



**ADDIS ABABA UNIVERSITY**

**ADDIS ABABA INSTITUTE OF TECHNOLOGY**

**School of Civil and Environmental Engineering**

**Positional Accuracy Validation of Base Map and Investigating its  
Impact on Road Projects: A Case of Addis Ababa City, Ethiopia**

A Thesis Submitted to the School of Post Graduate Studies of Civil and Environmental Engineering Addis Ababa University, in Partial Fulfillment of the Degree of Master of Science in Geodesy and Geomatics Program (Specialization in Geomatics Engineering)

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## DECLARATION

I, the undersigned, declare that the thesis titled “Positional Accuracy Validation of Base Map and Investigating its Impact on Road Projects: Case Addis Ababa City, Ethiopia” carried out under the supervision of **Dr. Tullu Besha Bedada** is my work and has not been presented for a degree in any other university and that all sources of material used for the thesis have been appropriately acknowledged.

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As a Master's research advisor, I hereby certify that I have read and evaluated this MSc thesis prepared under my guidance.

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## Abstract

Positional accuracy is a topic that of renewed interest and concerns not only the distance between the geographic object and its actual or real location on the earth surface but also the accuracy with which map features are located. Collecting the highest quality independent ground-based data is a key factor in validating the useful location accuracy of digital geospatial data. This information simplifies geographic analysis and promotes better judgment. In this research the accuracy of the horizontal position of an orthophoto/line map had been investigated. The global positioning system and total station survey had been employed to access the accuracy of the horizontal coordinate of the line map. The horizontal coordinates of the terrestrial position of the points are observed using Sokkia Atlas GR5+ Differential Global Positioning System (GPS) device and the raw data are post-processed using various processing tools such as Leica Geo-Office and Topcon Tools v.8.2.3 reference with to local GNSS reference stations. In this study, we evaluated the 2D positional accuracy of the line map by matching its horizontal coordinates with the associated ground control point observed as in-suit data. Comparing the digital line map coordinates to the corresponding *in-situ* ground control points, RMSE between the digital line map and the GPS/total station position of the twenty-five reference points is 0.813 m in x and 0.903m in y respectively. Furthermore, in comparison to GNSS/Total Station data acquired through LGO processing, the digital line map exhibited a horizontal precision of 2.103 m at a 95% confidence interval. This inaccuracy can potentially impact the drainage line or buildings that are constructed parallel to the road center line. Specifically, for the Saris site, it results in a 1.398 m deviation from the road design center line. This discrepancy has had a discernible effect on ground surveys and the design of road projects in Addis Ababa city, necessitating repeated right-of-way surveys and redesign efforts. Consequently, the precision of digital line maps falls short of the national error budget requirement (30cm) for Standard Mapping tasks under all circumstances. However, it may be suitable for imaging and small demanding tasks. In its current status, it is applicable to projects like master plans and general economic development plans.

Keywords: Accuracy assessment, Digital Orthophoto, Digital line map, GNSS, RMS

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## List of Acronyms

2D	Two Dimensional
3D	Three Dimensional
AACRA	Addis Ababa City Roads Authority
ASPRS	American Society of Photogrammetry and Remote Sensing
CORS	Continuously Operating Reference Station
CSA	Central Statics Agency
DTM	Digital Terrain Model
EGII	Ethiopia Geospatial Information Institute
FIG	International Federation of Survey
FULLPRIA	Federal Urban Land and Land Related Property Registry and Information Agency
GCP	Ground Control Point
GDB	Geospatial Database
GDOP	Geometric Dilution of Precision
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSD	Ground Sample Distance
IGS	International GNSS Service
INSA	Information Network Security Agency
ISO	International Organization for Standardization
NMAAs	National Mapping Agencies
NSSDA	National Standard for Spatial Data Accuracy
OPUS	Online Positioning User Service
RINEX	Receiver Independent Exchange
RMS	Root Mean Square
RMSE	Root Mean Square Error
UTM	Universal Transverse Mercator
WGS	World Geodetic System

# CHAPTER ONE

## 1 INTRODUCTION

### 1.1 Background

Orthophoto a compute-aid visual representation of a photograph that shows an image of an object in its correct orthographic position. Linear representations, symbols and two-dimensional maps are becomes geometrically identical (Wolf et al., 2014). This time, the photograph has a variety of applications to rapidly map the surface and provide data for planning and monitoring. (Wemega and Amissa, 2013). Currently the Geological Survey investigating usage of the big size orthophoto output as a base map element for municipalities, counties, and municipalities. (Hood et al., 1989). It is a faster and less costly method to obtain geographic data in relative to the conventional mapping technique, especially in metropolitan areas. Digital orthophotography underlies many approaches to quantify and track these changes in urban environments. (Igor et al., 2004).

Orthophotos typically have many advantages, however not every photos will created in the same way. Sources of error include in particular property and standardization of the devices employed for photo capturing, like cameras/scanners. The rectification system also affected by precision of terrestrial control points, aerial triangulation, DEMs, and rectification tool (Greenfield, 2001). While orthophotos can provide significant benefits, there is variation in their quality. Various factors can contribute to errors, including the calibration and characteristics of the equipment used to capture the images. The rectification system also disturbed by other variables like the precision of the ground control points, the method employed for aerial triangulation, digital elevation models (DEM), and tool use for processing (Modiri et al., 2015). Furthermore, the collection, processing, and utilization of data can create and propagate concerns related to spatial data accuracy. The precision of spatial information is evaluated through the exactness of position, attributes, logical consistency, reliability, temporal precision, and meaning. Aerial photography may be utilized for particular mapping purposes, depending on the scale. Previously, mapping standards and customs were utilized to establish the possible horizontal and vertical precision obtainable via aerial photography techniques and the size of the output (Hood et al., 1989).

One aspect of spatial data quality is the accuracy of position, which deals with the precision of objects in spatially referenced system (Drobnjak et al., 2017). Furthermore, due to the opportunities presented by the global positioning system, it is a new area of concern (GPS) (López and Gordo, 2008). In this definition, "horizontal position accuracy" indicate how well the horizontal location of a spatial objects can be determined using geographic (latitude and longitude) or local grid (easting and northing) coordinate system (ASPRS, 2014). All mapping organizations utilizes statistical techniques to assure the quality, a procedure known as positional accuracy assessment methodologies, as the accuracy of position is crucial in map production (López and Gordo, 2008). The root mean square error (RMSE<sub>x</sub>, RMSE<sub>y</sub> and RMSE<sub>z</sub>) mostly employed in-order-to evaluate the two dimensional position of a spatial object (ASPRS, 2014). Ultimately, the main objective of this research was to evaluate the positional accuracy of orthophoto in comparison with terrestrially measured data.

## **1.2 Statement of the problem**

By ensuring that knowledge about urban tenure is openly acknowledged and by using the knowledge as the basis for any planning decisions and interventions, the creation of an modern land registration system support tenure security in developing nations (Chekole et al., 2020). Land parcel boundaries can be determined using photogrammetric technologies as an alternative to ground-based surveys, and different nations have adopted them in different ways at different times. (Siriba, 2009). As a result, Ethiopia has begun urban cadastral mapping utilizing aerial photographs to guarantee people's security of tenure and enhance the land management system. One of the chosen locations is Addis Abeba City, and an orthophoto has been created for it. Despite this, the accuracy and quality of an orthophoto will vary depending on the data utilized to produce it and the specific manufacturing method. The characteristics and calibration of the imaging devices employed, such as the camera and/or scanner, are what determine how accurate the image is. Greenfeld, 2001, stated that before using an orthophoto, the spatial accuracy and the quality of the photo should be assessed. In a similar vein, (Siriba, 2009) claimed that it is crucial to provide orthophoto pictures with a high level of accuracy by employing these images as a map. To prepare a large scale map (ranging from 1:500 to 1:10,000) by using aerial photograph which will be utilized for actual cadastral applications, the image and the registration data must be checked with a help of terrestrial observations. So, before using an orthophoto for the intended purpose, it is essential to check its quality. Additionally, there hasn't been much research in Ethiopia looking into the positioning accuracy

of digital orthophotos. As a result, this study evaluated the orthophoto's horizontal positional accuracy for the city of Addis Ababa.

### **1.3 Objectives of the study**

#### **1.3.1 General objective**

The general objective of the research was to assess precision of the horizontal position of the digital line map/orthophoto in Addis Ababa city and investigate its effect on road development projects.

#### **1.3.2 Specific objectives**

This research have the following specific objectives:

- To evaluate the accuracy of two-dimensional position of a line map/orthophoto by using ground GPS and total station observations.
- To assess the offset distance of the building corners from the road center line.

### **1.4 Significance of the study**

This study provides significant insight into the problems relating to the accuracy of digital orthophoto/line maps to comprehensive cartography and associated purposes. As a result, this investigation will prove advantageous for future academics, government entities, NGOs, and other interested parties who wish to explore related areas of study. Moreover, since the position of the ground control points are determined utmost accuracy, they can be used as a reference stations for other purposes.

### **1.5 Organization of the research**

The research organized in five chapters. Chapter one outlines the introduction, statement of the problem, objective of the study, and importance of the study. The second chapter comprises a review of the literature, which encompasses details on the digital orthophotos overview, measurement of positional accuracy, and other related work Furthermore, chapter three elucidates the method, material, and data source used in the study region. The fourth section

covers the outcomes and discussion. Finally, chapter five provide conclusion and recommendation.

# CHAPTER TWO

## 2 LITRATURE REVIEW

### 2.1 Introduction

An examination of the body of research concerning the measurement of horizontal position accuracy in digital orthophotos has illuminated the primary studies conducted in this area. Orthophotos, which are computer-generated graphical representations, show the objects exact geographic placements. These are comparable in terms of geometry to traditional planimetric maps that display accurate orthographic object placements using lines and symbols (Wolf et al., 2014). Digital orthophotos have become invaluable in making prompt decisions, particularly in regulating countywide and large-scale operations. Furthermore, it is essential to evaluate the accuracy of an orthophoto in line with the concurrent development of image processing technologies (Bakc et al., 2008). Zuzelski et al., 2013, stated, the separation between the position of an object obtained from a secondary source and the position taken from the ground by measurement can be used to determine the positional accuracy of a spatial entities.

### 2.2 Digital Orthophoto

At present, digital orthophotography is the most rapid and efficient way to obtain the latest digital base in the field of geomatics. Effective applications of this information have been found in geomatics, city planning, resource management, engineering, and other areas. Moreover, it is known for its accuracy, affordability, and, most importantly, its ability to provide photographic information. Large-scale orthophotos are also considered a crucial source of data for managing spatial phenomena in urban areas. Compared to traditional cartography techniques, digital orthophotography is a faster and more economical method of providing up-to-date spatial information, especially in metropolitan regions (Nedeljković et al., 2004).

By specifying a global accuracy level, GIS environments frequently integrate digital spatial data from various sources of varying quality. Additionally, a new category of map users has emerged as a result of the development of geographic information systems (GIS). While it is not difficult to produce an orthophoto that is acceptable in small areas, it becomes challenging to produce an orthophoto that is of high quality and uniform in large areas. However, scaling the quality of digital orthophotos is equally challenging if there are no agreed-upon quality

requirements. The interior and exterior orientation parameters of the utilized imageries are determined by the quality of geodetic data from other sources, which can be used to evaluate geometric quality. The Two of these parameters are the optimum distance of the picture components from the nadir point and the 2D and elevational precision of the 3D model. As a result, the Positional Accuracy Standard for Digital Geospatial Data (ASPRS) used to evaluate positional accuracy of mosaicked image produced from less accurate digital surface model.

### **2.3 Accuracy assessment**

The level of precision with which information is depicted on a map or in a digital database may be deemed as a reliable definition of accuracy. Consequently, any inconsistency between the encoded attribute values and the actual values of specific feature. In essence, accuracy refers to the number and quality of errors in a given dataset or map. When dealing with a GIS database, the accuracy of the geographic position is evaluated based on horizontal and vertical accuracy, as well as attribute, conceptual, and logical correctness. The degree of accuracy required for different applications varies significantly. Obtaining highly precise data can be challenging and expensive. Since accuracy is always measured against specific criteria, it is a relative metric. Reviewing what is provided in accordance with the specification and taking into account the restrictions of the standard are essential to determining if the data is suitable for usage. The variance plus the squared bias for an estimate, or the mean squared error, can be employed to determine the degree of deviation of an estimate from its true value. The choice of metrics depends on the entities' dimensionality under consideration. For points, accuracy is measured in terms of the distance between the encoded position and the actual location. In summary, an error can be characterized based on the 3D coordinate, and dimensions. The magnitude of error are derived from conventional statistical metrics like mean error, root mean squared error, inference tests, confidence limits, etc. However, the problem becomes more complex when dealing with lines and areas since the error is a combination of locational and generalization error. One of the critical factors in a GIS data layer is positional accuracy, which can be used to describe the spatial position's locational error for any arbitrary entity (Capriol et al., 2003).

### **2.4 Positional accuracy assessment**

Positional accuracy is the precision of a value's location within a geographic database. It is imperative to meet positional precision requirements concerning a GDB's intended functions.

A statistical analysis of random and systematic errors is performed to investigate it (DOD, 1990). Furthermore, possible to assess by using either the average error value and its standard deviation or RMSE. As a result, according to ANSI, 1998, the most preferred method for assessing positional accuracy is to compare it with a self-determining or independent source of superior precision. Along with logical consistency, it is the quality aspect of geographic information that national mapping agencies (NMAs) focus on the most and evaluate more frequently (Jacobson and Vauglin, 2002). As a result, it is a subject of increasing interest given the capabilities made available due to GNSS and enhanced spatial compatibility is required to support spatial information architectures. Aspects of data sets behaving differently in terms of locational value behavior indicate the internal product location changes and an obstruction to collaboration (Lopez et al., 2008).

Concerning the map's planimetric survey coordinates (X, Y) for test points, which are computed at a complete ground scale, the map's accuracy can be distinguished from the RMS error. The RMS error takes into account all errors, including those that occur during terrestrial data collection cartographic design and the last terrestrial value determination. To assess horizontal precision, two dimensional local coordinate of well-known are compared to the coordinates of the same sites determined through a more accurate horizontal check survey. The term "well-defined points" refers to characteristics that are distinguishable as distinct points, while points with unclear definitions are not included in the intended accuracy test. Unclear picture sits, such as highways which meet at acute angles, are examples of features lacking clearly defined midpoints. The NSSDA, which has been employed by the Minnesota Department of Transportation to assess locational accuracy of data sets, multiplies the x and y RMSE by 0.181 and the z RMSE BY 0.134 (PAH, 1999).

To determine the approximate positions of points, an aerial photogrammetry survey is carried out from an airborne vehicle, which involves taking precise measurements from images and other data sources which enable to determine distance, angle area, altitude and other parameters. Metric photogrammetry is commonly used to create orthophotos from digital images, planimetric and topographic maps from photographs, and other types of maps (Wolf et al., 2014). When using aerial photography for specific mapping purposes, the scale of the photography is an important factor to consider which is decided in consideration of the map preference and experience, as well as the accuracy requirements for positioning and elevation using photogrammetric techniques. So, when aerial photography is used to cadastral mapping the cartographic design of the output have to be taken in to consideration. However, it is

important to consider the best way to eliminate geometric distortions and displacements (Siriba, 2009).

Linear features and geometric constraints are also important considerations in photogrammetric applications. When using linear entities, particularly relevant for imaging and renewing developed sites due to the prevalence of linear curves in man-made materials. Natural features such as waterside lines, shorelines, and plant borders are also good candidates for a feature-based approach (Heikkinen, 2002). Establishing the relationship between vector maps and picture features is necessary for exterior orientation. Typically, the map and image comparable image points and ground control points are manually extracted for this purpose. The space resection approach can then be used to determine the picture parameters. However, this technique may be less effective in certain situations where obvious places on the map cannot be identified. The use of linear properties as control information can be beneficial in such cases (Zhang et al., 2008).

## **2.5 Cadastral mapping**

Despite limited resources, developing countries require reliable information more than ever before. One of the challenges faced by these countries is the absence of well-managed land records in real estate transactions. This leads to difficulties in identifying the actual cause of ownership issues and distinguishing between individual and collective rights. To ensure that land is accessible for habitation and urban purposes, there is a need to establish a functional land market, which presents opportunities for public and private development. Therefore, developing and implementing a national digital cadastral information system requires careful attention. However, it is necessary to initiate attempts to complete this complex task in a planned manner. Preliminary efforts will pave the way for achieving the desired objectives and overcoming the current situation. Maintaining official records of land parcels, including their location, form, size, use, land holding, is crucial, and the cadastral map plays a vital role in this regard. This process is fundamental to property taxation, which is one of the primary goals of the digital land cadastre in developing countries. Additionally, the information derived from the map help the management in a number of additional ways, including making it a valuable tool. Cadastral maps generally have scales between 1:500 and 1:10000.

## **2.6 GNSS for accuracy checking**

Accuracy of the location of an orthophoto relates to the degree of accuracy in the positional of an object which can be visible in the aerial photo. This degree of accuracy should match their respective terrestrial position obtain through a technique called global navigation satellite system (GNSS) (Congalton et al., 2009). GPS satellite dependent systems has significantly enhanced in 3-D location determination for geodetic and surveying work. It is now more efficient, practical, and precise, and its local, regional and global application is undoubtable (Mohamed et al., 2010). Unlike the conventional surveying technique, Global Positioning System technology has greatly improved mapping features by providing cost-effective and dependable data. Personalizing lobar Positioning System is preferable to sampling spatial accuracy (GPS). Correspondingly, GPS offers various advantages for observing and calculating exact coordinate values for checkpoint locations. To determine the required spatial precision, the estimated position of the checkpoints must be compared with the location of their corresponding image on the digital orthophoto (Greenfield, 2001).

The accuracy of the transmitted ephemeris data is inadequate for certain GPS applications that require high precision, such as geodynamics and precise relative positioning over long distances. To achieve accuracy at the meter level, post-processed ephemerides are necessary. These ephemerides are typically generated using observations from a globally distributed tracking network over a week. The Global Navigation Satellite System (GNSS) has been widely used for surveying in a variety of engineering disciplines, thanks to its success. Numerous companies have developed user-friendly, unrestricted, and mostly free online services to replace costly scientific and commercial software for post-processing and analyzing GPS data. Depending on various factors, online services can provide accuracies ranging from millimeters to decimeters. The degree of coordinate variation decreases with longer observation periods. The type of observation (single or dual frequency) has an impact on precision. Additionally, satellite availability is crucial for internet-based applications in urban areas, otherwise global positioning System (GPS) does not significantly improve accuracy (Adam, 2017).

## **2.7 Data accuracy standard**

The ASPRS (2014) is the favored benchmark for assessing digital spatial information and is employed to gauge the level of precision in the horizontal dimension of an orthophoto for cartography at a large scale. Consequently, for optimal accuracy, standard mapping, GIS,

visualization, and less precise applications, orthophotos of 15 cm, 30 cm, and 45 cm caliber are utilized, respectively.

The Ethiopia Geospatial Information Institute (EGII) has established a standard for the precision of orthophotos' horizontal position, however, the vertical position's accuracy is around three pixels or 45 cm.

# CHAPTER THREE

## 3 MATERIAL AND METHOD

### 3.1 Description of the study area

Addis Ababa lies at an elevation of 2,355 m and is a grassland biome, located at 9°1'48"N 38°44'24"E spanning an area total of 527 km<sup>2</sup>. The city lies at the foot of Mount Entoto and forms part of the watershed for the Awash. From its lowest point, around Bole International Airport, at 2,326 m above sea level in the southern periphery, Addis Ababa rises to over 3,000 m in the Entoto Mountains to the north. The city is divided into 11 boroughs, called sub-cities. Depending on height and dominant wind patterns, the city's highland climate zones can vary in temperature by up to 10°C. Because of the city's proximity to the equator and high elevation, temperatures are consistently moderated throughout the year.

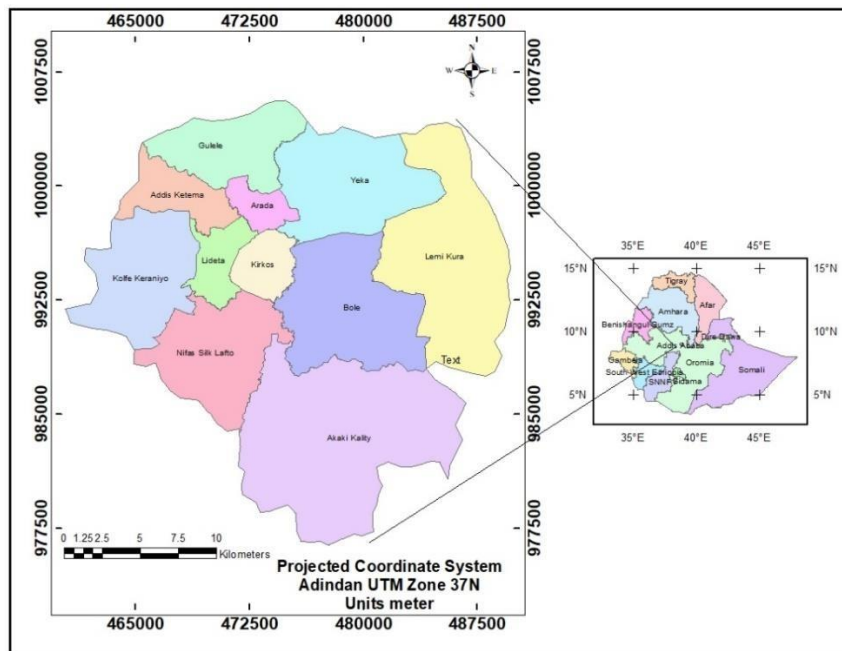


Figure 3.1: Location map of the study area

### 3.1.1 Road network

The road network of the city forms a radial pattern due to the five primary roads run from the central business district (CBD) to the periphery of the city. An orbital shape has been added by including a ring road. The roads can be divided into four categories, even though a proper hierarchy has not yet been established: Sub-artifacts, collectors, and local or residential roads are all examples. The paved road network of AACRA covered all four types of roads as of

July 10, 2010, and measured approximately 642 kilometers in length. Table 3.1 displays the AACRA-reported distribution of the network's length. Arterial roads: As per the master plan, these roads have varying widths ranging from 30 m to 60 m.

**Sub arterial roads:** links in a lower hierarchy, these roads have projected widths of 20m to 25m.

**Collector roads:** These roads are further lower categories in the network hierarchy and are proposed to function as connectors in the master plan. The proposed minimum width of the collector and local roads are proposed as 15m and 10m respectively.

**Local roads:** These are access links to residential or business areas.

Table 3.1: Road hierarchy (Source AACRA)

S. No.	Road hierarchy	Unit	Total length	No. of Bridges	Pavement status
1	Arterial	km	308	108	Very Good
2	Sub Arterial	km	108	44	Very Good
3	Collector	km	100	49	Good
4	Local	km	126	31	Good
Cumulative		km	642	232	

### 3.2 Data

This study looked at a variety of data sources to figure out how accurate an orthophoto is at determining horizontal position. The following data were utilized in this study: the test GCPs and digital orthophotos. Orthophoto and digital line map data were obtained from the aerial photogrammetric survey that was carried out over the entire city of Addis Ababa, covering a total area of 519.52 km<sup>2</sup>. The photogrammetric surveying was carried out for the REAL PROPERTY REGISTRATION AND LAND INFORMATION (CADASTRE) SYSTEM DEVELOPMENT project by Hansa Luftbild Consulting International GmbH, Germany, according to an agreement with the Addis Ababa City Administration. The city of Addis Ababa put out a tender in 2009 to build a real estate register and cadastre system. The cadastral map data update was one of the services that were planned for in the tender.

New aerial photography for the project (System: Platform: Digital camera (pan) aircraft and the resolution of geometry: 0.02–0.5m) was obtained with an average ground resolution of 17 cm. Digital orthophotos at a ground sampling distance (GSD) of 20 cm, which is also equivalent to a

map scale of 1:2000, and mapping at a scale of 1:2000 were both possible with this resolution. At the contractor's suggestion, the project only focused on the need for a real property registration system. However, the new high-resolution aerial photography was also used to create a digital terrain model (DTM) with orthophotos and hydrography data. The update produced precise building and parcel data for the entire 520 square kilometers of the city. Additionally, with local datum and reference ellipsoid of clark 1880 ( $a= 638249.145$ ,  $1/f = 293.465$ ) digital line map and orthophoto are included. The geographic data was created using translational transformation settings from EGII. Control points, were also used in this study. As a result, stable reference GCP points established by Hansa Luftbild within the city were used for post-processing after reference points were observed for a sufficient amount of time with a static GNSS receiver (Sokkia Atlas GR5+ dual frequency).

### 3.3 Material and Software

In order to accomplish this research, Sokkia Atlas GR5+ Differential GPS, Leica Total Station TS11, Leica Geo-office (LGO) 8.4, Topcon link v.8.2.3, Arc GIS 10.7 and Microsoft Office had been employed. The materials and software that were employed, together with the related application fields, are shown in (Table 3.2).

Table 3.2: Materials and Software used

<b>Materials</b>	<b>Applications</b>
Sokkia Atlas GR5+ Differential GPS	For Static GNSS observation
Leica Total Station TS11	For observation of building corners
<b>Software's</b>	<b>Applications</b>
Leica Geo Office 8.4	For post-processing of observed GPS data
Topcon Tools v.8.2.3	For post-processing of observed GPS data
Eagle Point 2007	For the processing of Total Station survey data
Auto CAD 2007	For the processing of Total Station survey data
Global Mapper 15	For coordinate Transformations
Arc GIS 10.7	to create a map layout and to handle, analyze, and display spatial data
Microsoft office	to evaluate, present, and write up the results

## **3.4 Methodology**

### **3.4.1 Checkpoint sampling design and sample size**

An accurate assessment representation necessitated a sample design with a solid statistical foundation. Given a variety of spatial patterns and densities, this design ought to produce an accurate estimate. The size of the sample and the location of the checkpoints are critical factors in determining how well any geographical data can be evaluated. By comparing the coordinates of a number of its points to those of comparable points in a different, more accurate data collection, the correctness of a data set is evaluated. Because the selection and distribution of the checkpoints (CP) mostly depend on the visibility and recoverability of clearly defined places on an orthophoto by ground observation, the cluster sampling method was used for this (Sisay et al., 2018). The international standard like ASPRS, NSSDA and FGDC were used to design the location of sample checkpoints and their size. Different points have been selected based on the type and the necessary quality of the map. The information obtained from property image, plats, or maps had tested at features like junctions of sidewalks, curbs, or gutters, and utility access covers. For datasets derived from surveys, or other identified locations used for validation. This led to the study's usage of precisely identified locations, like creating corners. The second requirement is that there must be at least twenty test points to carry out an evaluation that is statistically significant for increased accuracy. This investigation utilized 25 building corner points per the ASPRS 2015 standard.

### **3.4.2 GPS data acquisition**

#### **3.4.2.1 Planning**

Any type of geospatial application start from planning. It is necessary to ensure that GPS surveys are carried out efficiently and in the allowable limit. Due to elements like the necessary precision, measurement procedures, type of GPS, usage and analyzing tool, proper preparation for GPS surveys is almost mandatory. To put it another way, it's preferable to choose what to do, where to do it, when to do it, what tools to use, and how to use them, among other things. As a result, the task at hand in this phase is to use data on both strong and poor satellite coverage to plan and schedule a GPS project. Additionally, several issues were taken into consideration in the planning. These include the project's use, the need for accuracy, the location's accessibility and limitations, the equipment available, the GPS method, the network's architecture, measurement method, so on.

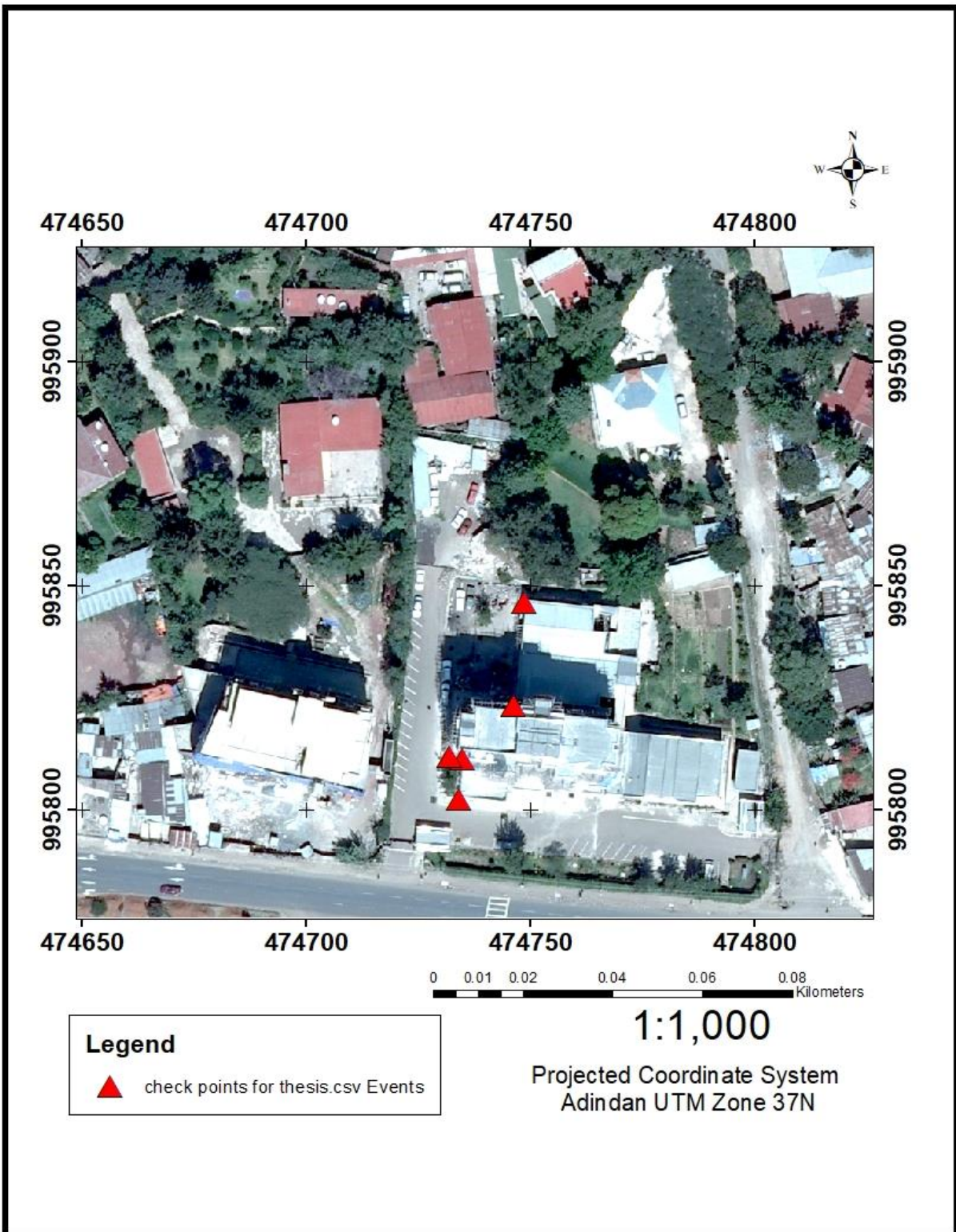


Figure 3.2: Checkpoints location at Federal Attorney

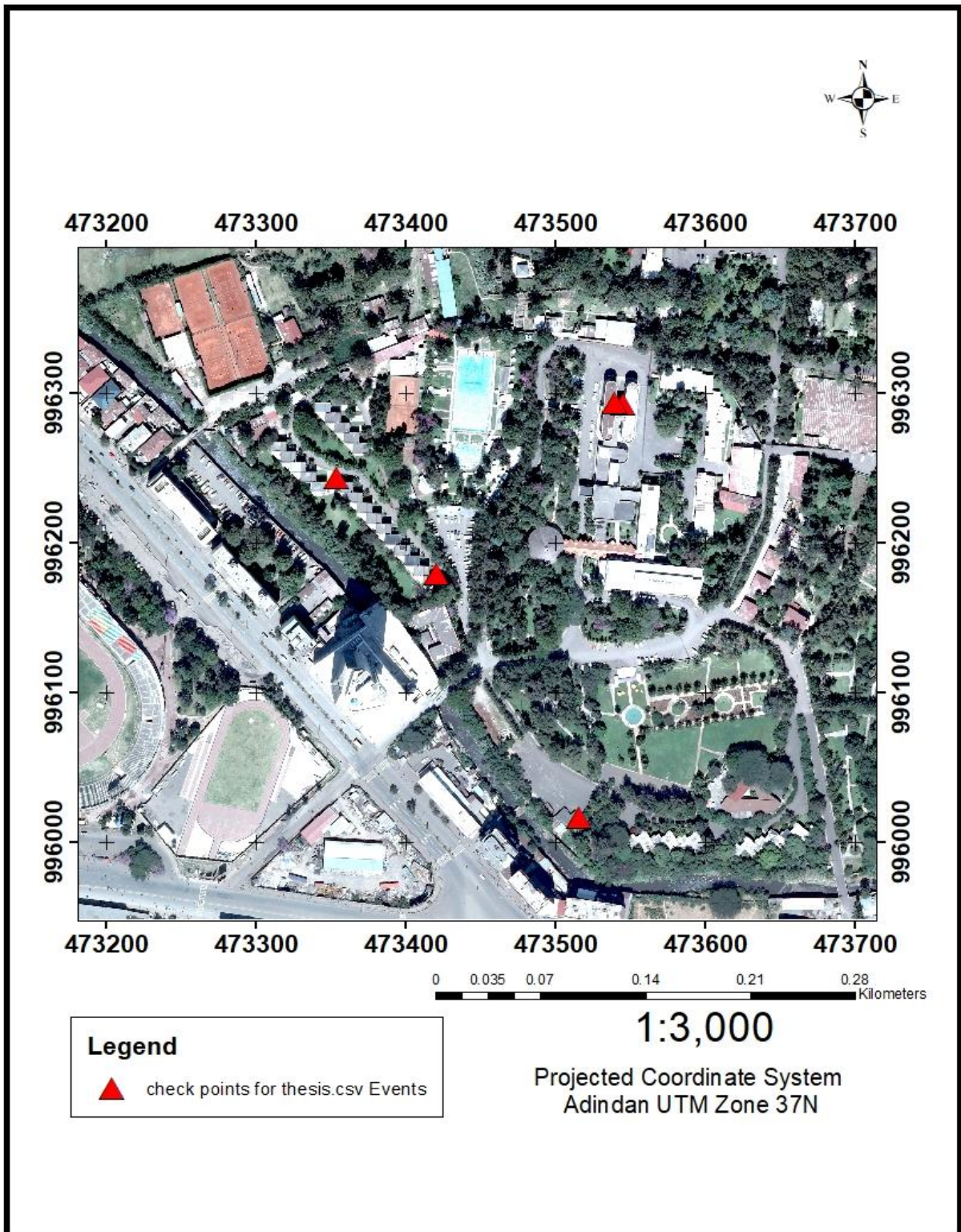


Figure 3.3: Checkpoints location at Ghion Hotel

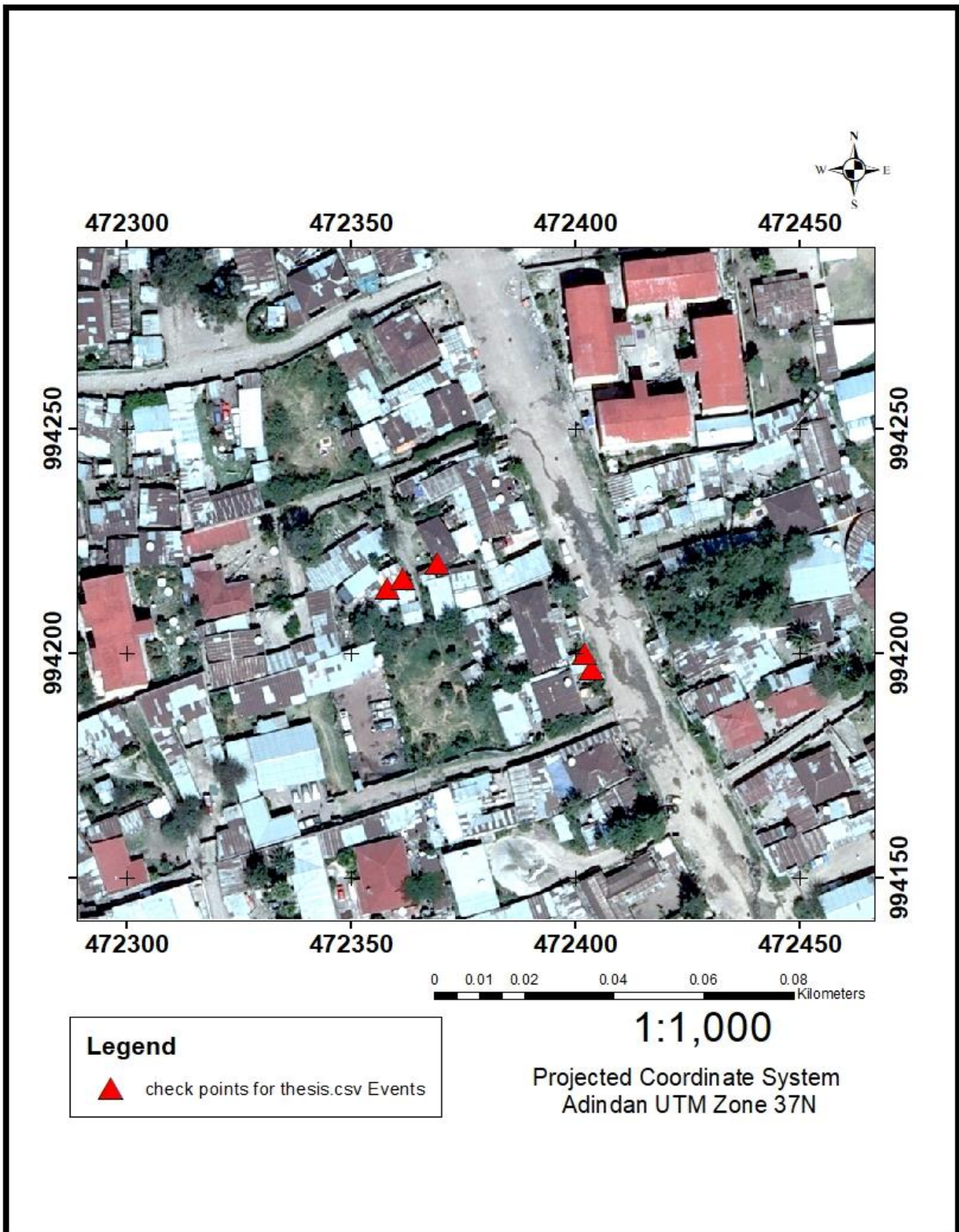


Figure 3.4: Checkpoints location at Ministry of Revenue - Bulgaria

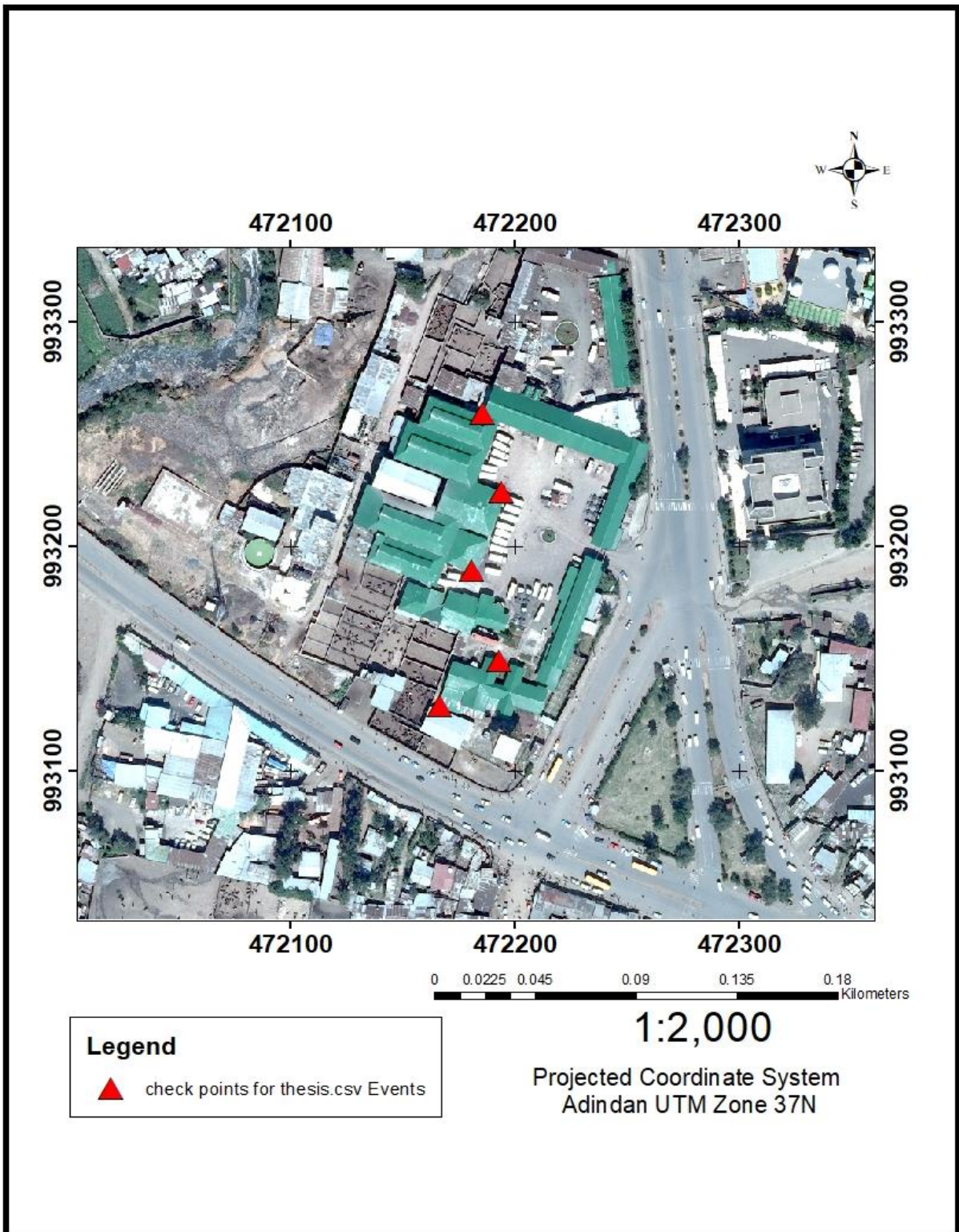


Figure 3.5: Checkpoints location at Addis Ababa Abattoirs Enterprise - Kera

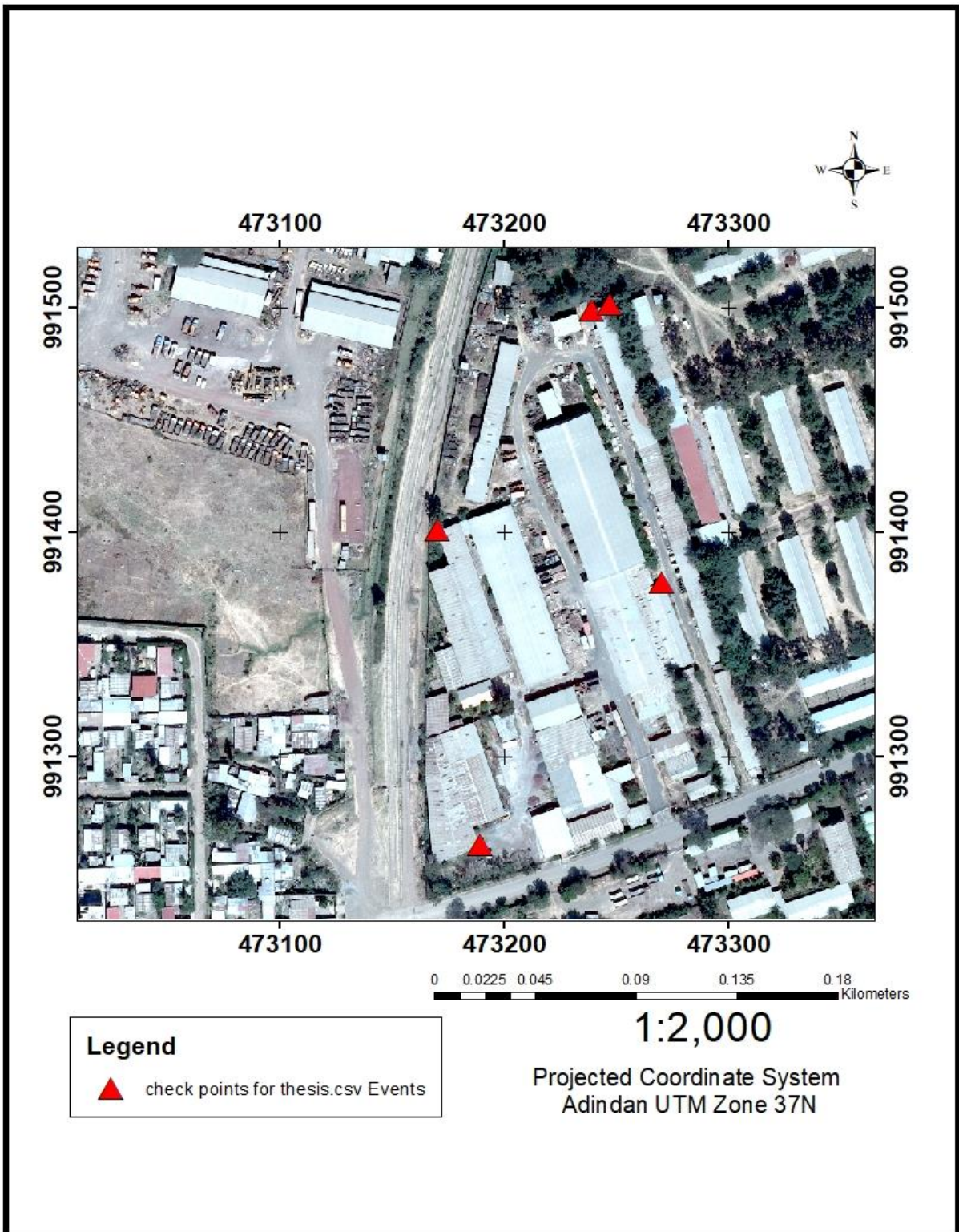


Figure 3.6: Checkpoints location at Ethio Engineering Group - Saris

### **3.4.2.2 Reconnaissance**

After conducting a field trip and examination, the investigator measured the area at this point. After conducting a thorough investigation of the area, which provided us with an overview of the type of the area and a recommended course of action, we chose 25 clearly defined test spots to serve as the reference ground control points. In addition, a brief description and sketch of the site have been created to assist visitors in locating the chosen locations. The degree of difficulty in occupying points as a result of issues like point accessibility, multipath effects, and satellite accessibility ought to have considered. The site obstruction/visibility condition is the term for this. The selected checkpoints are shown in a more illustrative manner in the subsequent image.

### **3.4.2.3 GNSS Observation**

Ground control point observation remained a crucial component in determining the two dimensional reliability of orthophoto. As a result, the static GPS location method was used. This method is the most accurate and requires the most time for observation. The positional accuracy of aerial photography can be ascertained by using static method of GNSS survey. The technique has capability of providing the position of a point at millimeter level. Additionally, the accuracy of the validation point must be three times accurate than the data collected for to be validated, as stated by the ASPRS (2014). After the test point were clearly defined, a GPS measurement were carried out by Sokkia Atlas GR5+ GNSS receiver. The observation was carried out for a sufficient number of minutes, following the length of the baseline. Additionally, the measurements were carried out between the hours of six in the morning and five in the evening local time, when the satellite was unobstructed by clouds.

### **3.4.3 Post processing and Adjustment**

In order to obtain a more precise coordinate, the static GPS measurement must be post processed by using a processing tool. First, the GPS observed DBX field data were transferred into external memory, then imported into the Leica Geo Office program utilizing DGPS equipment (Sokkia atlas GR5+). Additionally, the reference RINEX data for each control point from the same day were retrieved. LAGP, 472778.733, 995866.226, and 2354.308 KIRKOS were utilized as references. Information is offered in the common RINEX format. The Sokkia Atlas GR5+ instrument was used for field observations on the ground, making it a good candidate for processing with this software. In the end, the coordinates were analyzed, and the information from the fundamental control point was located in the WGS 1984 coordinate system.

### **3.4.4 Coordinate Transformation**

The orthophoto and the checkpoint must have the same two dimensional positional parameter in order to compare each other. In this manner, Ethiopia utilizes a neighborhood datum called Adindan with a reference ellipsoid of Clarke 1880. Since the data collected by the static survey had a reference ellipsoid of WGS84, it must be transformed to the local datum Adindan by using a transformation parameter define by EMA. According to the information obtained from EMA, the transformation parameter between WGS84 and Adindan is 162m, 12m, 206m in the X, Y and Z respectively. After processing the data, Global Mapper software were used to perform the coordinate transformation from WGS84 to Adindan. The converted data finally exported as text file in the excel sheet.

### **3.4.5 Data analysis**

In order to assess the accuracy of the aerial photograph, the coordinate of the test point extracted from the photo was compared with the coordinate of the same points obtained by ground based measurement by the static survey. Digital aerial triangulation does not take into account the position of independently taken standard points, which were obtained by GPS, and Total Station observation. Also, the predefined building's computerized line map was utilized to decide the test spots' directions in the orthophoto. The orthophoto's positional accuracy was evaluated by utilizing every one of the reference values that were generated utilizing offline GNSS processing methods. Therefore, RMSE<sub>x</sub>, RMSE<sub>y</sub>, and RMSE<sub>h</sub>, RMSE can be utilized to evaluate horizontal accuracy, as stated by ASPRS (2014). According to Tsarovski (2015), RMSE is the average of the squared differences between the coordinate values from the dataset and those from a different source with higher precision for the same points. At the end of the day, "flat guide exactness" alludes to the rms mistake for test focuses at the undertaking's planimetric review facilitates (X, Y) estimated at the guide's full ground scale. The RMSE is the final result of overall error, including occur due to map compilation, terrestrial dimension extraction from the map, and ground control point surveys. All calculations and visual explanations were carried out using the Microsoft Excel program for the examination. The NSSDA standard from 1989 can be used to calculate the horizontal RMSE as follows:

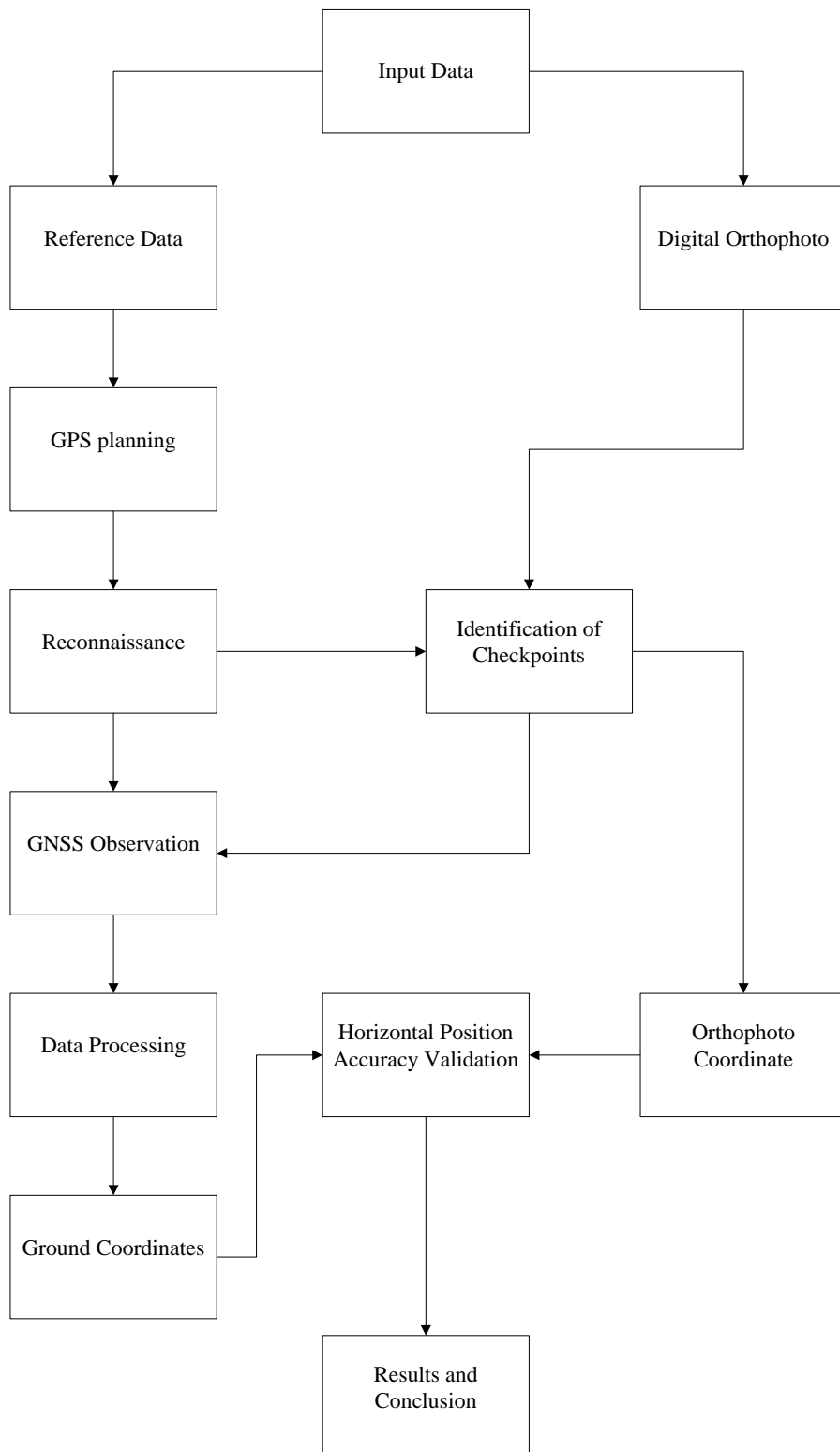


Figure 3.7: General workflow of the study

RMSE for X and Y coordinate is determined as:

$$RMSE_x = \sqrt{\frac{\sum_i^n ((X_{data\ i} - X_{check\ i}))^2}{n}} \quad (1)$$

$$RMSE_y = \sqrt{\frac{\sum_i^n ((Y_{data\ i} - Y_{check\ i}))^2}{n}} \quad (2)$$

Where:,  $X_{data}$  and  $Y_{data\ i}$  are orthophoto positions and  $X_{check\ i}$  and  $Y_{check\ i}$  are check point position obtain from static GPS, n the amount of GPS points, and i a number bounded from 1 to n.

So the horizontal RMSE can be computed as:

$$RMSE_h = \sqrt{\frac{\sum_i^n ((X_{data\ i} - X_{check\ i})^2 + (Y_{data\ i} - Y_{check\ i})^2)}{n}} \quad (3)$$

Or the consistent RMSE provided as:

$$RMSE_h = \sqrt{(RMSE_x^2 + RMSE_y^2)} \quad (4)$$

According to NSSDA, at 95% confidence level the horizontal accuracy of a measurement can be determined by:

$$Accuracy_h = 1.7308 \cdot RMSE_h \quad (5)$$

According to PAH, 1999, the accuracy in X and Y component of the coordinate can be computed by multiplying the RMSE by a number denotes standard error of the mean at 95% confidence level. The number 1.7308 used for horizontal accuracy and 1.96 for vertical accuracy.

## CHAPTER FOUR

### 4 RESULTS AND DISCUSSION

The research looked into ground surveying, and design processes for the Addis Ababa City projects to see how accurate digital orthophotos were in terms of horizontal position. In the following sections, specific findings from the orthophoto accuracy assessment are discussed in detail.

#### 4.1 Horizontal positional accuracy assessment point based

By comparing the orthophoto-recovered coordinates with the horizontal position of check point observed by GPS, the two-dimensional accuracy of the orthophoto was evaluated. The GPS data in this study can be evaluated, verified, and compared to digital orthophotos using statistical indices. The overall location accuracy and RMSE of X and Y were involved to determine position variation. The result obtained from offline processing tool were applied as a standard value for comparison analysis to assess the orthophoto's positional accuracy. In contrast, the ASPRS (2014) suggested that the large-scale map's horizontal accuracy criteria should be 15cm, 30cm and 45cm respectively for the highest precision work use, standard mapping and GIS work use, and visualization and less accurate work use. The ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014), which require RMSE<sub>x</sub> and RMSE<sub>y</sub> accuracy of 30 centimeters for standard mapping and GIS work, were determined to be met by this data set as a result of this. Nevertheless, the output indicates for the 25 GPS points the horizontal (x and y) RMSE were 0.813m and 0.903m respectively. The accuracy level is 2.103 m with a 95% confidence level, compared to an orthophoto taken in 2019 using GPS data obtained from LGO processing. The orthophoto-derived point coordinates' horizontal shift in comparison to the reference coordinates is shown in Table 4.1.

The easting and northing components have root mean square errors of 0.813 m and 0.903 m, respectively, according to the findings. In fig 4.1 the easting, northing and two dimensional accuracy related to LGO GNSS result and orthophoto are presented. These values correspond to the horizontal RMSE of 2.103 m.

Table 4.1: comparison of GPS data with orthophoto

Point Id	Map Derived Values		Survey Check Point Values		Residuals (Errors)	
	Easting	Northing	Easting	Northing	$\Delta X$ Easting (E)	$\Delta Y$ Northing (N)
	Meters	Meters	Meters	Meters	Meters	Meters
1	473545.713	996294.112	473545.064	996293.132	0.649	0.980
2	473539.605	996294.450	473539.582	996293.775	0.024	0.675
3	473354.741	996241.735	473353.841	996243.598	0.900	-1.863
4	473421.542	996178.561	473420.480	996179.112	1.063	-0.551
5	473516.037	996016.294	473516.167	996016.791	-0.130	-0.497
6	472166.356	993128.083	472166.890	993129.260	-0.534	-1.177
7	472193.971	993148.338	472193.250	993149.130	0.721	-0.791
8	472182.934	993187.705	472180.980	993189.650	1.954	-1.945
9	472196.199	993223.350	472194.240	993224.300	1.959	-0.951
10	472186.144	993257.900	472185.870	993259.340	0.274	-1.440
11	473189.432	991259.963	473189.190	991260.766	0.243	-0.802
12	473271.473	991377.875	473270.048	991377.898	1.425	-0.023
13	473170.305	991400.778	473170.294	991401.290	0.011	-0.512
14	473239.447	991498.244	473239.326	991499.082	0.121	-0.838
15	473248.213	991501.154	473247.100	991501.593	1.113	-0.439
16	472403.961	994197.030	472403.783	994196.549	0.178	0.481
17	472402.617	994200.243	472402.077	994200.154	0.540	0.089
18	472358.201	994214.759	472358.089	994214.782	0.112	-0.023
19	472362.202	994217.079	472361.732	994216.773	0.470	0.306
20	472369.165	994219.404	472369.220	994220.257	-0.055	-0.853
21	474734.575	995802.629	474733.945	995802.569	0.630	0.060
22	474735.382	995811.404	474734.812	995811.532	0.570	-0.128
23	474732.459	995811.672	474732.010	995811.945	0.449	-0.273
24	474746.824	995821.494	474746.133	995823.286	0.691	-1.792
25	474749.098	995846.245	474748.554	995846.253	0.544	-0.008
Number of CheckPoints					25.000	25.000
Mean Error (m)					0.557	-0.493
Standard Deviation (m)					0.604	0.772
RMSE (m)					0.813	0.903
RMSE <sub>h</sub>					1.215	
NSSDA Horizontal Accuracy, (ACCr) at 95% Confidence Level					2.103	

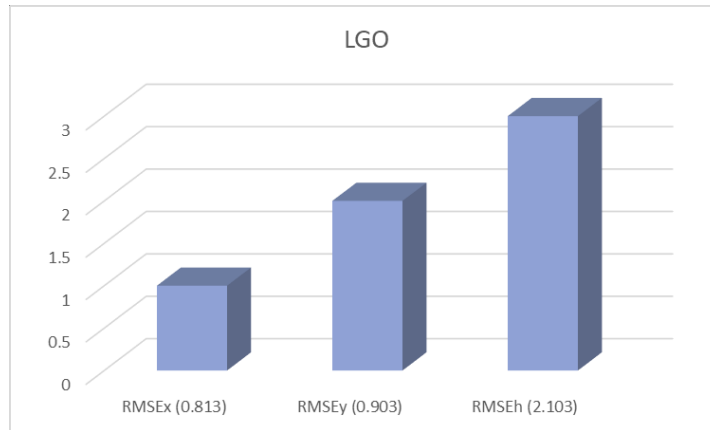


Figure 4.1: RMSE (ground check point and orthophoto point)

#### 4.2 Horizontal positional accuracy assessment offset distance

The offset distance of the building corners from the road design center line observed with the ground survey and extracted from the base map is also compared and the result is tabulated in (Table 4.2).

Table 4.2: Comparison of Offset distance from the road design center line Saris site

Building Corner Offset from Road Design Centre Line			
	Map Derived Values	Survey Check Point Values	Residuals (Errors)
	Offset from Road Centre Line	Offset from Road Centre Line	$\Delta$ Offset
Point Id	Meters	Meters	Meters
1	10.481	12.107	-1.626
2	10.619	12.185	-1.567
3	10.996	12.629	-1.632
4	9.671	9.915	-0.245
Number of CheckPoints			4
Mean Error (m)			-1.267
Standard Deviation (m)			0.682
RMSE (m)			1.398

### **4.3 Discussion**

As previously mentioned, several parameters, including those related to photo acquisition, GCP densification, and the rectification processes, will influence the spatial accuracy of an orthophoto. As a result, the aforementioned tables show the degree of two-dimensional values difference between aerial photo and GPS coordinate. Without looking into individual mistake sources, this study largely concentrated on the effect of a overall erro on the final quality of the aerial photo. As a result, a theoretical analysis of errors and how they affect the orthophoto has not been provided here. Only the evaluation of the Digital Orthophoto's current errors has been presented.

## CHAPTER FIVE

### 5 CONCLUSION AND RECOMMENDATION

Since orthophoto has play greater role in the modern land registration system and road planning purposes, it is necessary to assessment of the product's precision and quality. Regular testing of the orthophoto data's positional accuracy using a more precise independent source guarantees the accuracy of location-based information, which supports the validity of decisions. Consequently, this dissertation aimed to assess and check the two-dimensional positional accuracy of the orthophoto and identify its impact on Addis Ababa's road construction projects. For the research, carefully selected twenty-five checkpoints that were measured using static GNSS and Total Station and processed using LGO software packages and Eagle Point Software. Finally, the spatial dataset's horizontal RMSE and positional accuracy at a 95% confidence interval were determined to be 2.103 m between the orthophoto and the most dependable LGO processing outcome.

#### 5.1 Conclusion

As indicated in the aforementioned results section, none of the horizontal point placement accuracies of the processing results meet the standards set by national and international organizations for Standard Mapping purposes. Nevertheless, it can be utilized for less precise activities such as visualization since the accuracy cited by ASPRS (2014) and the Ministry of Urban Development and Housing (2015) for a map scale of 1:2000 is 0.30 m. This study's findings should enhance our comprehension of how to evaluate the two-dimensional positional accuracy of orthophotos. Additionally, those results have revealed tasks that can be executed using the evaluated orthophoto.

#### 5.2 Recommendations

However, to ensure the dependability of such decisions, a comprehensive assessment of the dataset's location is necessary. Moreover, GNSS data acquired from diverse offline and online processing services can be employed to verify the authenticity of the orthophoto and bolster its reliability. The focal point is to assess predefined GCPs by using precisely measured GPS data's and authenticate the orthophoto through both coordinates. The research also suggests that to tackle the present land-use alteration issue and achieve superior outcomes, future studies could use a recently captured aerial photograph. Lastly, although the vertical precision assessment of the orthophoto is not encompassed in this study, it could be investigated further

by incorporating the vertical component while extracting line maps for 3D mapping applications.

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<https://geodesy.noaa.gov/OPUS/>

<https://www.gnss.ga.gov.au/auspos>

<https://www.bernese.unibe.ch/z>












<https://cddis.nasa.gov/archive/gnss/data/daily/>

<https://cddis.nasa.gov/archive/gnss/products/>





### Appendix 3: Raw Data Collected by Static GPS

Name	Date modified	Type	Size
 GPSGH4ABASE.tps	04-Mar-21 11:31 A...	TPS File	803 KB
 GPSGH4ABASE.tps	03-Mar-21 12:08 PM	TPS File	1,501 KB
 GPSK4BASE.tps	01-Mar-21 1:54 PM	TPS File	755 KB
 log20010716_121613.tps.tps	01-Mar-21 12:52 PM	TPS File	179 KB
 log20010716_131218.tps.tps	01-Mar-21 1:47 PM	TPS File	223 KB
 log20010718_080808.tps.tps	03-Mar-21 8:51 AM	TPS File	271 KB
 log20010718_091708.tps.tps	03-Mar-21 10:38 A...	TPS File	482 KB
 log20010718_111127.tps.tps	03-Mar-21 11:56 A...	TPS File	279 KB
 log20010719_092118.tps.tps	04-Mar-21 10:02 A...	TPS File	202 KB
 log20010719_101137.tps.tps	04-Mar-21 10:41 A...	TPS File	185 KB
 log20010719_105344.tps.tps	04-Mar-21 11:24 A...	TPS File	196 KB