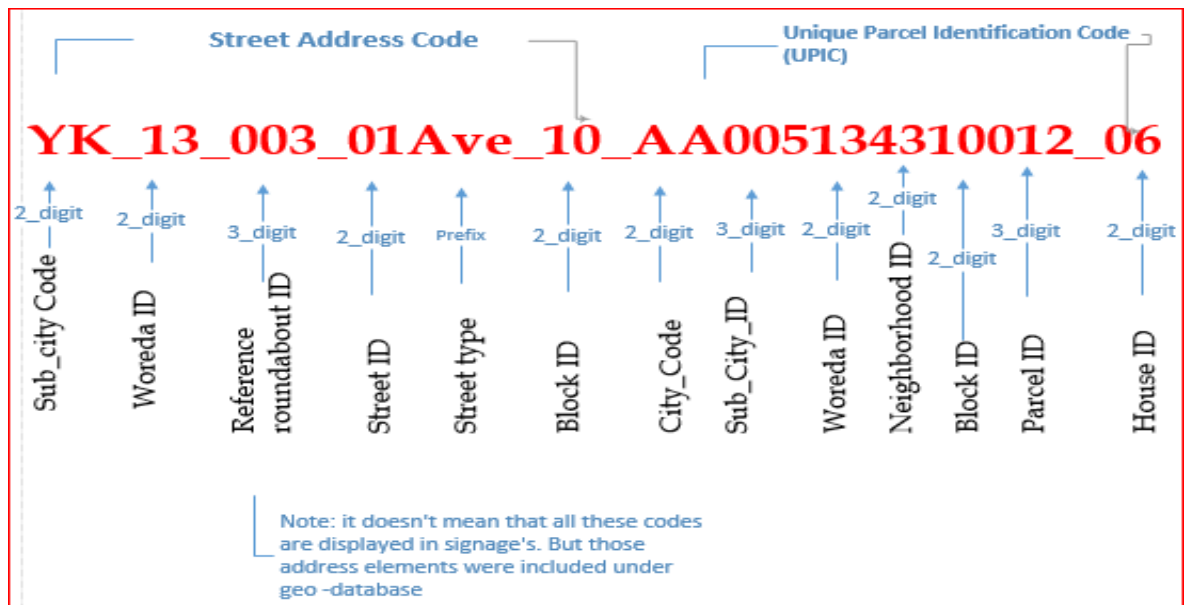


Plate 4.1: Sample codification of full street address for single apartments and holdings

In their simplest form, manual navigation can be possible if we have a single address point of a house. As shown in (Figure 4.11), A sample house point of the attribute fields consists of jurisdictional and non-jurisdictional fields, entrance address and even the direction in relation to the closest street. So, using this information we can simply explore the information's of the sub-city, woreda, reference roundabout, and the street including its type because street address entrance is used as a foreign key. There also can be more practical and accessible those address infrastructures using an address point system which was analyzed and integrated with this database later in the following section of this research.

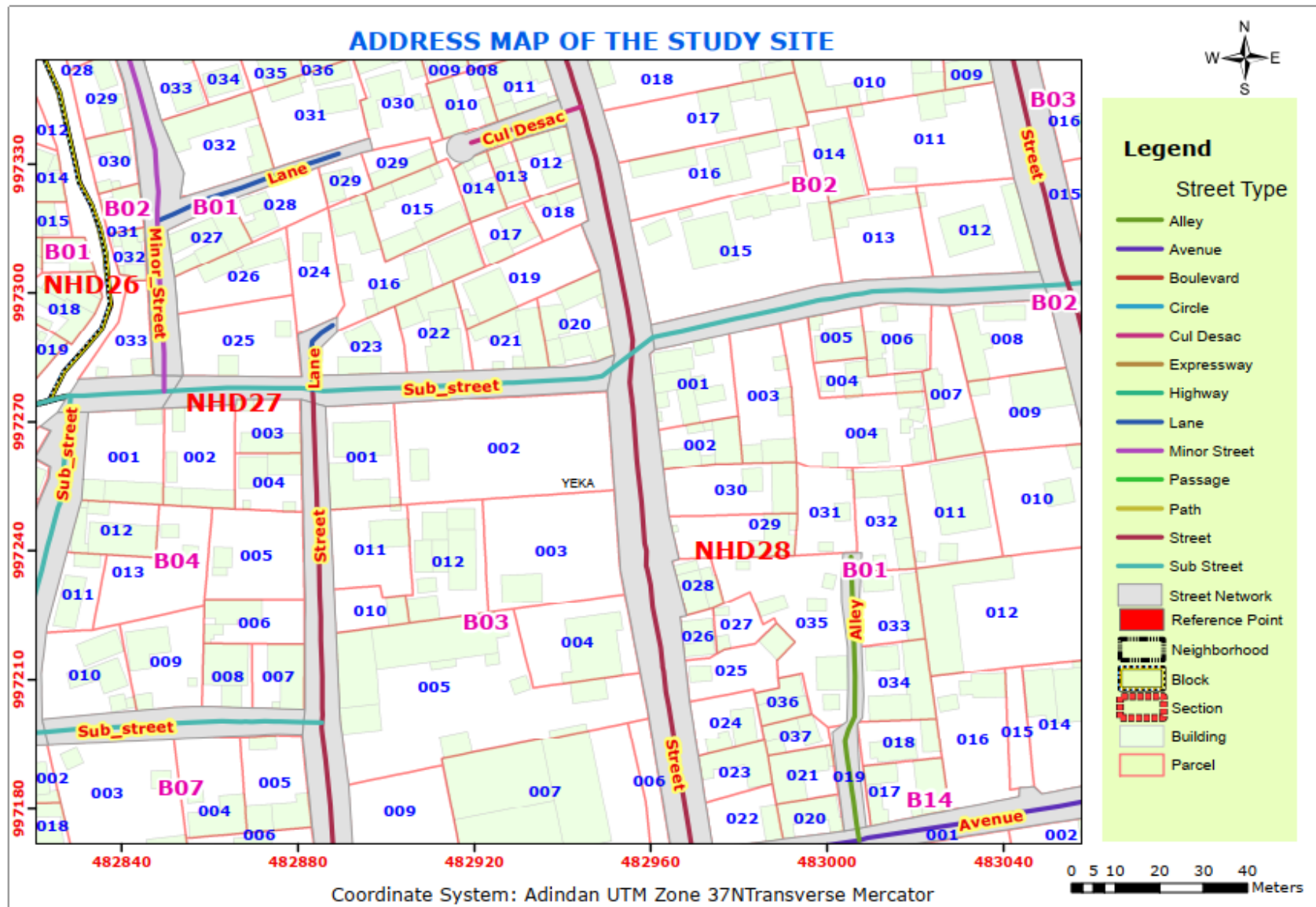


Figure 4.12: Street address map of the study site

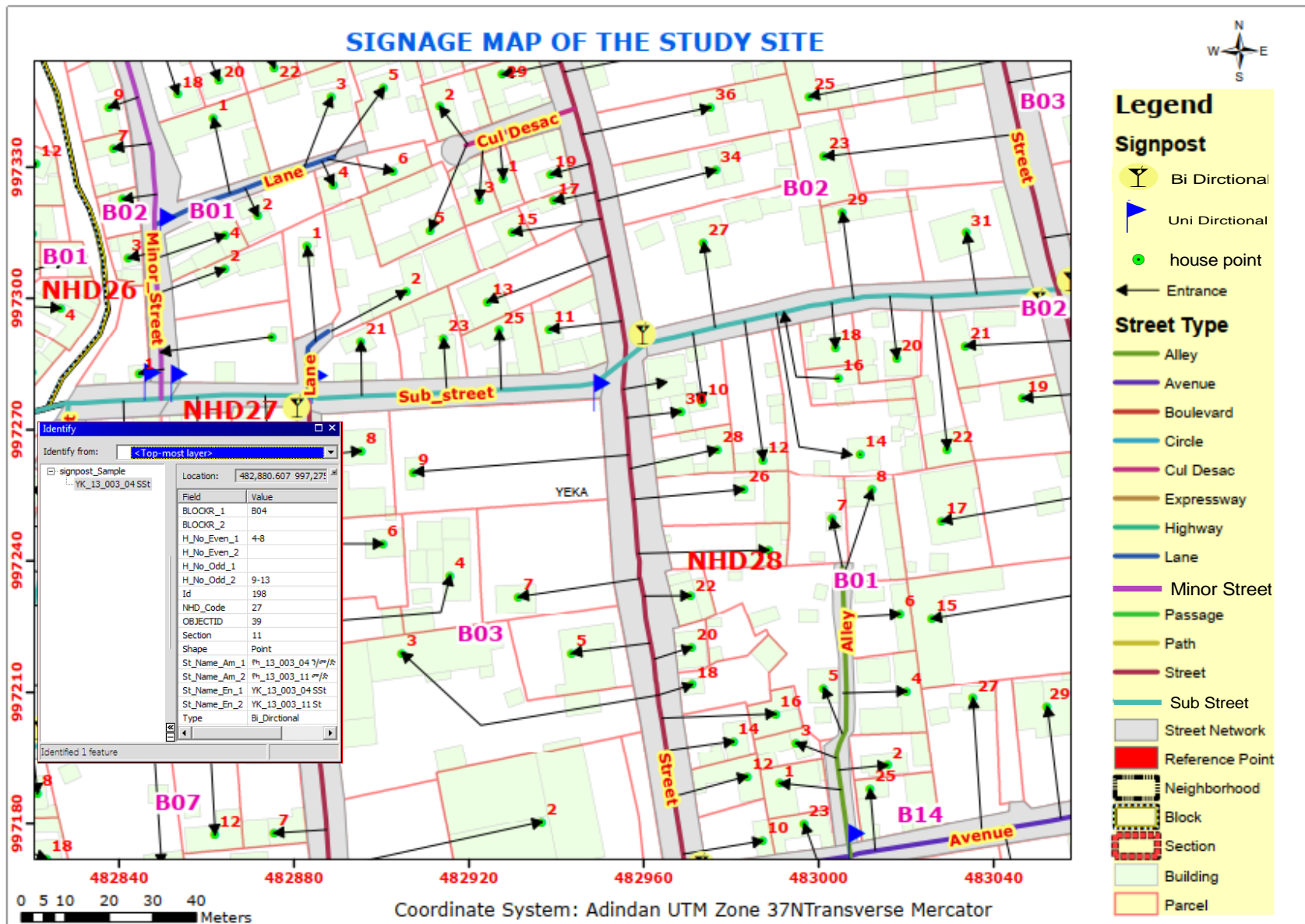


Figure 4.13: Distribution of signposts and their relation with the street network

The result obtained from a street address map of the study site in (Figure 4.12) indicated that the entity relationship analysis is based on the pre-analysis entity relationship shown in (Figure 4.2). The address elements like sample entrances, street, and reference point were converted into tables. Their relationships were also described using foreign keys and basic attribute fields.

Furthermore, the signage distribution map indicated in (Figure 4.13) that there is a close distribution with covering the whole holding parcels in a block. Their distribution is based on placing bidirectional signage for bidirectional entrances of the streets most likely in the corners of blocks and unidirectional signage for a single entrance of streets in the blocks. As shown in (Figure 4.13) taking an example, parcels existing in neighborhood 28, block 01 has entrances to the whole direction so that the block was represented by two bidirectional signage's fixed to show north-east and south-west directions of entrances in the block while, parcels existing in neighborhood 27, block 03 has entrances in two directions so that the block was fixed with two unidirectional signage. This implies that the density distribution of signage was depended on the type of streets and the direction of entrance address from the closest street.

In addition, most access streets existing in neighborhoods of the study area are characterized by poor dimensional, engineering standard and dead-ends. But, as the residents use those roads, we should have to include in the street address database so that they need signages. It's evident from the above example of neighborhood 28, block 01; additional unidirectional signage was allocated to locate parcels entrance started from the closer access road which was categorized under Ally Street. Therefore, the users can simply navigate and access those spatial data infrastructures without getting confused.

The summary of street address model from multiple reference point is depicted in (Figure: 4.11, 4.12, 4.13) have indicated that the operational street address database

was clearly modeled that can be accessible and navigable. These maps provide the reader with a vivid impression of multiple street address modeling and integration of addressing spatial data with other spatial data infrastructure like transport.

4.1.8. Codification Scheme of Multiple Floor Buildings

In urban centers, vertical growth of building is inevitable and it's a characteristic of modern urbanization. Multiple buildings can be mixed-use and multi-resident structures. This research dictates in (Figure 4.14) that the codification should start first from address number assigned to the entire building. Then, the floors and floor sections were assigned as secondary and tertiary location indicators respectively. The numbering system is sequential numbering system so that each of the building, floor and floor section ID was clearly codified with two digits.

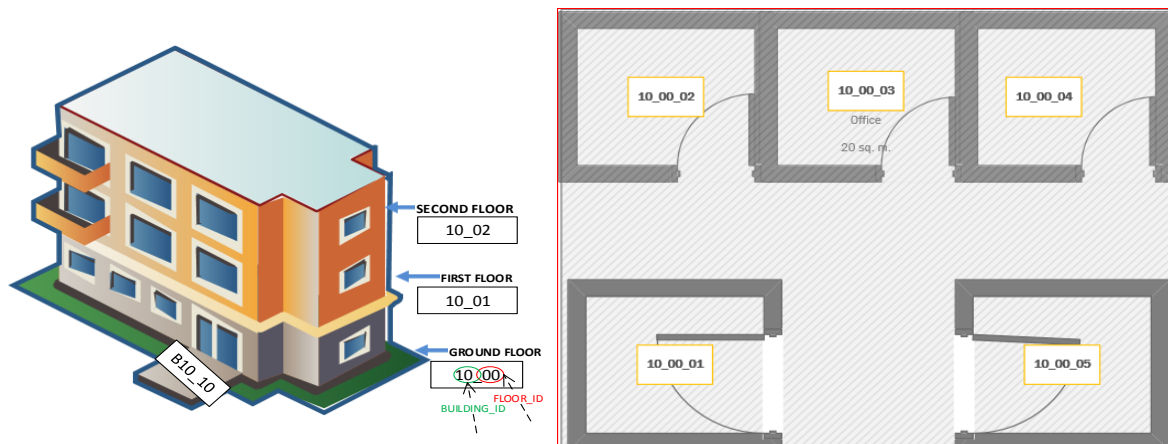


Figure 4.14: Numbering of multiple buildings on a single parcel, floors, and sections

For such occasion, where a single parcel consists of single multiple floor building, the full addresses become the sum of:

- Different jurisdictional administrative sections (City, Sub_city, Woreda)
- Reference ID
- Street code and street type
- Block ID
- The unique parcel identification code (UPIC)
- Building ID
- Floor ID and

➤ Floor section (House Number)

For example: If an owner has a single floor section in a single mixed-use building and we need to provide address for that holding, then his address will consist of the following basic address elements described in (Plate 4.2), The main difference between the single residential address and multiple building residential or mixed-use buildings are the existence of floors and floor sections. Due to this, the additional code should be used to link the floor sections with the floor and the floor with the building.

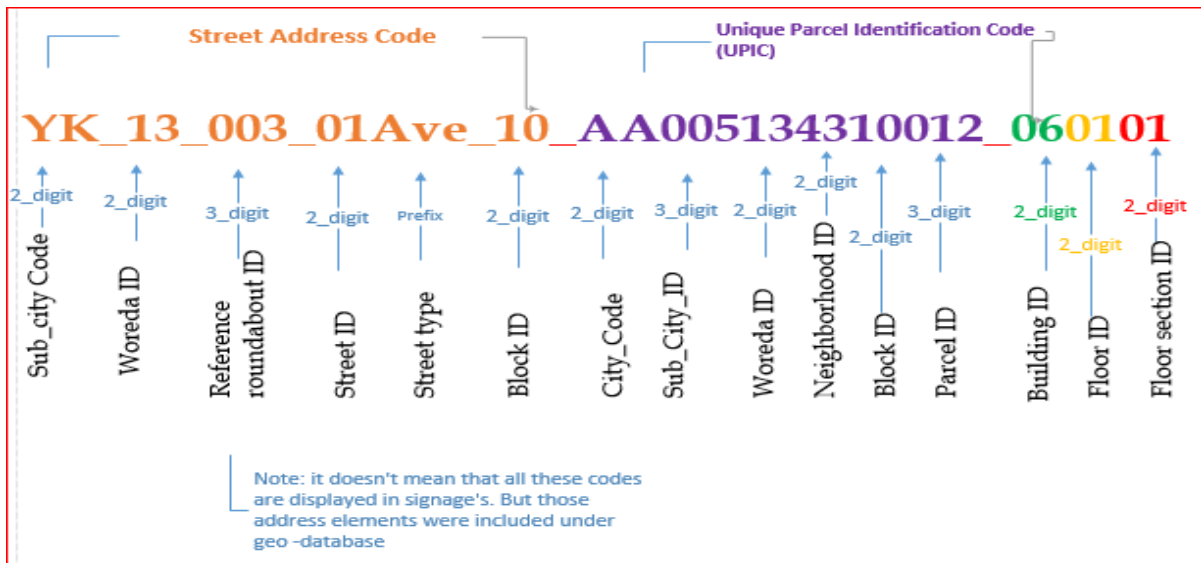


Plate 4.2: Sample codification of full street address for multiple and Mixed-use buildings

In an urban center, vertical growth of building can be constructed on the holding with a possibility of two conditions. A single mixed building can be constructed in a single parcel is the first condition while a single parcel can be the site of more than one multiplex building are the other condition. As shown in (Figure 4.14), a single building existed in a single parcel. While (Figure 4.15), indicates that multiple buildings existed in a single parcel and the codification is similar with the above shown in (Plate 4.2), but the only difference is the additional alphabetic code on house number from left in a clockwise direction.

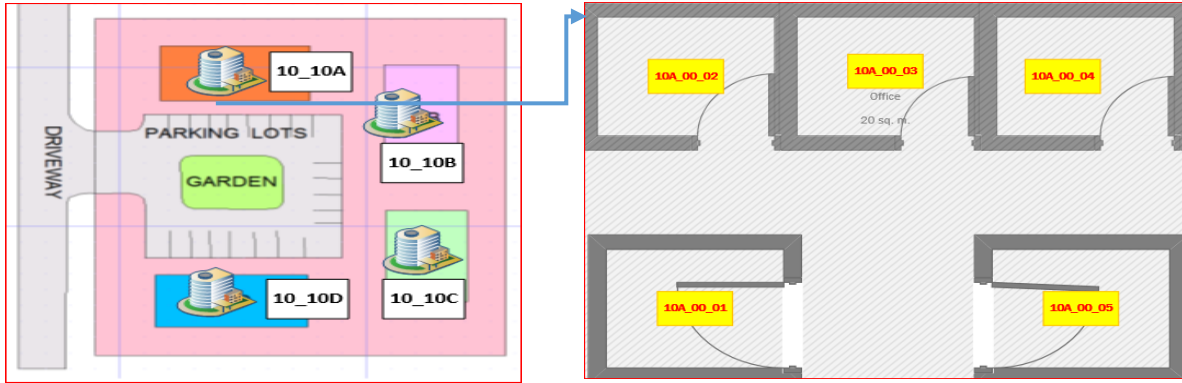


Figure 4.15: Sample codification for occurring multiple buildings in a parcel

4.1.9. Exploration Results of Centroid for Polygon Features

The result from spatial analysis of vector data sets shown in (Figure: 4.16) indicates that the centroid of each sample parcels was computed based on four different methods of algorithms in Arc GIS and QGIS software's but the way that the centroid point represents the polygon is quite different in terms of positional location.

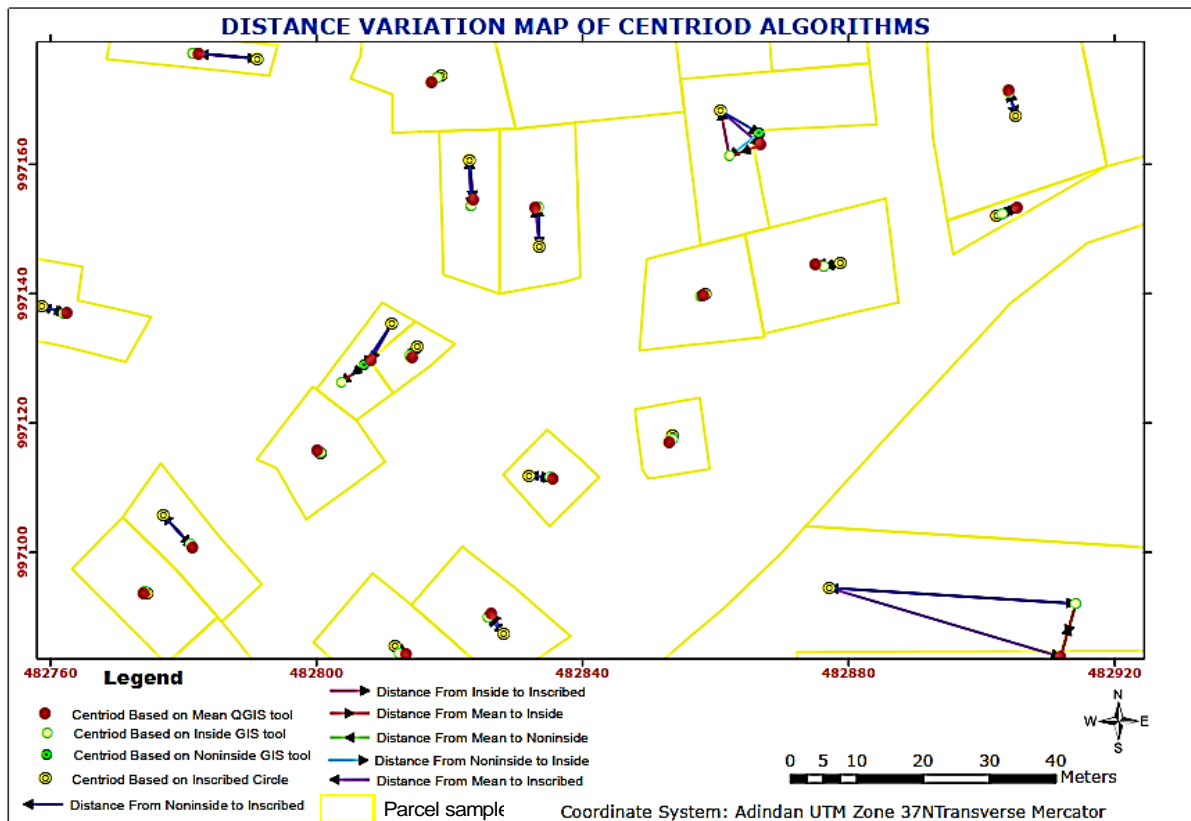


Figure 4.16: Distance analysis and horizontal distribution of the four centroid algorithms

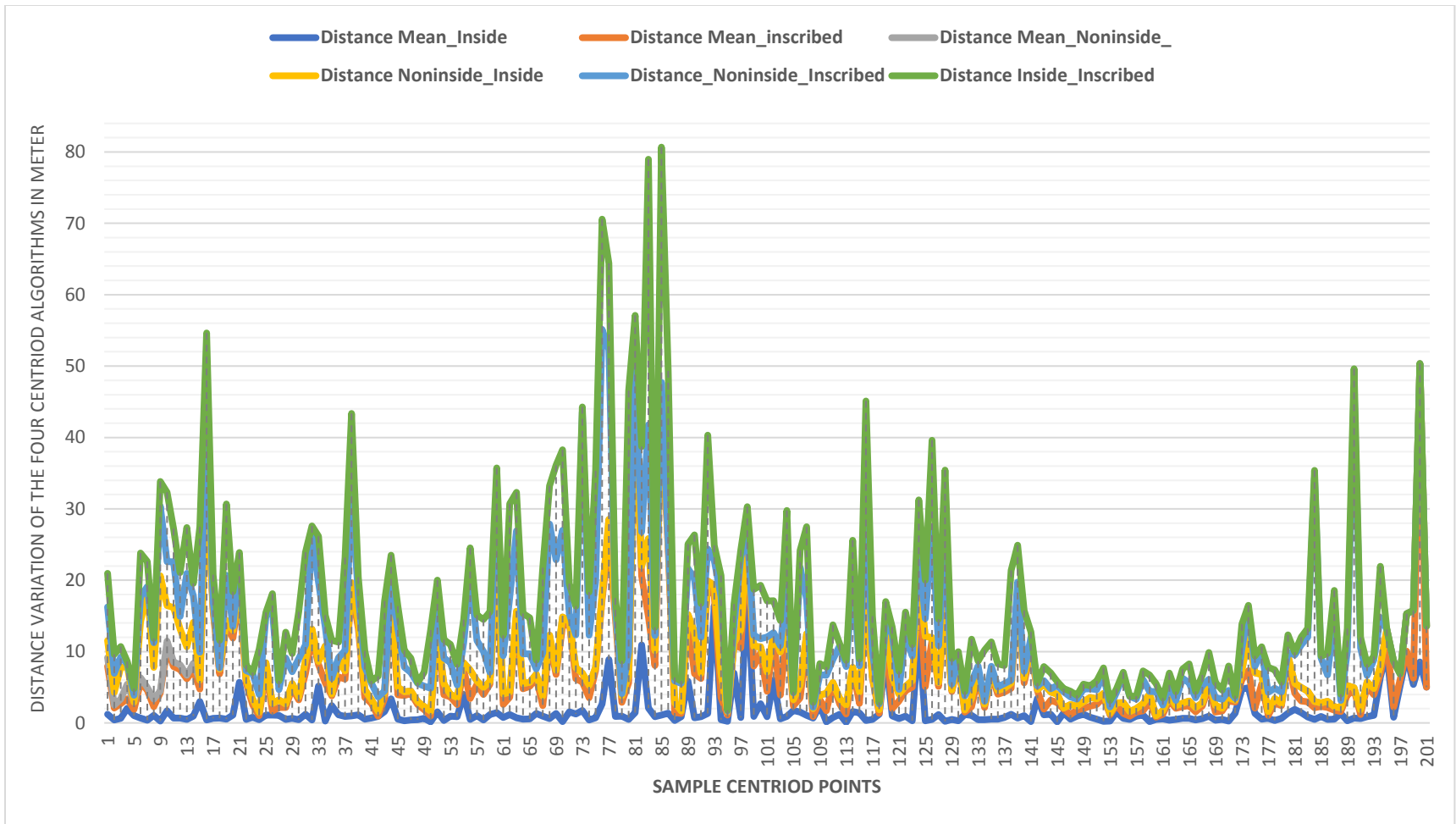


Figure 4.17: Horizontal distance variation of the four centroid algorithms

From the distance matrix analysis, we can see that some of the polygons are not represented by the centroid (the centroids are outside the polygons) while others are inside the polygon and are clearly describe how the positional accuracy and horizontal variations are there. In addition, the total horizontal distance variations of the four centroid algorithms for each sample points shown in (Figure 4.17) at sample point 146 has 4.153m and point 86 has 82.673m minimum and maximum distance variations were respectively observed.

Table 4.4: A cross-match rate of centroid computing methods and algorithms

Pair- Wise Comparison Match Rate Result of Centroid Computing Methods and Algorithms						
ID_NO	Algorithms used	Center of mass not contained by polygon feature	Based on the weighted mean coordinate of vertices	Based on biggest inscribed circle	Center of mass contained by polygon	Total cross match rate in %
1	Center of mass contained by polygon feature match rate %	93.53	0.00	0.03		31.19
2	Based on biggest inscribed circle	0.03	0.00		0.03	0.02
3	Based on the weighted mean coordinate of vertices	0.00		0.00	0.00	0.00
4	Center of mass not contained by polygon feature		0.03	0.00	93.53	31.19

According to the result shown in (Figure 4.18), algorithms based on the centroid of mass contained by polygon feature, the biggest inscribed circle, the weighted mean coordinate of vertexes and, the centroid of mass not contained by polygon feature has 99%, 100%, 96.51% and 98 % of sample polygons are represented by the sample centroid results respectively. Among them, the algorithm based on the biggest inscribed circle is more efficient to represent complex polygons than others. In another way, the approximate point to point distance matrix match rate of the centroid of mass contained by polygon feature, the biggest inscribed circle, the weighted mean coordinate of vertexes and, the centroid of mass not contained by polygon feature has 94.02%, 97.51%, 86.57% and 89.55 % of sample polygons are relatively represented by more accurate sample centroid results respectively.

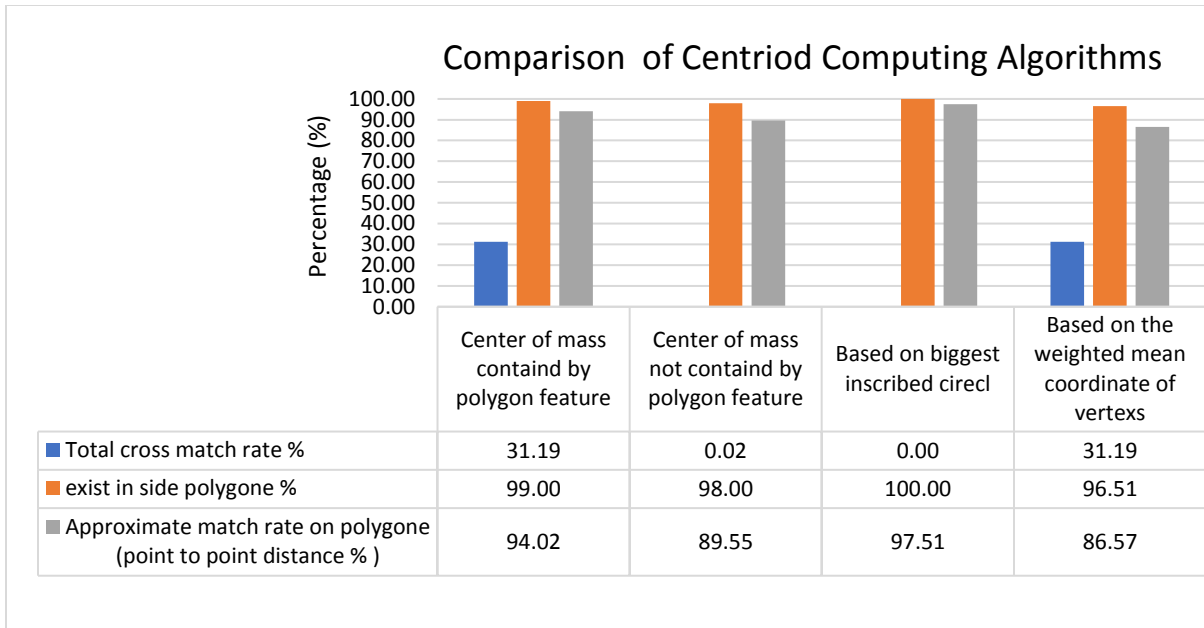


Figure 4.18: comparison of centroid algorithms based on polygon representation

According to the comparison analyses which were ensued previously, we can say that algorithm based on the biggest inscribed circle has better relative visual positional location than the others. The centroids of each address points were represented from the resulting algorithm of the biggest inscribed circle using MATLAB software. (See the algorithm in Appendix D). Because centroids are represented by which vertexes of polygon provide drawing the biggest inscribed circles shown in (Figure 4.19) with a higher radius so that it has a solution including for those polygons having a complex polygon in that the centroid is outside the polygons. This means the probability of the centroid drawn outside the polygon is almost zero.

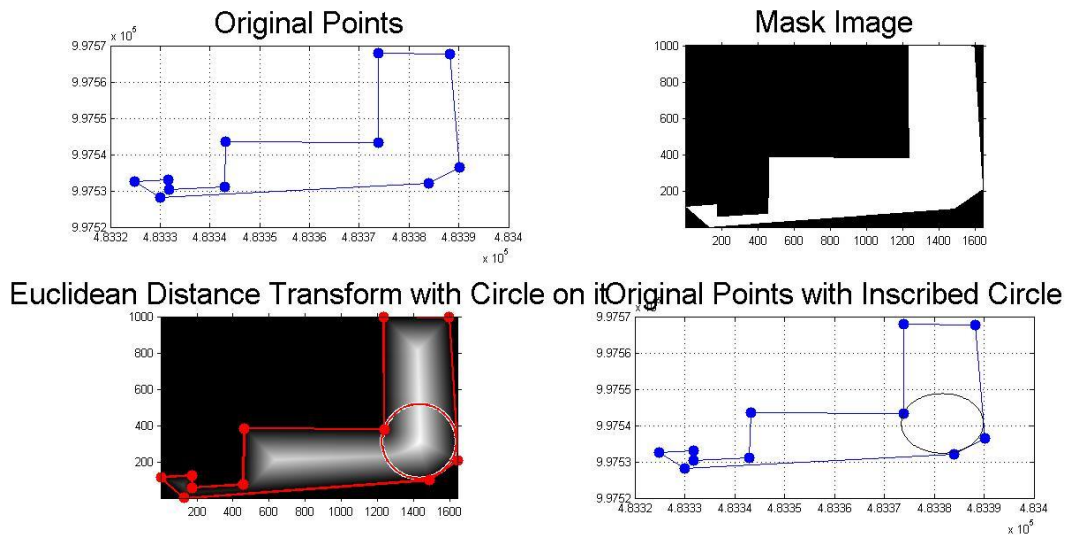


Figure 4.19: The biggest inscribed circle Euclidian distance transform analysis of the polygon centroid

4.1.10. Address Point Analysis and Geocoding in Street Address

Results obtained from address point analysis indicated in the figure 4.20 shows that the key attribute elements for navigation of owner's house address are indicated in the database with star symbols while others are supportive field elements are also included. During navigation both in manual or digital form, we can start from the reference point of the roundabout and then follow the street and entrance address so that the entrance direction dictates which house become. In the address point system, digital navigation is more supportive than manual, because the time spent is very short, easy to understand and access using the centroid coordinates of the holding parcel.

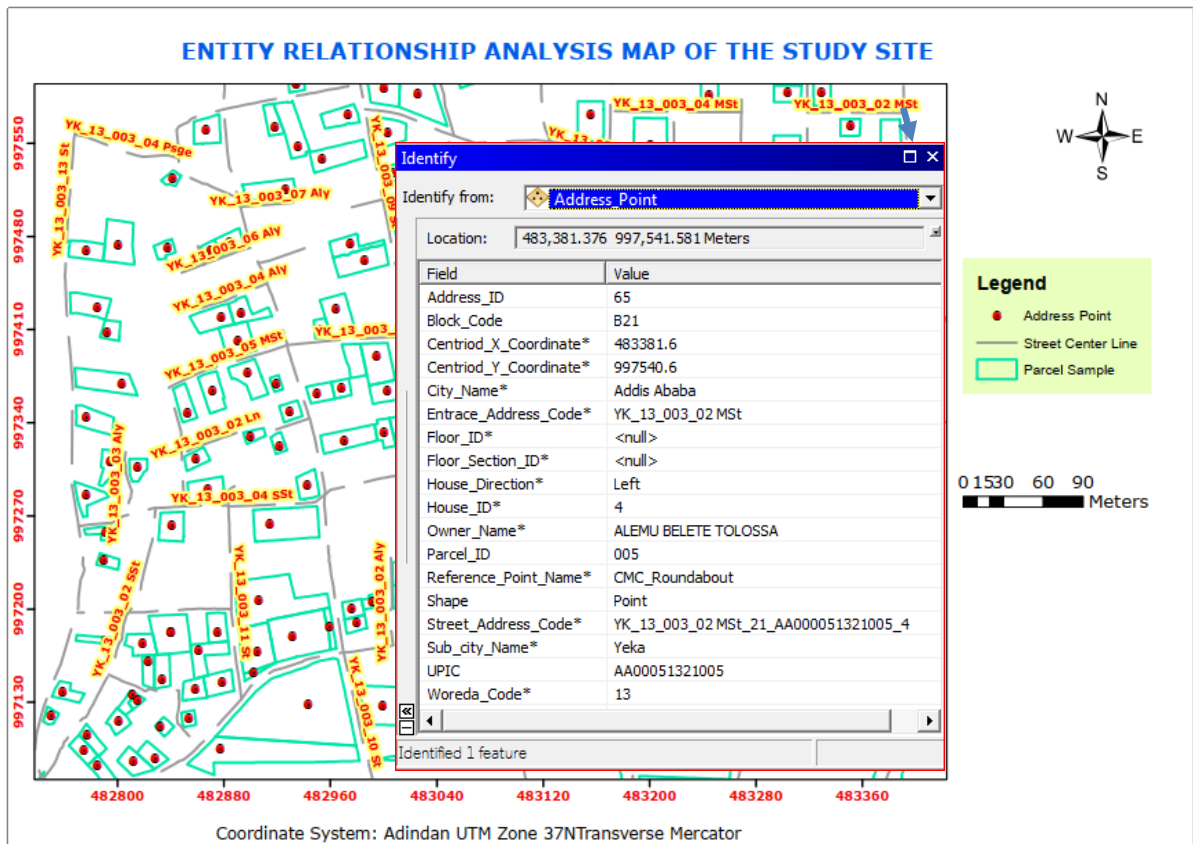


Figure 4.20: Address point map of the study site

4.2. Comparison of Street Address Between Studied and Existing Models

4.2.1. Comparison Based on Key Comparison Parameters

The Comparison indicated in (Appendix F) that, the comparative analysis of the two models were taken using the key comparison parameters broadly categorized under Geocoding technique, quality, navigation opportunity and accuracy, and compatibility comparison.

4.2.2. Comparison Based on Street Classification Scheme

Table 4.5: Comparison of street classification between the new and existing street address model

NO_	International Classifications			New Model		Existing model						
	Name category	equivalent category	Abbreviation	number of streets to be accurately categorised	number of streets accurately categorised under	number of streets to be accurately categorised	number of streets categorised under					
							Ave	St	Sq	Cud	not categorised	categorised percentage
1	Highway		Hwy	----		----	----	----	----	----		
2	Expressway	Limited-Access Highway	Expy	----		----	----	----	----	----		
3	Boulevard	arterial street	Blvd	2	2	2	2	----	----	----		0.00
4	Avenue	collector street	Ave	4	4	4	----	4	----	----		0.00
5	Street	Major street	St	16	16	16	----	16	----	----		100.00
6	sub street	local street	SSt	23	23	23	----	22	----	----	1	0.00
7	Minor Street		MSt	9	9	9	----	5	----	----	4	0.00
8	Alley		Aly	8	8	8		2		5	1	0.00
9	Lane	Way	Ln	3	3	3	----	----	----	1	2	0.00
10	Passage	Row	Psge	5	5	5	----	1	----	2	2	0.00
11	Path		Pth	1	1	1	----	1	----	----		0.00
12	cul-de-sac		Cud	7	7	7	----	1	----	3	3	42.86
13	Circle		Cir	1	1	1	----	----	1	----		0.00
Total number of street				79	79	79	2	52	1	11	13	12.99

As the geocoding techniques support geographic utilization, navigational street orientation, and justifiable street classification scheme shown in (Appendix F and Table 4.5), the accessibility of street address become reasonably increased. In addition, dense signage distribution improves the representation of parcels and blocks in proximity. Including jurisdictional and non-jurisdictional administrative division are also having their own advantage in terms of integrating street address model with other geospatial infrastructures like cadaster, land inventory, asset etc. When we consider the navigation opportunity and its accuracy, the linkage of point address data with the street address in the new model provides access to navigate in both manually and digitally than the existing model.

According to the focused group discussion shown in (Table 4.6), compatibility of the existing model in relation to the irregular and under standard road pattern makes ambiguity and creates a challenge in the identification of principal point and baseline as a reference so that referencing of a specific point from those benchmarks is being completed. Challenges faced during and after implementation especially on street classification and orientation.

As it's true that educated society is more familiar with such spatial data infrastructure than the non-educated one and street address are not only for the residents but also the migrant from surrounding urban-rural linkage and foreigners. The responses of focused group discussion dictate in (Table 4.6), that it's believed to be that that categorized society has a similar reaction (unfamiliarity with the spatial data infrastructure is dominated). Even though there is a positive response in understanding the street address model, use and accessibility by the street address unit experts, other urban sector units are not familiar with existing street address infrastructure.

The other important point of the street address is the application of manual and digital navigation. Discussing on this component was a long time taken brainstorming. The respondents supposed that navigation needs positionally accurate information so that existing street address has not justified centroid information rather it has house point data characterized by positional errors. In (Table 4.6), the respondents dominantly argue that manual navigation can be possible if the principal point and baselines are known with street address code and digitally can be possible using the house point data. But it has their own limitation in relation to the digitizing error and sensitivity in changes of house point. Another argument is the integration of street address data with other geospatial data infrastructure. According to the respondents, the existing street address model has a limitation in integration with postal address, cadaster, and other utility infrastructures. Because in most case, postal address and utility infrastructures are represented by point data rather than a polygon

4.2.3. Comparison Based on Focused Group Discussion

Table 4.6: Opinions given from analysis of focused group discussion

Focused group discussion Analysis			
	Theme points	Sub points dominantly respond by focused groups	Response summary
1	Geocoding technique compatibility as per our countries and city context	Principal point and baselines technique	The references are not clear to the users.
		Road pattern and standard street network	Has a limitation since the street network models are traditional and mostly practices with regular and standardized road pattern network
		Challenge in referencing a specific parcel	Complex as the distance too long and far from the principal point and the baselines related to the Positional error.
2	Challenges faced during and after implementation	During implementation	Has a challenge when selecting a principal point for the entire of Addis Ababa city as a reference and two baselines because of irregular road pattern with under standard street
			For those streets having other than North-South and East-West orientation, the classification scheme doesn't support. Generalization is being applied into two categories of orientation during street classification.
		After implementation	Creates ambiguity by the users
3	Accessibility	Educated society	Respondents believed that has a similar reaction (means that unfamiliarity with the spatial data infrastructure is dominated)
		Non-educated society	
		Immigrants and foreigners	
4	Attitude of experts and staff towards the concept	Experts and staff members	Has a positive response
		Other urban sector units	Has limitation to know the concept and use, they react negativity because of non-comprehensiveness among existing street address model and media champagne
5	Compatibility for navigation	Manually	Can be possible if the principal point and baselines are known unless it's become complex
		Digitally (Electronically)	Can be possible using the coordinates of house points but it doesn't provide the full information and has digitizing error makes less accurate
6	Integration with other geospatial infrastructure	With cadaster	Has limitation to link the full street address of a parcel with the cadaster data of that parcel
		With postal address	Has limitation because house point data is less accurate that centroid point data
		With utility infrastructures	Has limitation because house point data is less accurate that centroid point data

4.3. Conceptual Framework Design for Party-Centric Data Usage of Web Application.

To access the street address infrastructure with electronic platforms, integration of centroid address database with web application tools like Google map™, world map, and Arc GIS online are mandatory. The conceptual frame workflow is shown in (Figure 4.21) that basic address element shape files including address point system component are constructed in the Arc GIS street address geo-database. From those elements, reference point and street centerline key are important for web-based navigation in line with address point system component. This system component represents the address of each parcel with more representative centroid positional location of point data that was linked with all address elements using the foreign key and primary key.

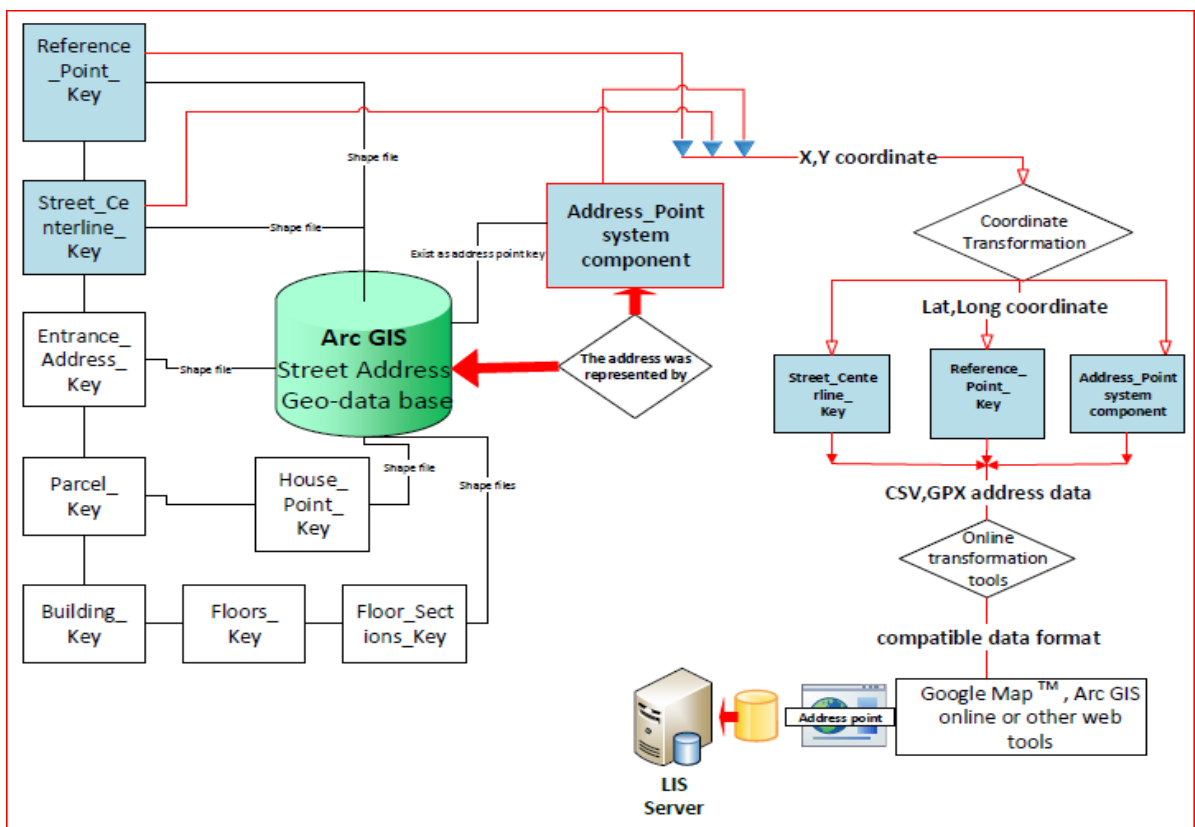


Figure 4.21: Conceptual flow chart for the conversion process of Arc GIS street address database into Web Server

Initially, the coordinates of those data sets are a local datum of Cartesian (X, Y) coordinate so that there should be converted to the geographic coordinate of latitude and longitude coordinate system using coordinate transformation. Because Web navigation tools are designed with the GNSS world global datum of geographic coordinates.

As shown in (Figure 4.21), street centerline, reference point, and address point system component datasets have geographic coordinate and essentially need to convert the attribute CSV or another file format into compatible data format like KML using online conversion tools. The other step will be importing of address point system component data into Google Map TM, Arc GIS online and other web navigation tools using mapmaker tools.

The conceptual framework chart is shown in (Figure 4.22) that, different governmental or non-governmental organization units can access the single street address infrastructure (address point component). This means that street address infrastructure can be possibly integrated and accessed by different organization system unit components so that a party-centric data usage system was showed. In parallel, public units like inhabitants, foreigners, and others are also primary users of address infrastructure in a day to day activities for various motives. Beside the manual navigation, those users are able to navigate and access using different technological advanced platforms like Laptops, Desktops workstations, Smartphones, Handheld GPS, and Car GPS. These platforms are able to support both online navigation systems like Satellite pro-Addis Ababa Google TM, Arc GIS and offline navigation systems like GPS, world map navigation etc.

Abstractly, both offline and online navigation system tools are directly using the LIS server and communicate with the integrated address point system as one component which was previously imported into a web application shown in (Figure 4.21). The conceptual framework dictates that blue lines show offline navigation relationship

flow while the orange lines show online navigation relationship flow. The other point lies on the way that different navigation options, means of transport, shortest path distance analyst and transport type network should be included in LIS server so that it plays a key role to integrate with address navigation and provide smart access to the users. From the conceptual diagram result, we can sum up that well-advanced party-centric data usage of address infrastructure in the industry of application domains using Web mapping for electronics navigation makes life to be easy and enjoyable.

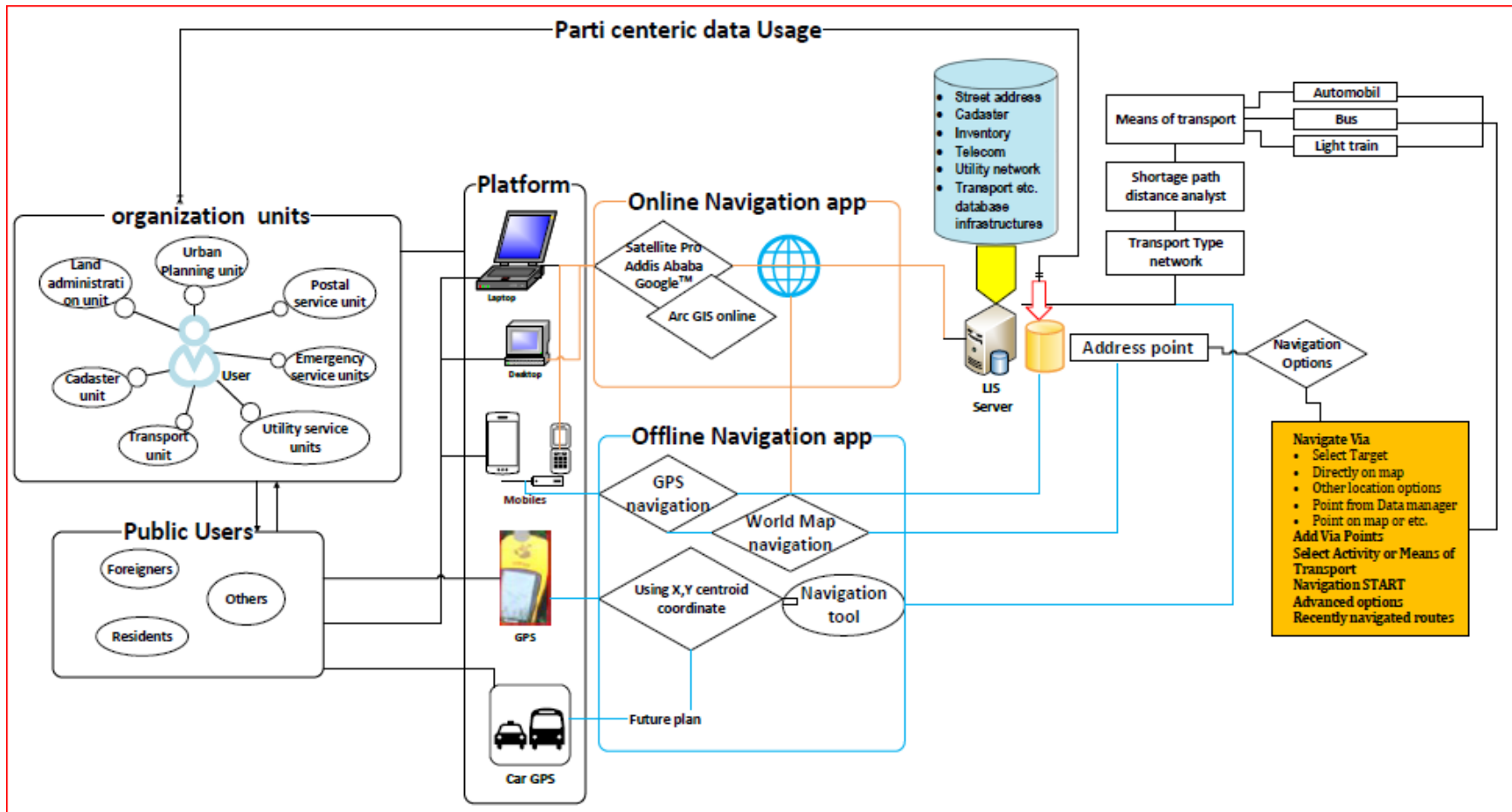


Figure 4.22: Conceptual framework for party-centric data usage in the industry of web application

4.4. Discussion

Street address infrastructure can be established using various geocoding techniques, systems and experiences in terms of technology, social and urban infrastructure development (Boqiu et al., 2010). That is why some researchers thought that standardized streets, electronic technology, and social development has their own role for the establishment of more accessible street address infrastructure in an urban setting.

Results from the comparative analysis of the studied and existing street address model has revealed that there is a clear difference among the two models in terms of geocoding technique, positional accuracy, navigation opportunity, geocoding quality and compatibility with other geospatial data infrastructures. Not only the study area of Addis Ababa City, Yeka Sub City but is no exception in this regard. Therefore, such detail modeling scheme analysis needs an effort like this research to address the accessibility problem of the street address in particular by the livelihood of the inhabitants before its implemented and takes high cost and budget. The fact that the study area has so far been rarely studied for the same purpose makes this study significant and timely effort to highlight the new approach in street modeling and predict the future party-centric navigation system development.

In street address modeling the basic concept is started from the principle in relation to the reference point (Goldberg 2011). The researcher's prior knowledge and current field observation analysis revealed that the more you took a zoning coverage of multiple reference point the more accessibility, feasibility, and familiarity by the society will be rather than using single principal point experienced in the existing street address model. The entity relationship diagram analysis of street address elements resulted in a precise point to model feasible, clear and accessible street address especially in multiple reference and address point system of address geocoding. The place or parcel and the owners are linked with their perfect address.

As its true that each address corresponds to a unique code locates a single element of the city on a particular street. The main references of street address model taken under this study are the roundabouts and squares which has the ability to be more habituated, accessed, and easily identified by the educated, non-educated and others society so that each unique address refer those known features as a reference.

Under this research, the overall analysis of reference points dictates that urban transport infrastructures, roundabouts, squares, Islands and other features have a limitation in terms of standard, design, construction, and nomenclatures. Experience shows that the nomenclature of those features has a direct impact on the accessibility of street address since address are started from known landmarks (Zandbergen, 2010; Coetzee et al., 2008 and Coetzee and Bishop, 2009). According to the research finding, roundabout structures are named as 'square' so that deviation from international nomenclature creates ambiguity among the users. Therefore, the indicator analysis evaluation of reference points used for street address modeling in the study site gives an insight into how much our roundabouts fulfill the criteria.

The Euclidian analysis also is taken to evaluate how much distance each of those roundabouts can cover as a reference from the whole direction and its strands of accuracy. Not only are these but higher performance evaluation method of the Euclidian method also clearly analyzed. To this end, three scenarios were considered: (1) The Euclidian distance coverage, (2) The Euclidian allocation analysis and (3) the Euclidian direction. The result of the present scenarios has revealed that the performance evaluation of Euclidian distance analysis has high evaluation performance for a selection of reference than others.

It is found to be important to carefully evaluate and classify streets based on international and national standards and key classification parameters (Catherine et al., 2005). This is because streets are the basic spatial data input for street address modeling. According to the street evaluation and classification analysis shown in the

previous section, 24.9 % of the study area was occupied by the street network. This implies that street infrastructures are insufficiently distributed and has their own effect in establishing a nearby street address infrastructure. The study done by national cooperative highway research program (NCHRP) has well thought-out the parameters for street classification and nomenclature and its role in urban address infrastructure (NCHRP, 2010). Clearly, there are many ways of parameters to evaluate and classify streets in an urban setting that indicate a numerous avenue to reach a different destination. This is because a different classification scheme is experienced for a different purpose or use. But, the most important point is to decide which parameters provide the best classification of streets for street address infrastructure.

According to the two-model comparison analysis of street classification result shown in (table 4.9), the existing street address infrastructure use generalization principle like most of street, sub-street and minor street, some of the ally, passage, path, and cul-de-sacs are generalized under the street category. The other critical problem in the existing street address database is that 16.5% of streets are not categorized in the database. Following this, the street address becomes characterized by a geocoding error results inaccessible address. According to the international and national classification standard, existing street address model has comparatively achieved 12.98% classification accuracy. While under this research of the new model, each street types were evaluated in detail rather than generalization and oversight without such geocoding error so that it supports a nearby street addressing and more accessible than farthest street reference used in the existing model.

Recently, peoples getting confused on signages to represent an existing model which was planted throughout the sections, neighborhoods, and blocks. But the photographic information extracted from Google engine sources (appendix G) gives an insight into what the existing street address infrastructure was responded by the users. Peoples are confused and said that “What are those signs?”.

This response is comparably similar to the response given by the model comparison analysis and focused group discussion shown in (Appendix F) and (Table 4.6) respectively. Due to this, the unfamiliarity of the existing street address leads to the complexity of access and to become difficult for the integration with SDI.

The researcher's prior knowledge and current field observation coupled with the multiple references and address point geocoding model analysis revealed that not only the study site but also the neighborhood of yeka sub city can be more accessible with the address point information. Because different social groups are more susceptible to know the nearby major landmarks and reference than the farthest and numerically coded references. And this research model principally starts from those nearby references.

This research output is more compatible with the current street network and navigation facilities than the existing model. Because, traffic facility signages (like roundabouts and squares) and tourist guide map boards having basic landmarks, (see Appendix G) street networks with provided street name, roundabouts name and square names were remarkably planted. In another way, a new address model was analyzed based considering roundabouts and squares as a reference so that it can support navigation using those traffic facilities including tourist guide map. Users can easily first identify the reference and street track from tourist map and then follow the street path with that roundabout and square signage's so that the street address provides the entrance, blocks, and parcel with detail information. Therefore, it is possible to command that the overall result from the entity relation and physical model diagrams has indicated not only the model of street address improvement but also provided to use those opportunities' that can maximize the manual and digital navigation in the study site.

The use of Arc GIS software in street address geo database establishment needs first the database property domain should be clearly molded using street address standards, specifications, geocoding formats, elements and other important components. This research has assessed the factors affecting the efficiency of existing street address. According to the focused group discussion, the use of various geocoding formats and characters, formless street address domain, manual digitization problems were raised. The new model has addressed those effects into a solution them by molding the database and using automatic digitization.

In order to integrate multiple reference street address with address point data, relatively accurate representative centroid data is required. This is performed using an efficient centroid determination algorithm results automated digitized centroid shape file rather than manual digitization in that it's susceptible to digitizing error. (Bolstad et al. 1990) strongly revealed that accuracy in a digitization environment is affected by the characterization of positional error where the error is contributed by the operator or media type so that automatic digitization is preferred than manually digitized.

Therefore, this study was sightseen and test four methods of determining the centroid of polygons. The result is shown in the distance matrix and horizontal distance variation analysis in (Figure 4.16 and 4.17) that all of them have started from different perspectives and principle so that their results are also quite different. Especially, representation of parcels using address point requires a relatively more accurate centroid using a better algorithm to represent the address of specific holdings. The result revealed that the algorithm based on the biggest inscribed circle which were applied using MATLAB software becomes the better option for automatic calculation of centroid polygons. Because it has score 97.5% shown in (Figure 4.18) point to point match rate of representing the polygon.

The purpose of more representative centroid points of the parcel is in the application of both offline and online navigation system in a web application. The conceptual framework diagram result shows that how the street address infrastructure can be integrated with other SDI which was further discussed by (Catherine et al. 2005, Fathul 2015) and supported by information technology providing to develop LIS system. Researchers like (Zandbergen,2008a) agree that address points appear very promising, more accessible and have high match rate than line and polygon data as an address data model for geocoding so that this research was tried to simplify the various datasets of street address geo database infrastructure using a point data.

The application of web service for navigation is now an interesting technological concept thought-out the world including Ethiopia to facilitate, coordinate the availability, exchange, and sharing of geospatial data and services between institutions, organizations, and stakeholders from different levels. So, importing and integrating those spatial data into web service tools like Google™ and Arc GIS online is very important. The conceptual framework shows that if LIS system was established in this fashion, how street address information's can be interacted and provide access with various spatial data infrastructures like cadaster, land inventory, transport network and different utility infrastructures by multi-users via different platforms.

CHAPTER FIVE

5. Conclusions and Recommendations

5.1. Conclusions

Establishment of more accessible street address model as one part of geospatial data infrastructure needs to consider the ground reality of three basic factors: digital technology, social development status, and urban infrastructure development standards. This study has been carried out to investigate the hybrid street address model through the integration of multiple references and address point techniques to reconcile those three basic factors and provide an improved and accessible street address model. The research has been conducted and aimed to investigate zoning based multiple reference address geocoding techniques, exploring algorithms that can reduce the errors come due to manual digitization and then introduce the application of electronic navigation system.

Reference points are crucial in street address infrastructure and determine the geocoding technique. Results from the thesis, current field observation analysis, and researcher's prior knowledge testified that the use of roundabouts and squares as multiple reference points are more user-friendly and practicable to the residents, foreigners and other social groups. The findings of this study firstly emphasized to analyze and evaluate the effectiveness of those reference points using key indicators and Euclidian analysis. From these results, the existing classification and nomenclature of those road network infrastructures are not based on the terminology used in the international standard. Although the Euclidian analysis takes the three scenarios namely distance, allocation and direction scored a positive result, the researcher concludes that the Euclidian distance analysis has a substantial evaluation performance for a selection of those reference points.

Under this research, although there is insufficient road network distribution percentage (< 30% from the total study area), the street evaluation and classification scheme has been more inclusive (including very small paths: playing a great role in street address infrastructure) and detail so that its compatible with ground reality road network of the study area. Based on the comparative analysis of street classification, the research finding provides suitable classification scheme, accurate geocoding result and uses internationally standardized terminology than existing street address model resulting in a generalization classification scheme. In parallel, A detail and inclusive street classification scheme promote the functionality of all street types in nearby accessibility of street addressing.

The fact that multiple reference and address point geocoding technique can parse not only improving the accessibility but also compatibility with existing traffic network roundabouts and square signages including tourist map. This opportunity has the ability to signify the research aim of establishing user-friendly, observable and comprehensive street address model promoting manual and digital navigation in the study site. The other result of this study was the exploration of centroid algorithms that will be used to better represent and integrate the address of parcel polygon in web application server infrastructures via in a single point data. The distance matrix and horizontal distance variation analysis of the four algorithms given away that the algorithm based on the biggest inscribed circle score 97.51% point to point match rate of representing the polygon and becomes the better option for automatic calculation of centroid polygons than others.

This research provides an insight how various vector data of street address models can be simplified into a single point data using entity relation concept and abstractly how these address point data are imported into a party-centric web application system access for offline and online electronic navigation. The investigation of this method is now an interesting technological concept that makes life easy and enjoyable them by facilitating navigation of interested address, exchange, and sharing of one

stock geospatial data center between institutions, organizations, and stakeholders from different levels. This is evident in the high rate of an improved address model values of the final results obtained.

Finally, Arc GIS software is a valuable tool in street address geodatabase model establishment more effectively and sufficiently. Lessons learned from this research dictates that both attribute and spatial data of street address might be vulnerable to different geocoding errors. This is due to the use of the unmolded domain database, unusual street address standard, geocoding format types, abbreviations, specifications, and other important elements.

5.2. Recommendations

Due to the fact that during this research certain hindrance were encountered, it is very imperative that they are mentioned so that if further investigation is required in the near future, having for knowledge of these impediments could be very valuable assets. I, therefore, recommend the following:

- a) The key element of street address infrastructure is standardized road network including roundabouts and squares which has the ability to remarkably determine the accuracy and accessibility of street address infrastructure. Therefore, institutional collaboration among those various ministerial offices at different administrative hierarchies should work on densification of the road network, roundabouts, and squares preserving the international and scientific reasoning standards in one way and upgrading of existing streets into better accessibility in another way.
- b) Accessibility of street address is affected by classification, nomenclature, and usage of prefixes of primary address elements like streets, roundabouts, and squares. There should be satisfying the international parametric scheme that reconciles the non-educated, educated, foreigner and other society to improve the user-friendly of the street address. Therefore, stakeholders like road

infrastructure, transport, street address, and other sectors should work on those critical practical schemes.

- c) Address point needs accurate centroid point data of a polygon that maximize the accessibility of electronic navigation system especially on complex polygons which are not easily determined by software like Arc GIS and QGIS. This research was exploring only four methods of determining centroids due to the time constraint. Researchers should work on the exploration of different algorithms for those complex polygons that will result in centroids efficiently used in address point system model.
- d) The application of web for electronics online and offline navigation has a paramount role for the society that makes life easy and pleasant if integrated with street address infrastructure. The conceptual model developed in this research give an insight into further investigation. Therefore, researchers should dig out scientific local navigation software models and means of street address integration with other geospatial infrastructures.
- e) Generally, further effort will consider incorporating socio-economic variables like detail urban transport infrastructure data, intention of the society for street address accessibility and usage, urban transportation network and traffic jams practice and policy, the housing development and land use practices that would exhibit the accessibility and acceptability of street address model and navigation system development using street address geo database infrastructure in a given area.

Reference

- Bichler, G. and Balchak, S. (2007) *Address matching bias: ignorance is not bliss. Policing: an International Journal of Police Strategies & Management* 30(1).
- Bolstad, Paul, V., Gessler, Paul, Lilles and Thomas, M., (1990) *Positional uncertainty in manually digitized map data: International Journal of Geographical Information Scienc.*
- Boquiet, L., Xueying, Z. and Yutian, C.K. (2010) *Automatic construction and visualization of address models: Proceedings of the Sixth International Conference on Natural Computation, Nanjing, China.*
- Brosowsky, John and Nathan Ekdahl. (2012) *Why You Should Invest in an Address Point Layer: Identifying 9-1-1 Caller Location. A GeoComm White Paper. Accessed March 18, 2015. <http://www.geo-comm.com/wp-content/uploads/2012/11/Address-Point-Layer-Development-GeoComm.pdf>.*
- Carswell, J. D., Gardiner, K., & Yin, J. (2010) *Mobile visibility querying for LBS: Transactions in GIS*, 14, 791–809.
- Catherine, Farvacque, V., Lucien, G., Hugues, L., Florence, V., and Roberto, C. (2005) *Direction in development: Street Addressing and the Management of Cities. World Bank Washington DC, United states of America.*
- Cayo, M.R. and Talbot, T.O. (2003) *Positional error in automated geocoding of residential addresses: International Journal of Health Geographics*, 2 (10). Available from: <http://www.ij-healthgeographics.com/content/2/1/10>.
- Chrisman, N. R. (1991) *The error component in spatial data: In D. J. Maguire, M. F. Goodchild, & D. W Rhind (Eds.), GIS (pp. 165-174). London: Longman.*
- Coetzee, S., Cooper, K.A., Lind, M., Wells, M.M., Yurman, S.W., Wells, E., Griffiths, N. and Nicholson, M.J. (2008) *Towards an international address standard, Small island perspectives on global challenges: the role of spatial data in supporting a sustainable future, Proceedings of the 10th International Conference for Spatial Data Infrastructure, St. Augustine, Trinidad.*
- Coetzee S and Bishop J (2009) *Address databases for national SDI: Comparing the novel data grid approach to data harvesting and federated databases. International Journal of Geographical Information Science* 23(9): 1179–1209.
- Coetzee S and Cooper KA (2007) *What is an address in South Africa? South African Journal of Science* 103(11): 449–458.
- COOPER, A.K. (2013) *Spatial data infrastructures (SDIs) and observatories for spatial analysis. Spatial Temporal Evidence for Planning South Africa (StepSA), Policy Note 3. available from :http://stepsa.org/nationalregionalspatialdynamics/topnav/knowledgeoutputs/1/policy_documents/policynote-3-spatial-data-infrastructures.*

- Couclelils, H. (2003) *The certainty of uncertainty: GIS and the limits of geographic knowledge*. *Transactions in GIS*, 7, 165-175.
- Cresswell, J. W., & Plano Clark, V. L. (2011) *Designing and Conducting mixed method research* (2nd ed.). Thousand Oaks, CA: Sage.
- Darrell Massengill and Ed Odom, (2010) *Now with Street-Level Geocoding PROC GEOCODE*: SAS Institute Inc., Cary, NC, SAS Global Forum 2010.
- Davis Jr., Clodoveu A. and Frederico T. Fonseca. (2007) *Assessing the Certainty of Locations Produced by an Address Geocoding System: Geoinformatica 11: 103–129*
- Dearwent, S.M., Jacobs, R.J., and Halbert, J.B. (2001) *Locational uncertainty in georeferencing public health datasets: Journal of Exposure Analysis and Environmental Epidemiology*, 11, 329–334.
- Drummond WJ, (1995) *Address matching: GIS technology for mapping human activity patterns*. *J Am Planning Association* 61, 240-251.
- D.W. Goldberg, J.P. Wilson, and C.A. Knoblock, (2007) *A Geocoding Best Practices Guide*.
- Esri. (2013) *ArcGIS Help 10.1*. Accessed April 29, 2018. http://resources.arcgis.com/en/help/main/10.1/index.html#/Essential_geocoding_vocabulary/00250000000400000/.
- Fathul Wahid, (2015) *Land Information Systems for Development (LIS4D): University of Agder Kristiansand, Norway, & Universities Islam Indonesia, Proceeding of the 48th Hawaii International Conference on System Sciences*.
- Goldberg, Daniel A. and Myles G. Cockburn. (2010) *Improving Geocoding Accuracy with Candidate Selection Criteria: Transactions in GIS*, 2010, 14(s1): 119–176.
- Hansa Luftbild Consulting International GmbH, (2011) *Real property registration and a cadaster system development: Development of Addressing System, Addis Ababa City Administration*.
- Harries, K. (1999) *Mapping crime: Principle and practice*: Washington, DC: U.S. Department of Justice, National Institute of Justice.
- Hart CT and Zandbergen AP (2012) *Reference data and geocoding quality: Examining completeness and positional accuracy of street geocoded crime incidents*. *Policing: an International Journal of Police Strategies & Management* 36(2): 114–294.
- Henry KA and Boscoe FP. (2008) *Estimating the accuracy of geographical imputation: International Journal of Health Geographics* 7(3): 1–10.
- Heri Sutanta et al. (2016) *Issues and challenges in developing geocoded address in Indonesia: Department of Geodetic Engineering, Faculty of Engineering, Published by the American Institute of Physics, Universitas Gadjah Mada, Jl. Grafika No. 2 Kampus UGM, Yogyakarta, Indonesia*
- Hinton, Curt, David Holdstock, and Crystal Phillips-Mustain, (2009) *GIS for Public Safety: Are You Providing a Full Suite of Tools to Protect Your Community? Emergency Number Professional Magazine* (August): 41-44.

- Ilker Etikan et al., (2015) *Comparison of Convenience Sampling and Purposive Sampling*. *American Journal of Theoretical and Applied Statistics* 2016; 5(1): 1-4, Published online December 22, 2015 (<http://www.sciencepublishinggroup.com/lj/ajtas>).
- Jacquez, G. M., & Waller, L. A. (2000) *The effect of uncertain locations on disease cluster statistics*: In H. T. Mowrer & R. G. Congalton (Eds.), *Quantifying spatial uncertainty in natural resources: Theory and applications for GIS and remote sensing* (pp. 53-64). Chelsea, MA: Arbor Press.
- Jimmy Tuan Dao, (2015) *Comparisons of Address point and street Geocoding techniques in a computer aided dispatch environment*: MSc thesis, University of Southern California, CA, USA.
- Kellison, M.T. (2012) *Address Points and a Master Address File: Improving Efficiency in the City of Chino*. MSc thesis, University of Southern California, CA, USA.
- Kravets, N. and Hadden, W.C. (2007) *The accuracy of address coding and the effects of coding errors*: *Health & Place*, 13, 272–299.
- Krieger, N., Waterman, P., Lemieux, K., Zierler, S., & Hogan, J. W. (2001) *On the wrong side of the tracts? Evaluating the accuracy of geocoding in public health research*: *American Journal of Public Health*, 91, 1104-1119.
- Lind, M. (2008) *Addresses as an infrastructure component: Danish experiences and perspectives*. *Proceedings of the ISO Workshop on Address Standards: Considering the Issues related to an International Address Standard*, Copenhagen, Denmark.
- MacEachren, A. M., Robinson, A., Hopper, S., Gardner, S., Murray, R., Gahegan, M., et al., (2005) *Visualizing geospatial information uncertainty: What we know and what we need to know*. *Cartography and Geographic Information Science*, 32, 149-180.
- Michael, T.K. (2012) *Address point and a master address file: improving efficiency in the city of chio.*, 10-12.
- Mothibi L.K. (2003) *Improved Tribal Land Information Management System: A Case Study of Molete Land Board, Botswana*. Master Thesis. Centre for Environment and Development, University of Natal, RSA.
- National Research Council. (2007) *National Land Parcel Data: A Vision for the Future*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/11978>, Internet, <http://www.nap.edu>.
- Nedim Vardar., Dr. (2015) *Centroids of Composite Bodies: Fundamentals of Statics and Dynamics*, ENGR 3340.
- Norwegian Mapping Authority (2009) *On allocation and management of addresses in compliance with the Cadastral law: Handbook for municipal address allocation*, published by the Norwegian Mapping Authority, the Ministry of the Environment and the Norwegian Association of Local and Regional Authorities.
- Oscar Martinez (2012) *An Efficient Algorithm to Calculate the Center of the Biggest Inscribed Circle in an Irregular Polygon*: cornell university library,

- Ratcliffe J. H. (2001) *On the accuracy of TIGER-type geocoded address data in relation to cadastral and census areal units: International Journal of Geographical Information Science*, 15, 473-485.
- Samuel G. Wanjohi, Dr. Felix N. Mutua (2015) *Developing a Web Based Integrated Land Information System for Ownership, Value and Taxation: Case Study of the Ministry of Lands, Housing and Urban Development, Kenya, International Journal of Science and Research*.
- Stroud, A. H. (1971) *Approximate calculation of multiple integrals: Prentice-Hall Inc., Englewood Cliffs, N. J.*
- Thompson, S. (2011) *The Geography of Geocoding: Impecations on Precision and Accuracy*. (p. 32-54). Redlands, CA: Esri.
- Timothy C. Hart and Paul A. Zandbergen (2013) *Reference data and geocoding quality, Examining completeness and positional accuracy of street geocoded crime incidents. Policing An International Journal of Police Strategies & Management Vol. 36 No.2, 2013 pp.263-294.*
- Wey CL, Griesse J, Kightlinger L and Wimberly MC. (2009) *Geographic variability in geocoding success for West Nile virus cases in South Dakota: Health Place 15(4):998–1119.*
- Yildirim, Volkan, Tahsin Yomralioglu, Recep Nisanci and Halilibrahim Inan. (2013) *Turkish street addressing system and geocoding challenges: Proceedings of the ICE - Municipal Engineer, 167(2): 91 –108.*
- Yonas Minalu. (2014) *Performance Evaluation of Addis Ababa City Road Network: A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in a Partial Fulfillment of the Requirements for the Degree of Master of Science in Road and Transport.*
- Zandbergen, P.A. (2008a) *A comparison of address point, parcel and street geocoding techniques: Computers, Environment and Urban Systems, 32 (3), 214–232.*
- Zandbergen, P.A. (2008b) *Positional accuracy of spatial data: non-normal distributions and a critique of the National Standard for Spatial Data Accuracy. Transactions in GIS, 12 (1).*
- Zandbergen, P.A. (2009) *Geocoding quality and implications for spatial analysis. Geography Compass, 3 (2), 647–680.*
- Zandbergen, A.P. (2010) *Influence of street reference data on geocoding quality: Geocarto International 26(1): 35–47.*
- Zimmerman, D.L. (2008) *Estimating the intensity of a spatial point process from locations coarsened by incomplete geocoding: Biometrics, Vol. 64 No. 1, pp. 262-270*
- Zhang, J., & Goodchild, M. F. (Eds.), (2002) *Uncertainty in geographical information. New York: Taylor and Francis.*

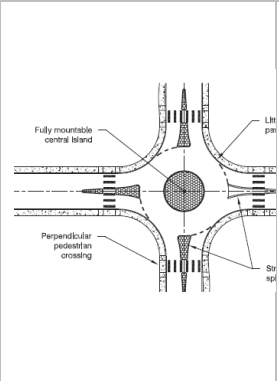
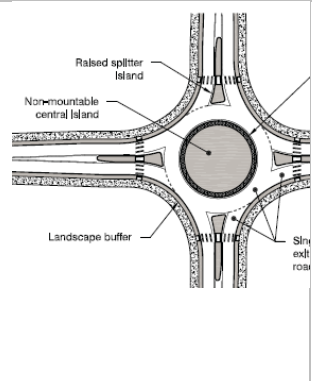
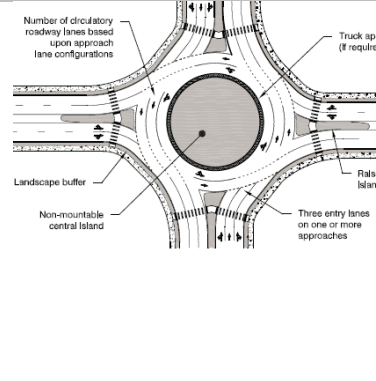
Appendix's

Appendix A.1: Description of Key Roundabout Features as An Indicator

Feature	Description
Central island	The central island is the raised area in the center of a roundabout around which traffic circulates. The central island does not necessarily need to be circular in shape. In the case of mini-roundabouts, the central island is traversable.
Splitter island	A splitter island is a raised or painted area on an approach used to separate entering from existing traffic, deflect and slow entering traffic, and allow pedestrians to cross the road in two stages.
Circulatory roadway	The circulatory roadway is the curved path used by vehicles to travel in a counterclockwise fashion around the central island.
Apron	An apron is the traversable portion of the central island adjacent to the circulatory roadway that may be needed to accommodate the wheel tracking of large vehicles. An apron is sometimes provided on the outside of the circulatory roadway.
Entrance line	The entrance line marks the point of entry into the circulatory roadway. This line is physically an extension of the circulatory roadway edge line but functions as a yield or give-way line in the absence of a separate yield line. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulatory roadway.
Accessible pedestrian crossings	For roundabouts designed with pedestrian pathways, the crossing location is typically set back from the entrance line, and the splitter island is typically cut to allow pedestrians, wheelchairs, strollers, and bicycles to pass through. The pedestrian crossings must be accessible with detectable warnings and appropriate slopes in accordance with ADA requirements.
Landscape strip	Landscape strips separate vehicular and pedestrian traffic and assists with guiding pedestrians to the designated crossing locations. This feature is particularly important as a wayfinding a cue for individuals who are visually impaired. Landscape strips can also significantly improve the aesthetics of the intersection.

Source: NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM (NCHRP), 2010,

Appendix A.2: Comparison and Design Characteristics of Roundabout Category

Design Element	Mini-Roundabout	Single-Lane Roundabout	Multilane Roundabout
Desirable maximum entry design speed	15 to 20 mph (25 to 30 km/h)	20 to 25 mph (30 to 40 km/h)	25 to 30 mph (40 to 50 km/h)
Maximum number of entering lanes per approach	1	1	2+
Typical inscribed circle diameter	45 to 90 ft (13 to 27 m)	90 to 180 ft (27 to 55 m)	150 to 300 ft (46 to 91 m)
Central island treatment	Fully traversable	Raised (may have traversable apron)	Raised (may have traversable apron)
Typical daily service volumes on 4-leg roundabout below which may be expected to operate without requiring a detailed capacity analysis (veh/day) *	Up to approximately 15,000	Up to approximately 25,000	Up to approximately 45,000 for two-lane roundabout
Sample Design			

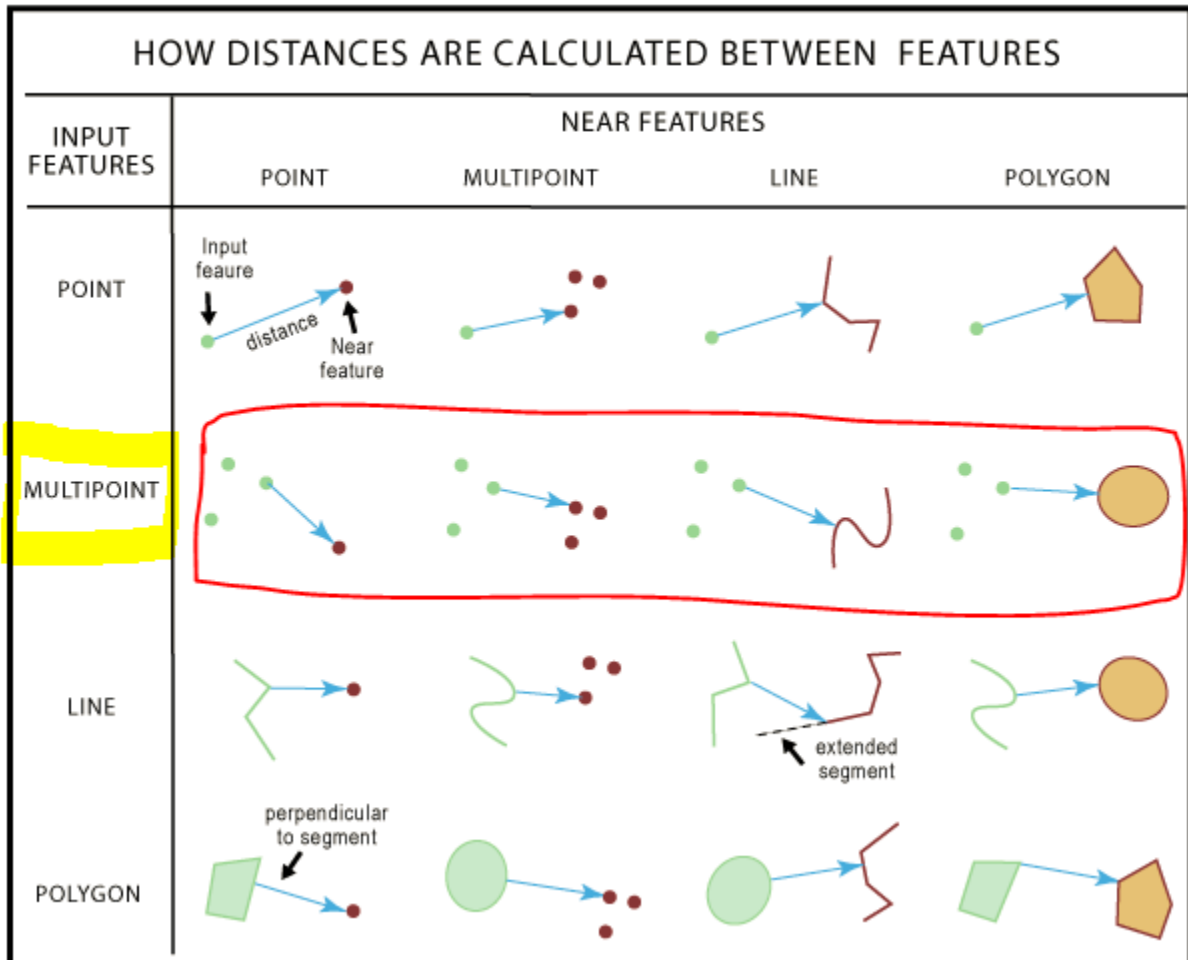
Source: NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM (NCHRP), 2010,

Appendix B: Classification of Streets Using the American Institute of Architects and The Province of Ontario Alternative Classification System.

NO_	International Classifications			General Description
	Name category	equivalent name	Abbreviation	
1	Highway		Hwy	Merely a high-speed road connecting 2 or more cities which denotes any paved road that provides transportation for vehicles and multiple roads can merge with/cross the highways at many places.
2	Expressway	Limited-Access Highway	Expy	A highway with partial access and extra facilities like access ramps and lane dividers. Normally 4 or more lanes divided highway that may have limited or controlled access, entrances and exits, which may include overpasses, over intersections. No other road merges with/crosses the expressway anywhere, thereby avoiding possible accidents and may or may not be a part of a highway.
3	Road			A road is a thoroughfare, route, or way on land between two places, which has been paved or otherwise improved to allow travel by some conveyance, including a horse, cart, or motor vehicle. a road is an improved path between two points whether in areas outside settlements, in the suburbs, or in urban areas
4	Boulevard	arterial street	Blvd	A long-distance, wider-scale street designed for high vehicular capacity and medium speed vehicular corridor that traverses and connects districts and cities; primary a longer distance route for all vehicles including transit and usually lined by parallel parking, wide sidewalks, or side medians planted with trees.
5	Avenue	collector street	Ave	A short-distance, high vehicular capacity and low to medium speed connector acting as a short distance connector between urban centers and may be equipped with a landscaped median. Unlike a boulevard, its axis is terminated by a civic building or monument. It may be conceived as an extremely elongated square that traverses and connects districts, links streets with boulevards for all vehicles including transit. an avenue is a road or street with trees planted along both sides, generally of the same species for uniformity.

6	Street	local street	St	A local small-scale, low-speed connector, multi-movement facility suitable for providing frontage for higher density buildings such as offices, shops, apartment buildings, and row houses. It Serves neighborhood, connects to adjoining neighborhoods; serves a local function for vehicles and transit. a street is a paved public path within a built-up area
7	sub-street	Major street	SSt	A locally oriented street that may play a more important role than the minor urban street and start node is from the street that provides access to streets within the neighborhood.
8	Minor Street		MSt	A small-scale, generally short internal local street and the start node are from sub-street and provide access to streets within the neighborhood.
9	Alley		Aly	A narrow access route servicing the rear of buildings on a street which have no sidewalks, landscaping, or building setbacks. Alleys are used by trucks and must accommodate dumpsters, usually paved to their edges, with center drainage via an inverted crown.
10	Lane	Way	Ln	A narrow access route behind houses on a road. Lanes are rural in character, with a narrow strip of paving at the center or no paving. While lanes may not be necessary with front loading garages, they are still useful for accommodating utility runs, enhancing the privacy of rear yards, and providing play areas for children.
11	Passage	Row	Psge	A very narrow, pedestrian-only connector cutting between buildings. Passages provide shortcuts through long blocks or connect rear parking areas with street frontages. Passages may be roofed over and lined by shop fronts.
12	Path		Pth	A very narrow pedestrian and bicycle connector traversing a park or the open country. Paths should emerge from the sidewalk network. Bicycle paths are necessary along highways but are not required to supplement boulevards, streets, and roads, where slower traffic allows sharing of the vehicular lanes.
13	cul-de-sac		Cud	A cul-de-sac is the end of a dead-end street or alley that widens to provide a circular turnaround for vehicles. a street that only has one way in or out with a round bulb at one end to facilitate the turnaround of an automobile in one seamless motion
14	Circle		CrI	A traffic circle is a type of intersection that directs both turning and through traffic onto a one-way circular roadway, usually built for the purposes of traffic calming or aesthetics

Appendix C: Distance Calculation Between Different Feature Types and Determination of The Closest Location



Sources: ArcGIS Desktop Esri (2013).

Appendix D: MATLAB Software Centroid Algorithm Based on The Biggest Inscribed Circle Using Distance Transforms.

```
allgorithm.txt - Notepad
File Edit Format View Help

% Initialization / clean-up code.
clc; % Clear the command window.
close all; % Close all figures (except those of imtool.)
clear; % Erase all existing variables. Or clearvars if you want.
workspace; % Make sure the workspace panel is showing.
format long g;
format compact;
fontSize = 25;
load e.txt
x = e(:,2)
y = e(:,3)
subplot(2, 2, 1);
plot(x, y, 'b.-', 'MarkerSize', 30);
grid on;
title('Original Points', 'FontSize', fontSize);
% Enlarge figure to full screen.
set(gcf, 'Units', 'Normalized', 'OuterPosition', [0, 0.04, 1, 0.96]);
% Make data into a 1000x1000 image.
xMin = min(x)
xMax = max(x)
yMin = min(y)
yMax = max(y)
scalingFactor = 1000 / min([xMax-xMin, yMax-yMin])
x2 = (x - xMin) * scalingFactor + 1;
y2 = (y - yMin) * scalingFactor + 1;
mask = poly2mask(x2, y2, ceil(max(y2)), ceil(max(x2)));
% Display the image.
p2 = subplot(2, 2, 2);
imshow(mask);
axis(p2, 'on', 'xy');
title('Mask Image', 'FontSize', fontSize);
% Compute the Euclidean Distance Transform
edtImage = bwdist(~mask);
% Display the image.
p3 = subplot(2, 2, 3);
imshow(edtImage, []);
axis(p3, 'on', 'xy');
% Find the max
radius = max(edtImage(:))
% Find the center
[yCenter, xCenter] = find(edtImage == radius)
% Display circles over edt image.
viscircles(p3, [xCenter, yCenter], radius);
% Display polygon over image also.
hold on;
plot(x2, y2, 'r.-', 'MarkerSize', 30, 'Linewidth', 2);
title('Euclidean Distance Transform with Circle on it', 'FontSize', fontSize);
% Display the plot again.
subplot(2, 2, 4);
plot(x, y, 'b.-', 'MarkerSize', 30);
grid on;
% Show the circle on it.
hold on;
% Scale and shift the center back to the original coordinates.
xCenter = (xCenter - 1) / scalingFactor + xMin
yCenter = (yCenter - 1) / scalingFactor + yMin
radius = radius / scalingFactor
rectangle('Position', [xCenter-radius, yCenter-radius, 2*radius, 2*radius], 'Curvature', [1,1]);
title('Original Points with Inscribed Circle', 'FontSize', fontSize);
```

Appendix E: Focused Group Survey and Responded Questionnaire

FOCUS GROUP: DEMOGRAPHIC DETAILS QUESTIONNAIRE

Please answer the following questions in the spaces provided, circle or tick the most appropriate options.

1. Age:

2. Are you: (please tick as necessary) Male Female

3. What is your professional background?

- Surveying
- Land Administration
- Civil engineering
- GIS
- Geomatics
- Land Information system
- Remote sensing and photogrammetry
- Other: (please describe) _____

4. How many years of experience have you had in the street address implementation and cadaster job?

- <1 Year 1-2 Years
- 2-5 Years 5-10 Years
- >10 Years

Thank you for taking the time to complete this questionnaire

FOCUS GROUP: DISCUSSION GUIDE

Purpose

- To examine the overall principles, geocoding challenges, pros and cons of existing street address model and its implementation so that the information to be an input for further modeling and improve the accessibility.

Procedures

- If you participate in this study, you will be in a group of approximately ten participants. There will be a facilitator who will ask questions and facilitate the discussion, and two note-takers to write down the ideas expressed within the group. If you volunteer to participate in this focus group, you will be asked some questions relating to your experience in street address modeling, implementations, and integration with cadaster schemes.

Your participation is voluntary. You may withdraw from this study at any time without penalty.

Benefits and Risks

- Your participation may benefit you to by helping those researchers who participate in street and cadaster geospatial infrastructures and provide a fruitful knowledge and skill and lastly improves the problems faced now. No risk greater than those experienced in ordinary conversation is anticipated.

Confidentiality

- Anonymous data from this study will be analyzed by the researcher and the results of this study may be reported and presented to the department of civil and environmental engineering at the University of Addis Ababa Institute of technology. However, your identity will not be disclosed. No individual participant will be identified or linked to the results. All information obtained in this study will be kept strictly confidential.

Consent

By signing this consent form, you are indicating that you fully understand the above information and agree to participate in this focus group.

Participant's signature: _____

Printed name: _____

Date: _____

If you have any questions or concerns about this study, please contact me using the following address.

Thank you!!

[Email: workumamo6@gmail.com, Tel: 0913779917].

FOCUS GROUP QUESTIONS

1. Question (15 minutes)

Prompt: what do you know about the Principle and techniques that the existing street address model was established and implemented?

Probe_1: What are the challenges faced as per our country and city context?

Probe_2: What do you think about the complexity of referencing specific place from the vast principal point and baseline?

2. Question (17 minutes)

Prompt: What are the attitude of you and other staff towards the concepts in the implementation of a street address? (What did people think/say/do?)

Probe_1: What drove the positive/negative reaction? If negative, how could it be rectified?

Probe_2: what do you think that the existing street address is accessible by society and even the foreigner?

3. Question (12 minutes)

Prompt: What do you know about the challenges faced during and after the implementation of the street address model?

Probe_1: what do you think that is the existing street address model being accessible with society and integral with other geospatial data infrastructure like cadaster?

Probe_2: What do you think are the pros and cons of implementing street address geospatial infrastructure?

4. Question (10 minutes)

Prompt: What do you think that the possibilities of a street address to be accurately navigable with online and offline devices and applications?

Probe_1: what international and national experiences do you prefer?

5. Question (12 minutes)

Prompt_1: According to you, how can we improve to provide better accessibility and integrality of street address with other geospatial infrastructure like cadaster?

Probe_1: Which parameters and fields are to be considered for the better user-friendly street address?

Concluding question (5 minutes)

Conclusion (4 minutes)

Appendix F: Comparison of street address between the studied and existing models of the study area

Comparison of street address models using Key comparison parameters			
No_	Key comparison parameters	A new model of street address	The existing model of street address
1	Geocoding technique		
1.1.	Broad address model category	Macro (support more geographic utilization)	Micro (support less geographic utilization)
1.2.	Geocoding technique	Multiple reference and address point system	Baseline and single reference system
1.3.	Geometry types and format in the representing address	Point and street network based	Street network based
1.4.	Street orientation	Consider the whole compass navigation system orientation	Only consider the two lines of North-South and East-West orientation
1.5.	Street classification scheme	Takes considering a street hierarchy, their capacity, street character, clearer connection between the land use and the multi-purpose role of the streets in the accessibility and navigation of street address	Takes considering the function and their capacity of streets
1.6.	Signage distribution density	Dense	Less dense
1.7.	Signage distribution method	Signage in the diagonal of blocks with the possibility of additional signage's for deed end access as it exists	Signage with the possibility of representing more than two blocks
1.8.	Street coding complexity	Simple	Complex
1.9.	Jurisdictional and Non-Jurisdictional administrative division	City>Sub-city>Woreda>Section>Neighborhood>Block>Parcel	City>Sub-city>Woreda>Section>Block>Parcel
2	Navigation Accuracy and Opportunity		

2.1.	Manually	Possible using the single centroid point data of full address point information's	Possible using the house point data of street address information's
2.2.	Digitally (electronic material)	Possible using only address point centroid of the parcel with higher accuracy	Possible with house point data but positional accuracy is reduced
3	Geocoding quality		
3.1.	Completeness	Relatively higher match rate in terms of attribute consistency	Relatively lower match rate in terms of attribute consistency
3.2.	Attribute (Thematic) Accuracy	The attribute is built based on the entity-relationship diagram of the geocoding model	The attribute is not built based on the entity-relationship diagram of the geocoding model
3.3.	Logical Consistency	More logically consistence	Less logically consistence
3.4	Positional accuracy assessment compatibility	Compatible to use point level, centerline and street matching	Compatible to use centerline and street matching
3.5	Reference point taken	Multiple	Only one
4	Compatibility comparison		
4.1.	Compatibility with further service infrastructure like postal address, telecom etc.	Possible since it has accurate address point data	Difficult since it has manually digitized house point
4.2.	Compatibility with traffic signage, city map infrastructures, and others	Possible since the model takes known roundabouts and squares as a reference point	Difficult since the model takes a single non-familiar reference point and baseline
4.3.	Accessibility and user friendless	User-friendly	Non-user-friendly

Appendix G: Sample Image of Existing Street Signage User's Response.



Source: [Google.com/1_xGp8sRziibitRHqOdjjT9A](https://www.google.com/1_xGp8sRziibitRHqOdjjT9A)

Appendix H: Sample Image of Existing Square, Roundabout, and Tourist Guide Map signage



Sources: Captured by the researcher during field observation (15/05/2018)

Declaration of originality

This is to avow that the work is entirely my own and it was carried out under the supervision of Mr. Andinet Ashagrie, School of Civil and Environmental Engineering, Addis Ababa University Institute of Technology (AAIT) in the year 2018 as a part of fulfillment for an MSc program in Geodesy and Geomatics (specialization in Geomatics stream). It is also my strong conviction that the work is not of any other person unless duly acknowledged (including citation of published and unpublished sources) and it has not previously been submitted in any form to Addis Ababa University Institute of Technology or to any other institution for assessment or any other purpose.

Name: Worku Mammo

Signed _____

Date: 1st Oct 2018

Addis Ababa, Ethiopia

Certificate

This is to certify that the thesis entitled “Modeling of street address using multiple references geocoding and address point technique. A case study on yeka sub city, Addis Ababa, Ethiopia” is bona fide by Worku Mammo under my guidance and supervision. This is the actual work done by the candidate for the partial fulfillment of the award of the Degree of MSc in Geodesy and Geomatics (specialization in Geomatics stream) from Addis Ababa University Institute of Technology in 2018.

Mr. Andinet Ashagrie (PhD Candidate)

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