ANALYZING THE SPATIAL DISTRIBUTION AND ACCESSIBILITY OF TAXI TERMINALS: A CASE OF ARADA SUB-CITY, ADDIS ABABA, ETHIOPIA.

Adem Hussen Agegnehu

Thesis Submitted to the Department of Architecture Engineering

college of Civil Engineering & Architecture (CoCEA)

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in

Geoinformatics Engineering

Office of Graduate Studies

Adama Science and Technology University

May,2025

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Under the Supervision of

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DECLARATION

I hereby declare that this Master Thesis entitled **"Analyzing the Spatial Distribution and Accessibility of Taxi Terminals a case of Arada sub-city, Addis Ababa, Ethiopia"** is my original work. that is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citations.

Adem Hussen _____ _____

Name of student Signature Date

RECOMMENDATION OF ADVISORS

I/we, the advisor(s)/ of this thesis, hereby certify that I/we have read version of the thesis entitled **"Analyzing the Spatial Distribution and Accessibility of Taxi Terminals a case of Arada Sub-City, Addis Ababa, Ethiopia"** prepared under my/our my/our guidance by Adem Hussen Agegnehu submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geomatics Engineering therefore, I/we recommend the submission of revision of the thesis to the department following the applicable procedures.

Dejene Tesema (Ph. D) _____ _____

Major Advisor /Supervisor Signature Date

APPROVAL PAGE

I, the advisor of the thesis entitled **"Analyzing the Spatial Distribution and Accessibility of Taxi Terminals a case of Arada Sub-City, Addis Ababa, Ethiopia."** and developed by Adem Hussen, hereby certify that the recommendation and suggestion made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the Undersigned, members of the Board of Examiners of the thesis by Adem Hussen Agegnehu have read and evaluated the thesis entitled "**Analyzing the Spatial Distribution and Accessibility of Taxi Terminals a case of Arada Sub-City, Addis Ababa, Ethiopia**" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geoinformatics Engineering.

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ACCRONYMS

Acronym/Abbreviations	Full Name
AAAMPS	Addis Ababa City Administration Master plan study
AATIA	Addis Ababa Transport Infrastructure Administration
AACTA	Addis Ababa City Transport Authority
AATA	Addis Ababa Transport Authority
AMS	Asset Management system
AOI	Area of interest
CBD	Central Beninese District
DOT	Department of transportation
EIC	Ethiopia Investment commotion
GDP	Gross domestic product
GNSS	Global Navigation Satellite Systems
GIS	Geographic Information system
ITIO	International Transport Infrastructure Observatory
IRB	Institutional Review Board
OECD	Organization for Economic Co-operation and Development
QGIS	Quantum Geographic Information System
GPS	Global Positioning System
LULC	Land Use land Cover
LISA	Local Indicators of Spatial Association
MCC	Main City Center
MCE	multi-criteria Evaluation
LQ	Location quotient

ABSTRACT

Transport infrastructure currently plays a vital role in Ethiopia's economy, contributing approximately 10% to the Gross Domestic Product (GDP). Among its key components of this infrastructure, the spatial Distribution and Accessibility of Taxi Terminals in Addis Ababa are critical for promoting economic growth, enhancing mobility, and urban development. The effectiveness of transport systems directly influences market accessibility, connectivity, and the overall mobility of citizens. However. challenges persist due to in inequitable terminal locations and accessibility barriers, particularly in densely populated areas like Arada Sub-City. This study analyzes the spatial distribution patterns and accessibility of taxi terminals in Arada Sub-City advanced spatial analysis tools in ArcGIS10.8, including Geostatistical Analysis, and Local Indicators of Spatial Association (LISA), alongside Accessibility measures. The research adopts a mixed-methods approach. that combines geospatial data, statistical analysis, field survey, and document reviews, to comprehensively address the research questions and objectives. the research reveals significant clustering of terminals around commercial hubs and marked spatial inequalities in accessibility, Results from the Global Moran's I analysis ($I = -0.36$, $p < 0.05$) reveals a statistically significant negative spatial autocorrelation, underscoring a lack of spatial balance in terminal distribution. The findings highlight the need for targeted spatial planning and policy interventions to optimize terminal placement, reduce disparities, and improve equitable access to public transportation. These recommendations aim to enhance urban mobility planning and support informed decision-making at the municipal level in Arada Sub-City. Ultimately, such interventions could support sustainable urban development and ensure inclusive access to transportation infrastructure.

Key Words: - *Spatial Distribution, Taxi Terminals, Accessibility, Arada Sub-City, Transportation Infrastructure, GIS (Geographic Information System).*

CHAPTER 1: INTRODUCTION

1.1. Background Of the Study

Transport infrastructure plays a vital role in Ethiopia's economic development, contributing approximately 0.6% to the country's annual per capital GDP growth over the past decade (EIC). As a foundation pillar of national growth, as well-functioning transport system is essential for facilitating the movement of people, goods, and services particularly urban centers like Addis Ababa.

According to the Addis Ababa City Structure plan (2017-2027) and the 17-year review on the road sector Development program (RSDP), the city is home to more than 8,500 minibus taxis, which are a central component of its public transport system.in addition, Addis Ababa operates 442 midi buses,1006 Anbessa city buses, and approximately 6,000 support vehicles. These services are critical in providing daily mobility and connectivity for residents and visitors alike.

Despite this extensive network, the spatial distribution and accessibility of taxi terminals across the city reman suboptimal. A strategically planned and equitably distributed system of taxi terminals is essential to ensure that all residents regardless of location have access to efficient, affordable, and reliable public transportation. This need is particularly urgent in Arada Sub-City, where population density and transport demand continue to rise rapidly.

Taxi terminals play a crucial role in promoting sustainable development, especially in rapidly urbanizing and growing economies like Ethiopia. As the country strives for broad-based economic progress in an increasingly globalized world, it is essential that all transport infrastructure be efficiently managed and spatially integrated. Poorly coordinated taxi terminals placement results in congestion, underutilized resources, and limited access, especially in underserved sub-cities like Arada. These issue not only hinder urban mobility but also negatively affect the broader goals of economic and infrastructure development goals.

This study aims to address these challenges by analyzing the spatial distribution and accessibility of taxi terminals in Arada sub -city. through the use of geospatial tools, descriptive statistical methods, and stake holder engagement, the research seeks to assess the current conditions, identify gaps, and propose data-driven strategies for improvement, A well-structured taxi terminals system can improve both tactical and operational decisions and offer valuable insights for long-term transport planning.

As emphasized by the International Transport Infrastructure Observatory (ITIO,2005), taxi terminals are critical transport infrastructure elements in cities worldwide. They are key to meeting the growing demands o urban populations, enhancing mobility, and supporting sustainable development. The Addis Ababa Transport Infrastructure Authority (AATIA)also stresses the importance of adapting transport facilities to match changing urban dynamics and ensure inclusive, accessible, and efficient service delivery.

Institutional advancements such as the recent establishment of a transport infrastructure department under the ministry of transport and logistics-reflect a national commitment to strengthening infrastructure management Directorate operates at the vice president level to coordinate infrastructure related activities at the city level.

However, inequitable distribution of Taxi terminals remains a major issue in urban planning. According to a World Bank study, inadequate distribution and poor maintenance of transport infrastructure in Ethiopia have led to significant economic losses over the past two decades. This makes it essential to conduct a thorough analysis of the spatial distribution and accessibility of taxi terminals in Arada Sub-City to support informed planning and contribute to both urban mobility improvements and economic development.

1.2. Statement of the problem

Efficient transport infrastructure is vital to Ethiopia's economic growth, taxi terminals in Addis Ababa facilitating about 70-80% of daily passenger trips, As a key part of the city's public transportation system. Improving taxi terminal management and accessibility has become a priority for local and national governments, aligning with global trends toward more sustainable and efficient urban transport systems.

Many national and local transport authorities are now required to adhere to formal performance and reporting standards regarding the management and operation of transport terminals, as a result, there is growing interest in adopting comprehensive transport infrastructure management practices within the sector (OECD,2001).

Addis Ababa, Ethiopia's largest city and Africa's diplomatic capital, is rapidly expanding. the city, located at altitudes between 1,800 to 3,200 meters above sea level. is a national economic hub, receiving around 54% of total Ethiopian investment (Peng Mo et al,2008). With rapid urban growth, Addis Ababa has seen a significant increase in the construction of taxi terminals both completed

and ongoing backed by substantial government funding. currently, billions of birrs have been invested in transport infrastructure, particularly in the development of taxi terminals.

However, despite heavy investments, the spatial distribution and accessibility of taxi terminals remain problematic. Many terminals are unevenly located, leading to congestion, bottlenecks, and limited access for many residents. This imbalance is especially acute in Arada Sub-City, a densely populated and historic district where demand for taxi services exceeds current terminal capacity and coverage.

The Urgency to address this issue lies in the rapid urban growth and increasing transport demand that threaten to overwhelm the existing infrastructure in not managed effectively. Applying spatial analysis now can uncover critical gaps and inefficiencies in terminal placement and accessibility of taxi terminals in Arada Sub-City. This Study aims to identify the existing gaps and inefficiencies and to propose practical, evidence-based solutions. The goal is to enhance delivery, reduce congestion, improve mobility for all residents and supporting sustainable urban mobility in Arada Sub-City before these challenges worsen.

1.3. Research Objectives

1.3.1. General Objective

The primary objective of this study is to Analyze the spatial distribution and accessibility of taxi terminals, in the Arada Sub-City, Addis Ababa. enhancing the overall effectiveness of current transportation infrastructure is distributed efficiently and fairly across the city.

1.3.2. Specific Objective

- To map the spatial distribution of taxi terminals within Arada Sub-City and identify areas with limited or inadequate access to taxi services.
- To identify areas that are not measurable or over-served by taxi terminals.
- To recommend relocation and optimization strategies for taxi terminals that prioritize equitable access and congestion reduction.

1.4. Research Questions

The research questions that this study will attempt to clarify and answer are;

- What is the current spatial distribution pattern of taxi terminals within Arada sub-city?
- what factors influence the location of taxi terminals in Arada sub-city?

- What recommendation can be made to improve the spatial planning and accessibility of taxi terminals in Arada sub -city?

1.5. Scope And Limitation of the study

Thematic Scope: The study focuses on the spatial distribution and accessibility of taxi terminals, specifically informal ones operating without formal regulation. It explores how these unregulated terminals function within the urban transport system and the challenges they pose for city planning and mobility, the theme also includes an examination of accessibility issue and urban transport dynamics in a developing city context.

Geographically Scope: the research is limited to Arada Sub-City, one of the administrative divisions within a larger urban area. The focus is on analyzing patterns within this specific Sub-City, allowing for a detailed, localized understanding of taxi terminal distribution and accessibility.

The study in limited to focuses the dynamic nature of informal taxi terminals operating without formal regulation, moreover, was where lack of up-to-date secondary resources to conduct the study.

1.6. Significance of the study

Practically, this study offers valuable insights for urban planners and policymakers by identifying spatial inefficiencies and accessibility gaps in the distribution of taxi terminals in Arada sub city. Enabling targeted improvements that enhance service coverage and equity. Methodologically, it showcases effective integration of advanced geospatial tools and spatial statistic with qualitative data, providing a robust framework for analyzing urban transport infrastructure that can be applied in similar context. Theoretically, the research contributes to urban transport and spatial planning literature by empirically demonstrating how the uneven placement of transport terminals influences accessibility and urban mobility, thereby informing more inclusive planning approaches in rapidly growing cities.

1.7. Motivation of the Research

The research was initiated based on own observation and growing concern regarding the uneven spatial distribution and limited accessibility of taxi terminals in Arada sub city, Addis Ababa. and to contribute data-driven insight that can support more coherent and equitable urban transport planning, ultimately fostering better infrastructure development and improved quality of life for city residents.

1.8. Definition of key Term

Public Transport infrastructures: Transport infrastructure is composed of the fixed installations of canals, waterways, airways, roads, and terminals, as well as pipelines such as seaports, refueling depots, trucking terminals, warehouses, bus stations, railway station, and air ports.

Spatial Distribution: The arrangement or spread of taxi terminals within a defined geographical area. It refers to how taxi terminals are distributed across Arada sub-city, considering factors such as proximity to key locations (residential, commercial areas0, density, and the pattern of their location (clustered, dispersed, or evenly distributed).

Accessibility: The ease with which people can reach a taxi terminal from their homes, workplaces, or other important locations. It measures how available and reachable the the terminals are to different segments of the population, including distance, time, and barriers to access.

Taxi terminal: These are designated areas where taxis line up to pick up passengers. taxi terminals are typically located near transportation hobs, commercial districts, and residential neighborhoods to provide accessible, on-demand transport services.

Taxi terminal capacity: The maximum number of taxis a terminal can accommodate at any given time, including factors such as waiting spaces, parking spaces for taxi, and infrastructure for operation.

Proximity to key Location: The closeness of taxi terminals to important destinations or land uses within the sub-city, such as residential neighborhoods, commercial areas, schools, hospitals, and transport hubs.

Walking distance: was defined as the maximum distance a passenger can comfortably walk from their location (residence, office, or a major transit hub) to the nearest taxi terminal.

1.9. Organization of the Thesis

The Research report is structured into five distinct chapters:

Chapter One: - provides an introduction to the research project.it provides a general background and provides the scope, research questions and objectives of the work.

Chapter Two: - provides a literature review of the issue of spatial analysis and accessibility theory, its importance, and how terminal planning and design, challenges in accessibility, and strategies for improving the efficiency and service delivery.

Chapter Three: - describes the research methodology and provide insight into the data sources.

Chapter Four: - presents the data analysis and discussion part of the research

Chapter Five: - parents the research conclusions, recommendation, frameworks, organizational structure and future research areas.

CHAPTER 2. LITERATURE REVIEW

2.1 General Overview of Transport Infrastructure

Transport infrastructure is fundamental to the economic development and spatial organization of cities. Globally, efforts to manage infrastructure such as roads, railways, airports, and terminals intensified in the second half of the 20th century, leasing to the development of integrated systems. Among these, taxi terminals represent one of the most widespread and essential urban facilities, especially in developing countries where formal public transit is limited. These terminals facilitate passengers' movement and act as access points to urban mobility networks.

Transport Infrastructure in Addis Ababa: As of 2024, Addis Ababa's, public transport infrastructure plays a key role in supporting the economy and improving accessibility. however, urbanization, population growth, and limited planning have led to significant challenges in terminal management, including un even distribution, traffic congestion, and informal terminal development.

The Addis Ababa city transport Authority (AACTA) is the main governmental institution responsible for managing, planning, and regulating the city's transport systems and infrastructure. According to AACTA records: Addia Ababa ci has registered fleet of 9576 taxis. within the city, there are only 2314 public buses operate within the city.

These figures underscore the vital role of taxis in Addis Ababa transportation landscape, study by a world Bank (2002) study found that minibus taxis account for 73 % of the city's total modal transport share. These taxis are critical, especially for middle- and lower-income residents who rely on them for daily commuting.

Minibus transportation service is provided by both code 1 blue minibus and code 3 supporting minibuses. Code 1 blue minibus taxi provide service with a total of 3481 vehicles along 318 routes and daily transport 668,352 passengers. Cod supporting minibuses provide service with a total of 4392 vehicles along 303 routes.

Compared to the other public buses, minibus taxi covers more routes, and the average waiting time for passengers is approximately 12 minutes (Addis Ababa Transport Authority (AATA), (2017). Taxis in Addis Ababa are generally organized into taxi stations (terminals)scattered across different parts of the city. These terminals function as departure and arrival hubs for fixed and semi-fixed route services. AACTA also oversees taxi terminal management, policy enforcement, and infrastructure development, including the planning and maintenance of terminals facilities.

The city's taxi system is composed of two main types:

1.Minibus taxi (12-15 seat capacity), which operate on semi-fixed routs.
2. Meter taxi (recently emerging-based or privately hired) which offer more flexible

Arada sub-city, located in the historical core of Addis Ababa, hosts several of the city's busiest taxi terminals (e, g., piazza, Ras Mekonnen Bridge, and Tewodros square). While its central location ensures a high density of routes and taxi the area also terminal congestion due to narrow streets and high pedestrian volumes, spatial inequality in access, insufficient terminal planning

2.2 The Role and Importance of Taxi Terminals

Taxi terminals are designated points where taxi wait to pick up passengers. Strategically located near transportation hobs, commercial centers, and residential neighborhoods, they provide essential, on demand mobility services. In urban transport systems, terminals function as nodes of transformer passengers switch between transport modes (e.g., taxi to bus or minibus). Ther performance directly influences network efficiency, accessibility, and commuter experience.

Key functions and attributes of transport terminals include:

- Location: Terminal should serve dense areas of economic and social activity. However, land scarcity and high central city cost often push new facilities to the urban periphery.
- Accessibility: Effective terminals are well connected to broader networks, enabling easy travel across local and regional areas.
- Infrastructure Needs: Terminals require specialized infrastructure (e.g., shelters, signage, safety measures) and ongoing investment to meet demand and ensure user safety.

2.3 Spatial Distribution of Taxi Terminals

The spatial distribution of taxi terminals affects how efficiently people can access transport services. In Addis Ababa, terminal location is often influenced by population density, commercial activity, and informal land use practices, Studies, Girma & Shiferaw (2019) have shown that unplanned or unofficial terminals frequently emerge in underserved areas, where formal infrastructure is lacking, these informal terminals, while responsive to local demand, may contribute to congestion, safety, and operational inefficiencies.

The spatial distribution pattern of taxi terminals refers to how taxi stands and terminals are distributed across a particular geographic area, including the location, density, and accessibility of these terminals within the urban landscape.

Several factors determine the spatial distribution of taxi terminals in a city. These include:

1. Urban Geography and land use

   Numerous studies have examined the relationship between taxi terminal location and urban geography. For example, Ma and Loo (2017) discuss how taxi terminals are strategically placed in areas of high demand, such as central business districts (CBDs) and near transportation hubs (e.g., airports, train stations). Their findings indicate that the accessibility of taxi terminals significantly influences their spatial distribution, prompting city planners to consider demand patterns when establishing new terminals.
2. Socioeconomic factor

   The spatial distribution of taxi terminals is also influenced by socioeconomic factors. research by Wang et al. (2018) suggests that terminal locations tend to coincide with high-density residential and commercial areas, driven by higher potential ridership. Additionally, socio- economic challenges, such as income disparities, can affect access to taxi services, reinforcing spatial inequities.
3. Environmental considerations

   The environmental impact of taxi terminals has garnered attention in literature. A study by Lin and chen (2020) explores how the placement of taxi terminals can be optimized to reduce traffic congestion and emissions, suggesting that strategically located terminals could encourage more sustainable urban mobility.

Spatial analysis tools such as GIS (Geographic information system) and Spatial statistics (e.g., Moran's I, LISA) have become crucial Identifying patterns of clustering, dispersion, and service gaps. tools for analyzing the spatial distribution of taxi terminals. IS enables the visualization and analysis of spatial patterns and the identification of service gaps (Akinmoladun et al., 2021). Using GIS, researchers can map taxi terminal location, calculate distance to key destinations, and assess accessibility patterns, are commonly used to determine areas with insufficient taxi coverage or areas with excess concentration of terminals (Al-kilidar & Jasim,2019). Understanding these patterns allows planners to develop evidence-based strategies for more equitable and efficient terminal placement.

2.4 Accessibility in Urban Transport planning

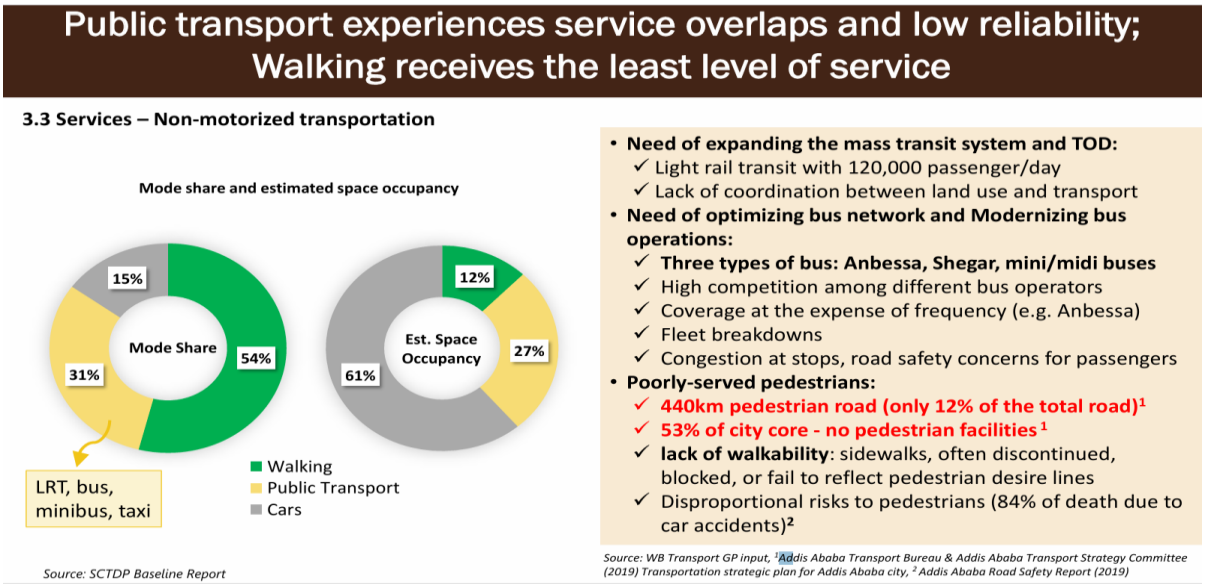
Accessibility refers to how easily people can reach essential services and destinations, including transport terminals.it is a central concept sustainable urban mobility and is widely used across various scientific fields such as transport planning, urban planning and geography, plays an

important role in policy making, this paper presents a thorough review of accessibility studies is transport policy appraisal. several authors have written review articles on accessibility measures. Highlighting various approaches to defining, quantifying, and applying accessibility in transport and land use planning contexts, as stated by Geurs, k.T., & van wee, B. (2004) accessibility measures into infrastructure-based, location based, person based, and utility-based categories.

Spatial Accessibility of Taxi Terminals A study on Addis Ababa's taxi system highlighted the challenges in the spatial distribution of taxi terminals across the city. The research found that taxi terminals were unevenly distributed, with higher concentrations in the central business district and fewer terminals in peripheral or low-income areas (Mengesha et al.,2021). Accessibility was significantly lower in these underserved areas, where residents had to travel long distance to reach the nearest taxi terminal. The study recommended that new terminals be placed in underserved areas to improve equity and service coverage.

1. Measuring Accessibility: Accessibility is a multifaceted concept, often measured using various indicators such as travel time, distance, and ease of access. research by Kwan (2018) illustrates the use of Geographic Information Systems (GIS) To quantify accessibility to taxi terminals, allowing for a more detailed spatial analysis that considers factors like public transportation availability and population density.
2. Socio Equity and Accessibility: The topic of socio equity in transportation access is increasingly relevant. A study by Crampton et al. (2019) investigates how marginalized communities are often located farther from taxi terminals, highlighting the need for policies that enhance accessibility for underserved populations. Their work emphasizes that improving access to taxi services can serve as a significant step towards greater urban equity.
3. Technological Advances: Advances in technology, particularly ride-hailing applications, have transformed the accessibility of taxi services. Chen et al. (2020) analyze the impact of these platform on traditional taxi Several comparative studies have been conducted to analyze how different cities address the distribution and accessibility of taxi terminals. for instance, a study by Liu et al. (2021) compares taxi terminal systems in New York city and shanghai, revealing significant disparities in both spatial distribution and user accessibility due to differing regulatory frameworks and urban development pattern. such case studies can inform best practices and potential policy intervention in other metropolitan areas. The spatial distribution and accessibility of taxi terminals are vital areas of research that intersect urban geography, transportation studies, and social equity discussions. Future research should continue to explore the dynamic relationships between these elements, especially in the context of rapid

technological advancements and changing urban landscapes. policymakers and urban planners are encouraged to consider these insights to create more inclusive, efficient, and sustainable transportation systems.



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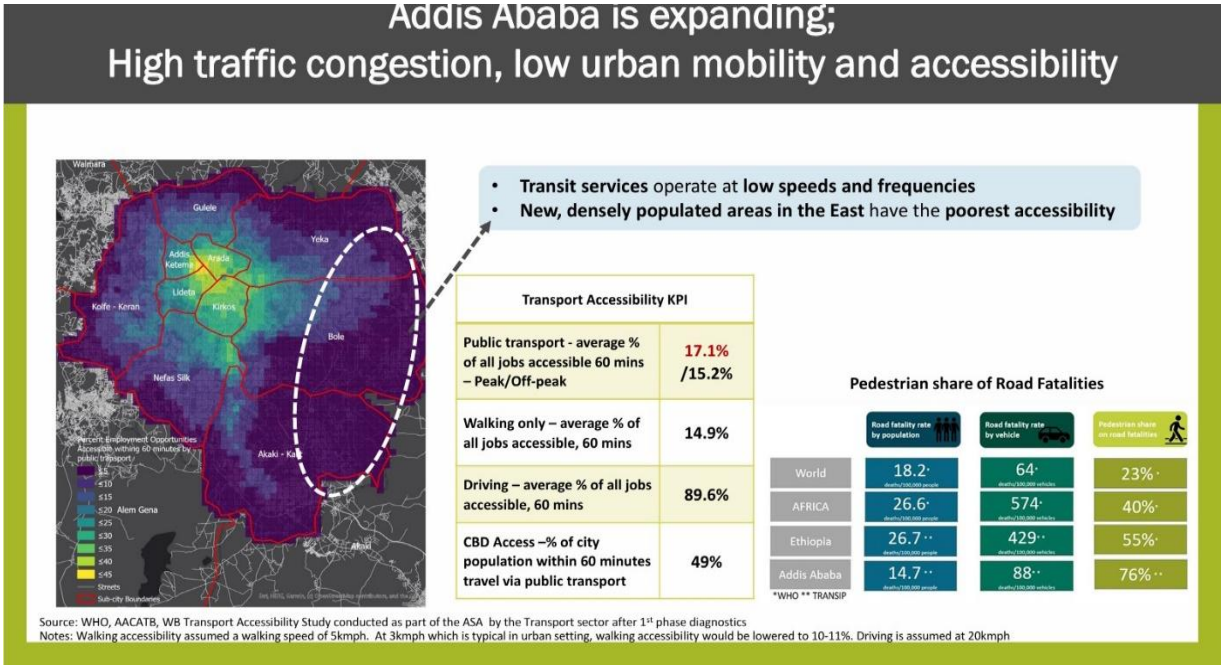


(b)

Figure 1. (a) Addis Ababa city transport Experience, (b) Addis Ababa transport accessibility

Source: world bank group report transforming Addis Ababa integrated strategic development

2.5 Challenges in Existing Taxi Terminal Practices

In rapidly urbanizing cities like Addis Ababa, Taxi terminal plays a vital role in facilitating urban mobility and ensuring last-mile connectivity. The effectiveness of existing taxi terminal practices is undermined by several persistent challenges that limit their efficiency, safety, and accessibility. The challenges result in inefficient service delivery, poor commuter experience, and unsustainable urban transport outcomes. Addressing them requires a combination of policy reform, stakeholder coordination, GIS-based planning, and investment in infrastructure modernization.

Key challenges in existing taxi terminal practices

2.5.1 Informal development without planning

Many taxi terminals have been established informally, often without to urban transport plans or regulatory oversight. As a result, these terminals frequently lack basic infrastructure such as passenger shelter clear boundaries, leading to disorder and safety risks.

2.5.2 Congestion and poor Management

Key terminals in high -traffic areas such as Mercato, piazza, and Arat killo suffer from chronic congestion. These sites are often overcrowded, poorly managed, and have minimal regard for traffic flow, pedestrian safety. or surrounding land use. The absence of designated entry and exit points, traffic marshals, and organized queuing systems leads to chaotic conditions that impede efficient operations.

2.5.3 Spatial Disconnection from Demand Centers

The spatial distribution of taxi terminals across Addis Ababa IS often misaligned with actual passenger demand. Terminals are unevenly located, with a concentration in central zone and a lack of service in peripheral and underserved communities. This results in reduced accessibility, increased travel times, and inefficiencies in service delivery.

2.5.4 Inadequate Infrastructure and Facilities

Most existing taxi terminals lack essential infrastructure required for user comfort and safety. common deficiencies include the absence of proper signage, weather protection, security, and pedestrian pathways. These shortcomings diminish the overall user experience and deter vulnerable groups such as the elderly or persons with disabilities from using the service.

2.5.5 Weak policy and Institutional Coordination

The challenges are further compounded by weak policy enforcement and fragmented institutional responsibilities. Different agencies may be involved in terminal management, licensing, and land use planning, but coordination is often limited. This institutional fragmentation hinders the implementation of strategic improvements and leads to inconsistent service standard

Table1: Existing Taxi terminal challenges

Category	Challenges
Infrastructure Deficiencies	-poorly designed or aging terminal structure -inadequate space for waiting, parking, and passenger flow
Congestion and traffic flow	-Terminal often located in high-traffic areas without integration into traffic management plans
Poor Accessibility	-Terminal not easily accessible by pedestrians or public transport -lack of facilities for persons with disabilities
Uncoordinated planning	-No integration with urban transport master plan
Lack of data and monitoring	-Minimal or no use of real-time data for monitoring taxi flows or user demand
Regulatory and Operational Issues	-Weak enforcement of loading/unloading rule -informal operations or unlicensed terminals

Figure 2: Issues with Existing Taxi terminals in Arada Sub-City and public transport experience service.

2.6. The project life Cycle Design of Taxi terminals

A successful study life cycle involves a comprehensive and systematic approach to Analyzing the spatial Distribution and Accessibility of taxi terminal infrastructure requires a comprehensive and systematic project life cycle that integrates all critical research phases. This research follows five key stages to examine the taxi terminals in Arada Sub-City. The process begins with problem identification, focusing on spatial and service-related gaps in terminal access. It proceeds with data collection using both primary sources—such as field observations, surveys, and interviews—and secondary sources, including maps, policy documents, and urban planning reports. Spatial analysis is then carried out using tools like ArcGIS 10.8, Local Indicators of Spatial Association (LISA), and accessibility models to detect patterns, disparities, and clustering of terminals. Stakeholder engagement follows, involving transport users, operators, and local authorities to ensure the findings are grounded in practical realities and diverse needs.

Finally, the study concludes with evidence-based recommendations aimed at improving the equity, efficiency, and sustainability of taxi terminal infrastructure, ultimately contributing to more effective urban mobility planning and inclusive service delivery in Addis Ababa.

2.7. Data Characteristics and Properties

The research of various sources on how agencies worldwide deal with decision making has brought to light particular attributes and characteristics that the collected data should possess in order to be useful for this purpose. Regardless of the particular type or category that the collected data fall into, it is of paramount importance that when incorporated in a database they exhibit the following characteristics.

According to Deighton (1991):data used in decision -support systems should fulfill the following conditions:

- **Integrity**: whenever two data elements represent the same piece of information must be identical.
- **Accuracy**: the data values represent as closely as possible the considered piece of information;
- **Validity**: the given data values are correct in terms of their possible and potential ranges of values; and
- **Security**: sensitive, confidential and important data are protected by restricting access to them and by properly ensuring systematic and frequent backing up in other storage media.
- **Relevance**: every data item collected and stored should support an explicitly defined decision need;
- **Appropriateness**: the amount of collected and stored data and the frequency of their update should be based on the needs and resources of the agency organization;
- **Reliability**: the data should exhibit the required accuracy, spatial coverage, completeness and be up-to-date.
- **Affordability**: data collection efforts should be cost-effective and within budget constraints.

The World Road Association (WERD, 2003) further advises that agencies must specify the type of data required, its collection frequency, and acceptable standards of accuracy and quality. It is recommended that data should be collected only when the expected benefits outweigh the associated costs. Smith and Lytton (1992) emphasize that the choice of data collection methods should reflect the level of detail and precision required by the decisions being supported.

In the context of taxi terminal panning, as stated by Lei Jin Al. (2023) taxi terminal investigate the rational layout of taxi stops using spatial trajectory data. their study employs GPS data to identify

areas with high taxi demand and proposes optimal locations for taxi station and aiming to enhancing the efficiency of taxi services and promote sustainable urban development.

2.8 Identifying Taxi Terminals Needs and Location

The identification of optimal taxi terminal locations is acritical aspect of urban transportation planning. Terminal placement has often relied on administrative decision or historical patterns, which may not reflect the dynamic system and growing needs of urban populations. However, advancements in Geographic Information Systems (GIS) Have introduced more data driven, spatially informed methods for evaluating and selecting terminal sites.

The Application of ArcGIS, section explores the use of ArcGIS platform, allows researchers and planners to analyze the spatial distribution pattern and accessibility of public taxi terminals. this involves using ArcGIS tools and techniques to collect, process, and analyze data related to public transportation. The identification of optimal taxi terminal location is a critical component of urban transportation planning traditional method often rely on administrative decisions, which may not accurately reflect the dynamic needs of urban populations. advancements in Geographic information systems (GIS) And spatial analysis have provided more robust tools for assessing and determining the most suitable locations for taxi terminals. Several studies have applied GIS- based methodology to identify optimal taxi terminals. for instance, Mekonnen et al., (2021) conducted a case study in Addis Ababa, utilizing GIS tools to analyze spatial data and determine the most suitable sites for new taxi terminals.

By incorporating spatial factors analysis provides a comprehensive approach to identifying taxi terminals needs and location.by considering various factor such as land use, infrastructure, and socioeconomic conditions, urban planners can make informed decision that enhance the efficiency and accessibility of taxi services.

2.9 Benefits-Cost Analysis (BCA) of Properly planned Taxi Terminals

Properly planned taxi terminals play a crucial role in enhancing urban transport systems by improving overall mobility, accessibility, and service reliability. When such infrastructure is integrated with a comprehensive Asset Management System (AMS), transport agencies can utilize data-driven tools—including condition prediction models and economic analysis—to guide cost-effective decision-making regarding maintenance and rehabilitation. A key component of this approach is:

Benefit–Cost Analysis (BCA), which evaluates the net benefit of an infrastructure investment by comparing the present value of its expected benefits to its associated costs. According to the Federal Highway Administration (FHWA, 2003), a project is considered economically justifiable when the benefits exceed the costs over time. While BCA is widely applied in large-scale infrastructure projects, such as highways, dams, and bridges, its application in urban transport terminals may face challenges, particularly in quantifying intangible benefits like accessibility, safety, and time savings. Alternatively,

Cost-Effectiveness Analysis (CEA) may be used to compare the relative efficiency of terminal planning options. CEA incorporates cost data in present value terms but evaluates outcomes through non-monetary indicators, such as improved service coverage or reduced waiting time. This makes it particularly useful in comparing options with social or environmental impacts that are difficult to monetize. Both methods, when applied carefully, support rational and transparent infrastructure planning and prioritization.

It is generally expected that properly planned taxi terminals are expected to enhance of urban transport systems by improving overall mobility and accessibility while simultaneously reducing long term operational and maintenance costs when integrated with an asset management system (AMS), transport agencies can apply decision-making tools such as condition prediction models and economic analysis techniques to identify cost-effective maintenance and rehabilitation.

2.10 Research Gap

In Ethiopia, there is a notable lack of research focusing specifically on the spatial distribution and accessibility of taxi terminals using Geographic Information Systems (GIS) and spatial analysis techniques. Existing studies in the field of urban transportation have largely concentrated on broader infrastructure systems, such as public bus networks or emergency services. For instance, kassaw, M., & Asefa, B. (2020). conduct a GIS-based analysis of ambulance accessibility in Arada sub-city, while Mulugeta (2020) examined the spatial accessibility to bus station along the Mexico to hayahulet corridor in Addis Ababa. While these studies contribute valuable insights into transportation infrastructure planning, they fall short in addressing the unique characteristics of taxi terminals, including location-specific service dynamics, informal operational practices, and user-level accessibility challenges. This Oversight is particularly significant given the increasing reliance on informal and semi-formal taxi services in rapidly urbanizing areas of Ethiopia. Therefore, there is a notable gap in the literature regarding the spatial distribution and accessibility

of taxi terminals, addressing this gap is central to the objectives of this study, this research aims to address the shortfall by evaluating the current distribution of taxi terminals in Arada Sub- City and proposing optimized locations using advanced GIS tools and spatial accessibility models.

2.11. Conceptual framework of the Study

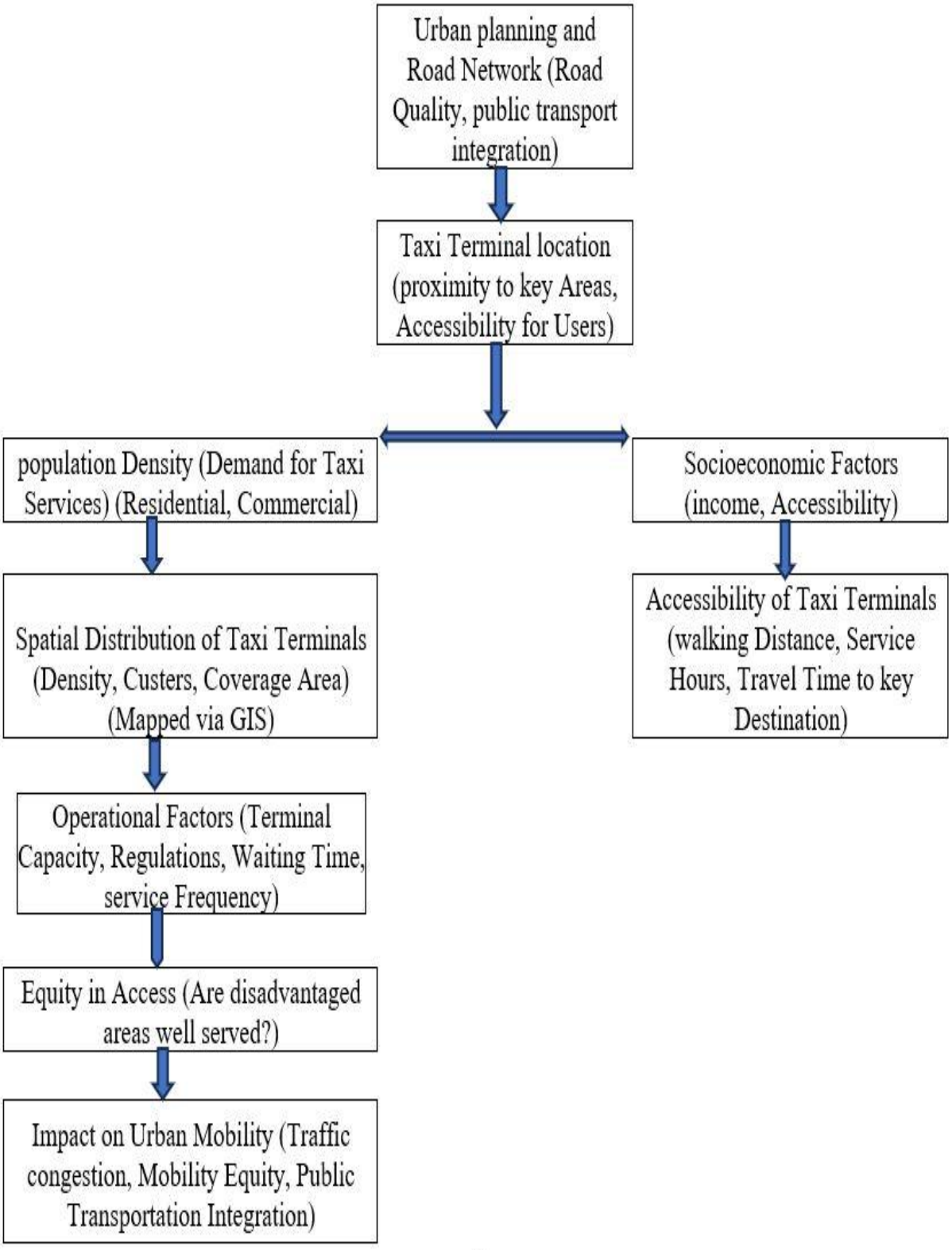
The conceptual framework for this study integrates key variables related to the spatial distribution and accessibility of taxi terminals, with the ultimate goal of optimize their placement of taxi terminals distribution and improving service delivery in Arada Sub City. The framework is grounded in Geographic information system (GIS) based spatial analysis techniques and is designed to evaluate existing terminal conditions, assess accessibility challenges, and identify potential locations for future development.

First, current spatial distribution of taxi terminals is analyzed using GIS tools spatial distribution mapping, nearest neighbor analysis, and service area(buffer)analysis. Secondly, accessibility is examined by overlaying population density, land use patterns, and road network connectivity to identify underserved areas and locations experiencing limited access. Third, Potential future sites for taxi terminals are determined through Multi-Criteria Evaluation (MCE) within the GIS environment. Taking into account geographic, demographic, infrastructural, and policy-related variables. The spatial pattern of taxi designed to examine the relationship between aspatial and non-spatial factors that influence the distribution and accessibility of taxi terminals. it identifies how geographic, demographic, infrastructural, and policy-related inputs affect accessibility outcomes and guides strategic transport planning decision. here is the framework is structured around three key components:

- **Input variables:**
  The framework is based on land use characteristics, population density, road and transport infrastructure, socioeconomic indicators, and existing regulatory frameworks. these variables determine the spatial context in which taxi services operate.
- **Analytical Process:**
  The framework is based on GIS spatial analysis, accessibility modeling, and data integration techniques are employed to evaluate how well existing taxi terminals serve the surrounding population. method include buffer analysis, service area modeling, and network analysis
- **Output variable;**
  The outcomes of the analysis include detailed insights into distribution pattern, level of service accessibility, and identification of underserved or poorly connected areas. these

results inform evidence-based recommendations aimed at improving the efficiency, equity, and sustainability of taxi terminals infrastructure in the study area.

Overall, the conceptual framework supports strategic planning by highlighting the relationships between geographic, demographic, infrastructural, and policy-related factors that affect the accessibility and spatial equity of taxi terminals.



. **Figure 3: Conceptual Frameworks of the Study**

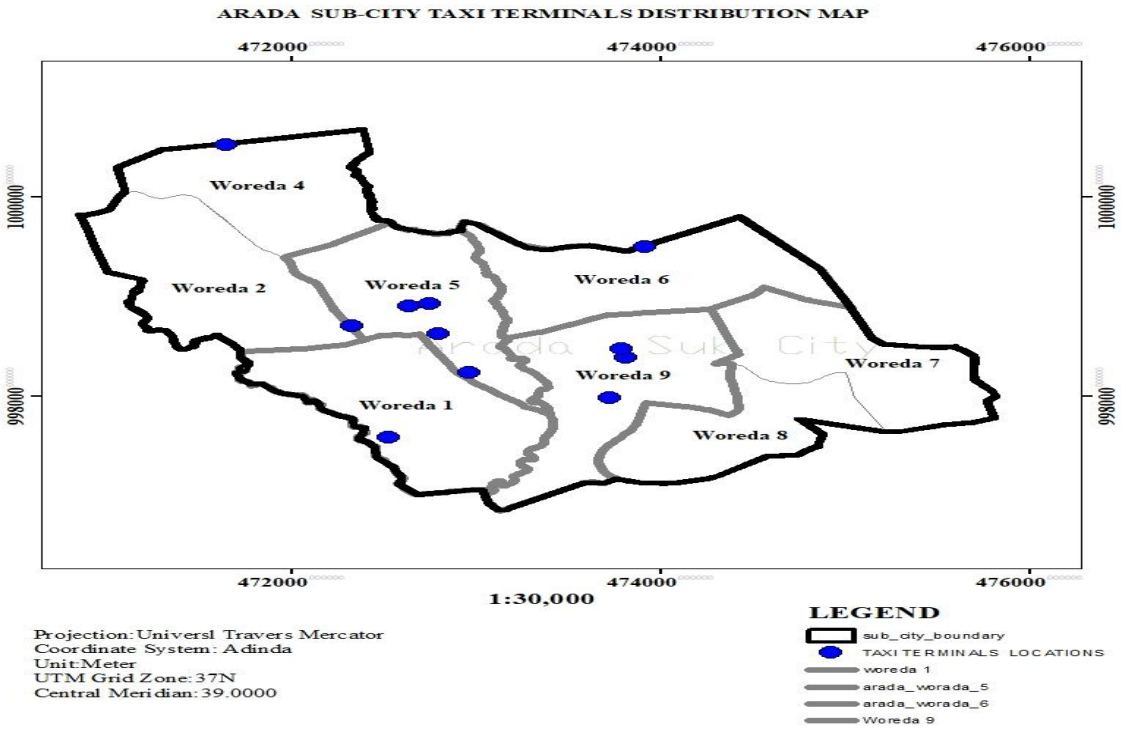


Figure 4. Existing Taxi terminal location map of Arada sub city

Table 2.0: Types of Taxi terminal and Definition

Types of taxi terminal	Definition
On-street Taxi Stand	A designated area on a public street where taxi can pick up and drop off passengers
Off-street Taxi stand	A designated area away from traffic where taxi can park, wait for passengers, and pickup/drop off
Taxi Rank	A designated area, often at transport hubs (airport, bus station, etc.), were taxi queue for passengers.
Taxi Depot	A facility where taxi is stationed when not in use, providing storage, maintenance, and operational facility
Integrated Transport Hub Terminal	A multi-modal terminal that combines taxi services with other transport modes like buses, trains, or metro station.
Temporary Taxi Terminal	A short-term setup for taxi events or during construction or renovation of regular taxi terminals
Shared Taxi Terminal	A terminal serving multiple forms of shared ride services (e.g., taxi, buses, rideshares)
Luxury Taxi Terminal	A high-end terminal designed for premium or executive taxi services, such as luxury sedans or airport limos.

CHAPTER 3. MATERIALS AND METHODS

3.1. Introduction

Transport infrastructure projects consume substantial portions of a nation's budget, underscoring the necessity for systematic management to ensure optimal resource utilization and service delivery.in this context, the primary objective this research is to assess the spatial distribution and accessibility of taxi terminals in Arada Sub-City. The assessment started with a comprehensive and thorough review of relevant literature in order to gain related experiences. The literature reviews underscore the critical role of transport infrastructure in urban development. globally, the management of infrastructure such as roads, railways. airports, and terminals has intensified, leading to the development of integrated systems. Among these, taxi terminals are essential urban facilities, particularly in developing countries where formal public transit options are limited. In Ethiopia, and specifically in Addis Ababa, transport infrastructure plays a pivotal role in supporting the economy and enhancing accessibility. However, challenges such as rapid urbanization, population growth, and limited planning have led to significant issues in terminal management, including uneven distribution, traffic congestion, and informal terminals development. The current practice of transport infrastructure following methodology has been adopted in the study.

3.2. Description of Study Area

Arada Sub-City is geographically located at 9º 01' - 9º 03' North Latitude and 38º 44' - 38º 46' East Longitude. Arada is one of the 11 Sub-Cities of Addis Ababa, the capital of Ethiopia. It covers an area of 950 hectares. the Sub-City is roughly situated in the northern part of Addis Ababa nearby the center bounded from the south by Kirkos and Lideta, from West by Addis Ketema, from East by Yeka, and from north by Gulele sub-city. the district is one of the oldest commercial and most historical districts of Addis Ababa. and due to its central location and urban significance.it plays a critical role in the city's social, economic, and administrative functions.

The study area, Arada Sub- City Administration, was selected due to its substantial taxi activity, making it one of the largest taxi markets in Addis Ababa, the sub city's district were categorized into three classes based on their district land use patterns, population density, and urban functions.

The first class comprise 2 administration districts, known as CBD areas. which function as MCC, historical, Administration, and commercial centers within Arada sub city. these districts are

characterized by dense infrastructure and area woreda 1, worada 5 and woreda 6. The second class encompasses administrative districts, recognized as inner city areas, which fulfill dual roles as both residential and commercial zone. these districts are worada 2 and woreda 4The third class comprises administrative districts, categorized as residential zone, these woredas are woreda 7, woreda 8, and woreda 9.

Arada sub-city is one of the most populous urban centers within the Addis Ababa region. a population density of approximately 30,687 people per km². this density is among the highest in Addas Ababa, according to the Arada Sub -City administration office, the registered population in 2023 was 304,610 reported by the population and housing Census [19]. The sub-city administrative area currently encompasses 8 woredas.

The locations and boundaries of all 8 administrative district are visually represented figure 5.

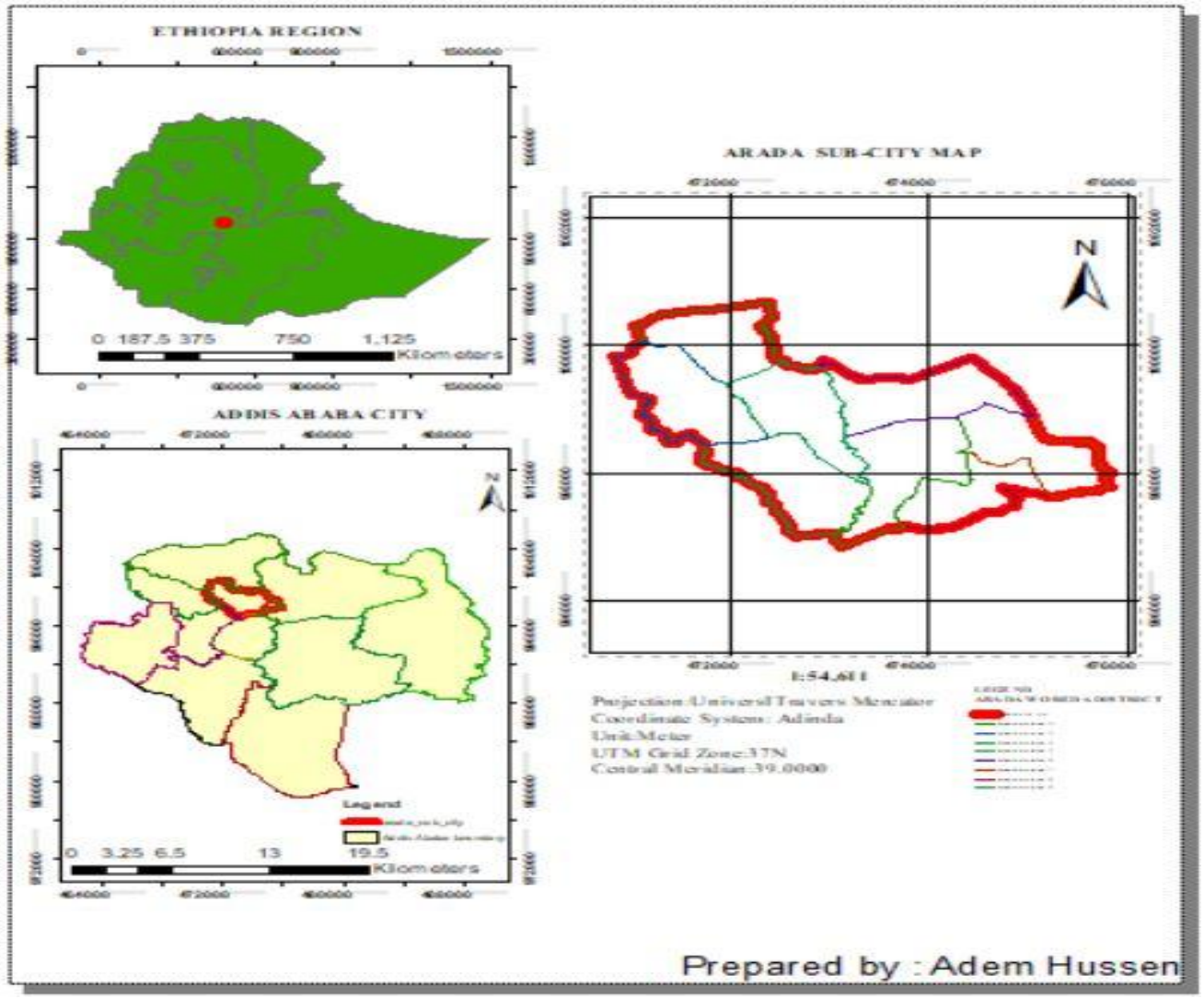


Figure 5. Location of study area

3.3. Case Study Area Selection Criteria

Arada sub-city, one of the most prominent and historically significant areas in Addis Ababa, Ethiopia, was selected as the case study area for this research due to several interrelated and contextually relevant factors. The sub city currently engaged in the implementation of a smart city development program, which necessitates efficient, inclusive, and accessible public transportation infrastructure, particularly well-functioning taxi terminals. Analyzing the spatial distribution and accessibility of taxi terminals in Arada directly supports the broader objective of the smart city initiative by identifying existing gaps, informing infrastructure improvements, and enhancing mobility for all users, particularly vulnerable populations. additionally, the area's proximity to the researcher and the availability of relevant data made Arada a practical choice, enabling valuable contribution to urban mobility and smart city development goals.

3.4. Research Approach

In order to find answers to the research questions and to achieve the objective of the study, quantitative and qualitative ways of research adapted. Qualitative research of explanatory type will be adopted in order to diagnose a situation, assess alternatives, and discover new ideas. Mixed-method research seems to be appropriate and is helpful in gaining a better understanding of both the physical distribution and the functional condition of taxi terminals. Through an in -depth study of the new phenomenon based on it qualitative and quantitative aspects of the study. The overall approach to be followed are; having established the basis of research, necessary data will be collected, analyzed, and conclusions and recommendations will be made based on the findings. the methods of data collections employed for the research are: - surveys, interviews and observational techniques.

Quantitative Data: distribute structured surveys to passengers and service providers. Questions will cover perceptions of accessibility, satisfaction with current facilities, and specific barriers encountered.

Qualitative Data: conduct semi-structured interviews with a subset of passengers, service providers, and advocacy groups. to gain in-depth insights into personal experiences, perceived inequities in terminal access, and systemic challenges such as regulation gaps, urban planning issues, and user safety.

Quantitative Analysis: use statistical methods to analyze responses and audit results. This includes calculating the percentage of compliance with accessibility standards and identifying statistical correlation tests (Pearson's) between accessibility features and user satisfaction

Qualitative Analysis: Employ thematic analysis to interpret interview and focus group data, identifying recurring themes and insights related to accessibility barriers and facilitators.

Expected outcomes

- **Identification of accessibility barriers:** comprehensive understanding of accessibility and inclusivity barriers faced by different user groups at taxi terminals in Arada sub-city.
- **A comprehensive map** showing spatial distribution of taxi terminals
- **Evaluation of Accessibility Features:** Assessment of the effectiveness of current accessibility features and services at taxi terminals in Arada sub-city.
- **Spatial Distribution and Equity Analysis:** analyze the spatial distribution of taxi terminals across Arada sub-city. Measure compliance and identify infrastructure gaps
- **Policy Recommendations:** practical and actionable recommendation for improving accessibility and inclusivity of taxi terminals in Arada sub-city. based on empirical data and feedback from users and stakeholders.
- **Baseline data:** for future urban transport planning in Arada sub city**.**

3.5. Data Type and Sources

To analyze the spatial distribution and accessibility of taxi terminals in Arada Sub City, the survey data collection techniques. As indicated in the introduction chapter, the present study will use Geospatial data and primary field survey data as the main types of data source to analyze the spatial distribution and accessibility of taxi terminals. The following sub-section discusses the two kinds of data and data sources for this study.

3.5.1. Primary Data

Geospatial data

- Taxi terminal Location: obtain Geographic coordinates (Easting and Northing) and attributes of all taxi terminals from city databases, transport agencies, and GPS tracking system.

Table 3: Esting Taxi Terminal's location selected for the data collection

Taxi terminals Name	Location Coordinates		Remark
	Easting	Northing	
Arat killo	473810.52	998388.44	Woreda 9
Bashawolde	473725.85	997984.69	
Minilik square	472793.75	998241.49	Woreda 5
De Gaulle Square	472967.32	998241.49	
Tewodros Square	472530.54	997584.93	Woreda 1
Yekatit 12	473790.66	998473.51	Woreda 9
6 killo Square	473914.28	9999500.42	Woreda 6
Firefighting station	472746.49	998903.98	Woreda 5
St. Geoge's cathedral	472640.66	998903.98	
Addisu Gebeya	471648.08	1000524.85	Woreda 4
Abune petros square	472325.99	998708.32	woreda 5

- Woredas Boundaries, the sub-city woreda administrative boundaries obtain from AAMPS

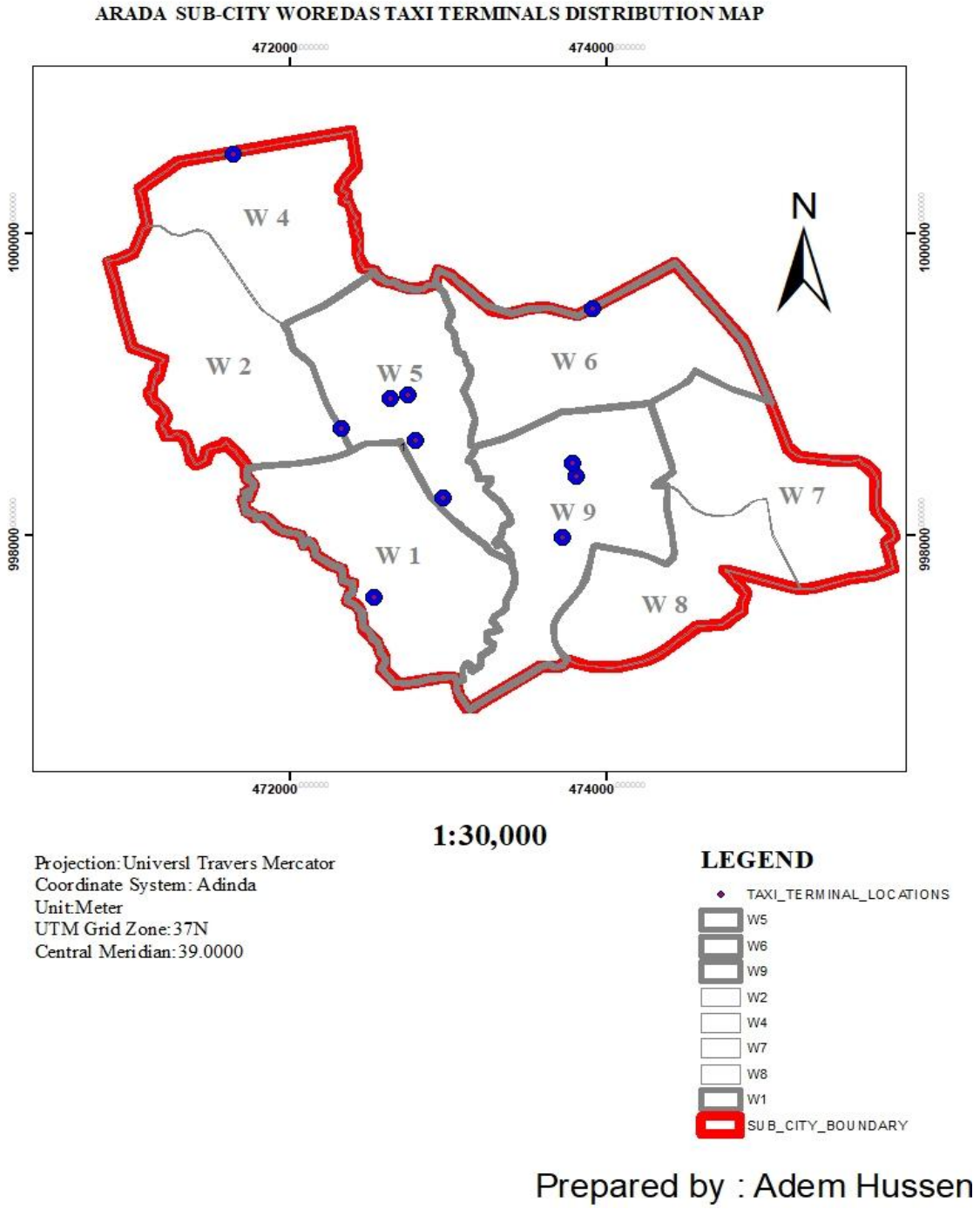


Figure 6. Administration Region and Districts of Arada sub city

- Road Network data: Acquire data on the area's road infrastructure to understand traffic patterns and accessibility

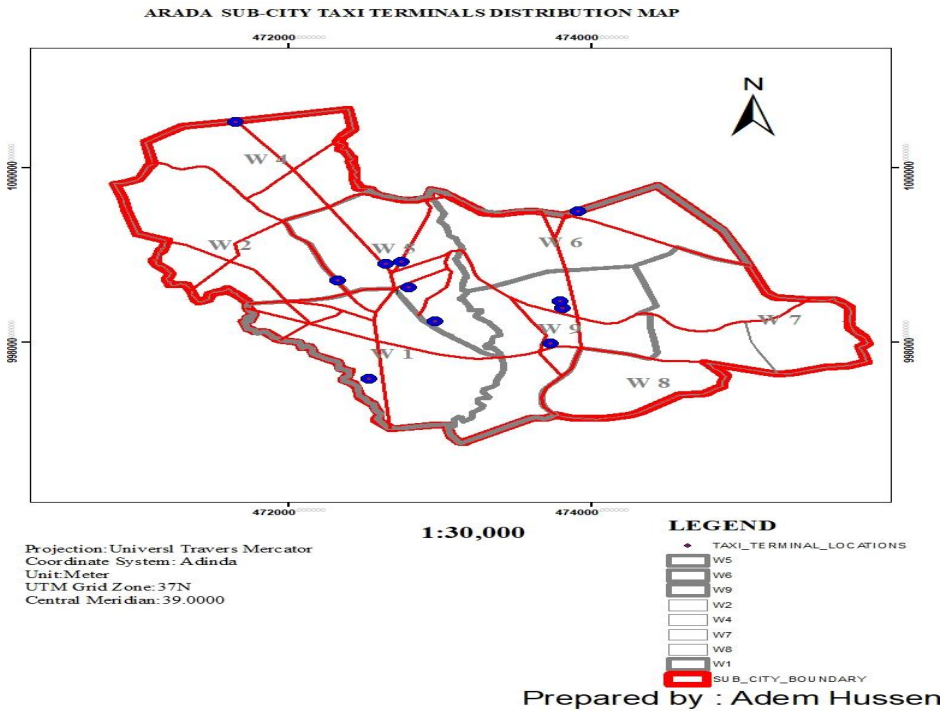


Figure 7. Structural plan main road network in Arada sub-city.

- Land use data: Gather information about land use in the region AAAMPS (residential, commercial, industrial) to contextualize terminal locations.

Figure: SP land use provision of the study area

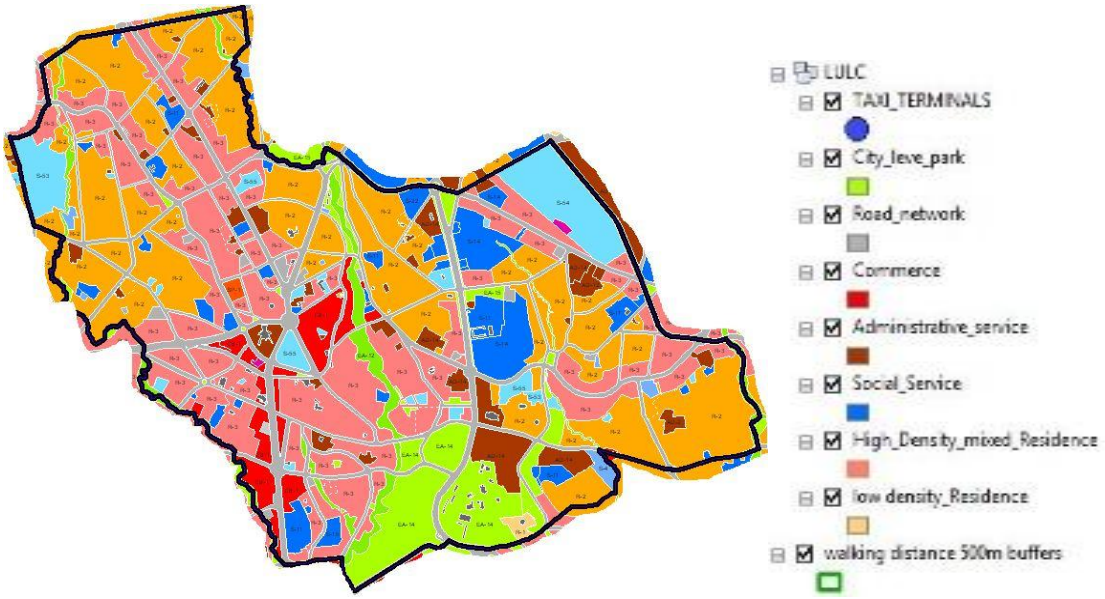


Figure 8 : Land use Structural plan provision of the Arada Sub City.

Source: Addis Ababa Structural plan summary report (2017-2027)

- Demographic data: collect population density and relevant demographic information to analyze equity in access.

Table 4: Demographic data population of Arada sub city

Sub city	Total population			Area	Remark
Arada	Female	male	Total		In 2023
	141,373	163,237	304,610	950 hectares	

Source: Central statistical Agency CSA (2023)

3.5.2. Secondary data collection

- Geographic information Systems (GIS): Utilize GIS to analyze spatial data related to the locations of taxi terminals. This may include overlaying maps of demographic data, transportation infrastructure, and urban land use.
- Public Transport Data: access transportation department data that includes the location of taxi terminals, routes, and schedules to analyze connectivity with other transport modes.
- Census Data: use demographic and socio-economic data from national census records to assess the population density and characteristics surrounding taxi terminal locations.
- Existing Research and literature review: review existing studies, reports, and academic articles focusing on taxi services, urban mobility, and transport accessibility.
- Satellite Imagery: -High resolution satellite imagery will be sourced from platforms such as Landsat, sentinel, or commercial providers, these images will support the assessment of taxi terminal patterns, boundaries verification, and spatial analysis.

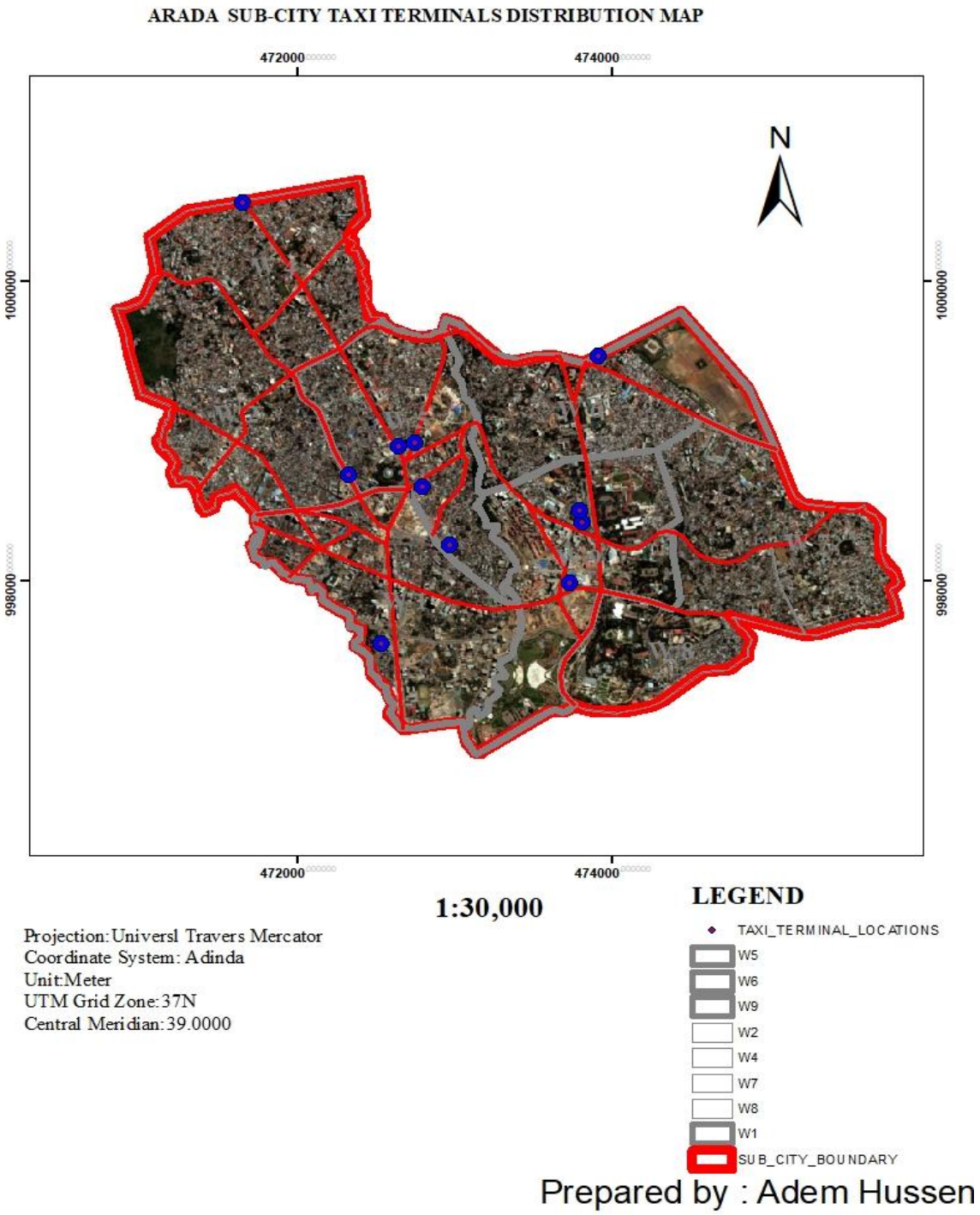


Figure 9: Digital Orthophoto of the study area captured in 2014.

3.6. Materials and Software

In this study, different materials and software tools, such as hardware's and software's were used to achieve the objectives of the study as indicated table

Table 5. List of materials and software used in the study.

Type	Name/description	Purpose/for
software	ArcGIS10.8	Spatial analysis, map creation, service area modeling
software	Google Earth pro	Satellite imagery analysis, based map referencing
hardware	Handheld GPS	Terminal location mapping and coordinate recording
documents	Urban transport policy report, municipal plans	Secondary data for context and comparison
software	Microsoft Excel	Data organization, attribute table creation

3.7. Sample size determination

The data collected to analysis to this thesis is collected from different stake holders in different data collection techniques using surveys, interviews and observational techniques, which werw adapted to both quantitative and qualitative insights into the accessibility and functioning of the terminals.

the summary of the stakeholders and data collection techniques is summarized bellow

Table 6: Sample Population

Target population	Arada sub-city residence and transport service providers
Specific population	passengers
Sample	Transport service providers and pick hours transport users like private and public employees, students and others

The total population expected to use the public taxi terminals is taken as 51606 from the total population of the sub city this figure is taken from Arada Sub - City transport Authority (AACTA). Base on the total population the sample size is determined bellow

In Arada Sub-City does not have formal taxi owner association, the existing network of approximately 340 minibus taxies remains a cornerstone of urban transport.

$$\text{Sample size} = Z^2 \times P \times \frac{(1-P)}{M^2}$$

Where,

S = sample size for infinite population

Z = Z score

P = population proportion (Assumed as 50% or 0.5)

M = Margin of error

Note: Z score is determined based on the confidence level.

Confidence Level	Z-score
80%	1.28
85%	1.44
90%	1.65
95%	1.96
99%	2.58

Table 1 Confidence level

No of population = 51,606

Confidence level = 95%

Standard deviation = .5, and

Margin of error = +/- 5%.

Based on the above the calculated sample size is:

$S= ((1.96)^2 \times 5(0.5))/ (0.05)^2 =$ **384**

Sampling Techniques

Woreda Selection

Stratified Sampling: -Arada Sub-City was first stratified into different categories based on factors such as population density, transportation needs, and infrastructure quality. These categories helped identify woredas with varying levels of access to taxi services and different infrastructure challenges. Woredas with high and low transportation demand were included to ensure a balanced representation

Random Selection within Strata: After stratifying the woredas, a random sampling method was applied within each Strata to select 3-5 woredas that best represented the range of urban conditions in Arada. This random selection ensured that no bias was introduced in the process, and all areas had an equal chance of being included.

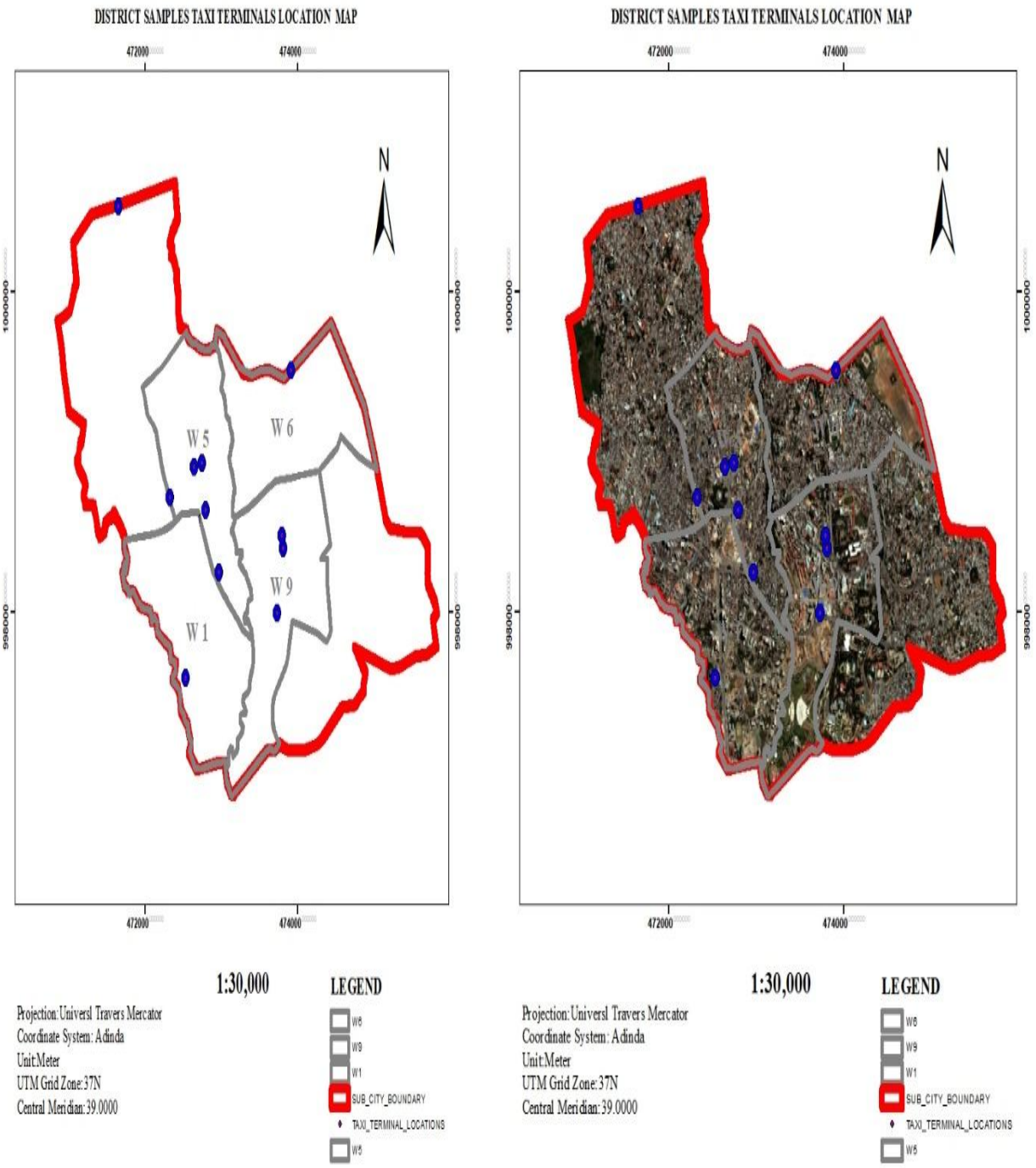
Taxi Terminal Selection:

Once the woredas were selected, random sampling was again applied to identify specific taxi terminals within those woredas. The following criteria were used for terminal selection:

- Geographical Spread: Terminals located in both central and peripheral areas of the woredas were selected to account for geographic disparities in service delivery.
- Type of Terminal: A mix of formal and informal terminals was included to understand how the lack of infrastructure or regulatory frameworks affects accessibility and service quality.

Sampling Size: The number of participants (taxi drivers, passengers, and terminal staff) was calculated using a sample size formula, ensuring statistical validity while balancing practical constraints like time and resources. For passenger interviews, a systematic random sampling technique was applied at selected taxi terminals to ensure diverse representation of passengers across different times of day and days of the week.

Quantitative and qualitative sampling: To ensure a comprehensive and representative analysis of the spatial distribution and accessibility of taxi terminals in Arada Sub-City, the sampling framework needs to address both the spatial and demographic variability of the study area. The proposed framework should combine both quantitative and qualitative sampling method to gather comprehensive data. The study will focus on four sample district(woredas) that are woreda 1, woreda 5, woreda 6, woreda 9, within the Arada sub-city.



(a) (b)

Figure 10. Taxi terminals selected for the data collection (a)woredas Existing taxi terminals. (b) in sample woredas, overlaid on 2014 orthophoto

3.8. Methods of Data Collection

Data collection, data management, and data integration form the core components of the analytical framework for evaluating the spatial distribution and accessibility of taxi terminals are essential parts of the analyzing the spatial distribution and accessibility of taxi terminals. these processes are critical to ensuring the accuracy, consistency, ad relevance of the analysis, ultimately enabling evidence-based planning and policy interventions. Geurs & van wee, (2004)

Data collection is very much dependent on the intended use of the data. It is obvious that the level of detail and the depth needed for the collected data varies according to the hierarchical level of decisions that need to be made. although all decision-makink levels are undisputedly part of the overall transport infrastructure process. Data collection requirements have to specifically consider how the collected information is going to be used at the various management decision levels. Data need for supporting strategic, network, or project level are significantly different in terms of degree of detail and required accuracy. Nemmers, C. (1997).

The methods used for the collection for analyze the spatial distribution and accessibility of taxi terminals data include:

3.8.1. Geospatial data;

Geospatial data is data that includes geographic positioning (latitude and longitude) and often stored in the form of:

- Coordinates
- Maps
- Layers in Geographic information system (GIS)
- Satellite imagery
- Digital Orthophoto

Table 7: Types of Geospatial Data for Taxi Terminal Analysis

Type of Geospatial data	Description	Example use
Point Data	Specific location represented by coordinates (e.g., taxi terminals)	Mapping taxi terminal's locations
Line Data	Represent transport routes (road. Taxi routes, walkways)	Route network analysis
Polygon Data	Represent areas (e.g., neighborhoods administrative zone)	Analyzing terminal service coverage
Raster Data	Grid-based data such as satellite images or heatmaps	Land use analysis. Population density overlays

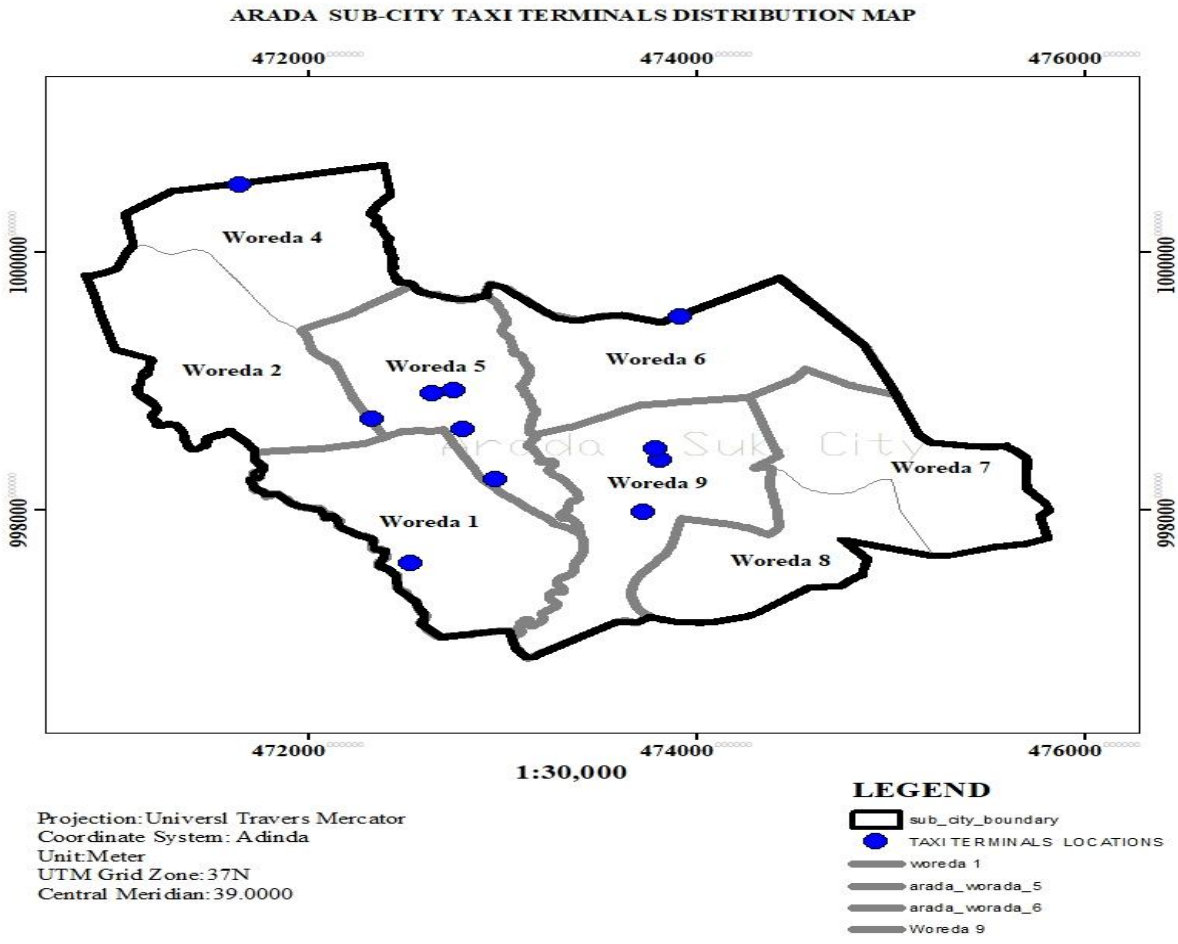


Figure 11. The distribution of taxi terminals in Arada Sub City in relation to woredas

The details of data used in this study are shown in table 8.

Table 8: Data and Data Source

Data	Data Type	Data Sources	purpose
City and sub city boundary	shapefile	Addis Ababa city plan commission (AACPC)	
GPS points	Shape file	Field surveying	To locate the existing location of taxi terminals
Road network	Shape file/AutoCAD	Addis Ababa City Road Authority	For road network analysis
Land use and parcel data	Shape file/AutoCAD	Addis Ababa City Plan Commission (AACPC)	
Population data	Excel	Central Statistical Agency (CSA)	
Image data	Image	Google Earth Pro	
Digital Orthophoto	Image	City Administration	To digitize road networks
Questionnaires		researchers	To assess the user's satisfaction

3.8.2 Field observation

To analyze the spatial distribution and accessibility of taxi terminals, the researcher to directly observe and record real time conditions and activities at selected taxi terminals. Observed include traffic flow, commuter behavior, waiting time, safety measures, and physical condition of terminal infrastructure. observations were conducted systematically using an observation checklist. The researcher visited the sites at diff time of the day (morning, afternoon, and evening) to capture temporal variation in terminal usage and performance.

3.8.3 Surveys and questionnaires

To gather Quantitative and qualitative data from taxi users and operators and terminal staff regarding the accessibility, efficiency, safety, and service quality of taxi terminals. Structured questionnaires were distributed at selected terminals, covering topics as travel frequency, satisfaction level, accessibility challenges, waiting times, and suggestions for improvement.

3.8.4 Document Review

To collect existing documents and reports related to transport infrastructure in arada sub city different secondary data sources are use such as government publication, Addis Ababa city urban planning documents, transport policy papers, previous research studies, and statistical data from relevant institutions. To identify historical trends, policy frameworks, and infrastructural gaps in the transport system.

These data collection techniques will provide a comprehensive understanding of the spatial distribution and accessibility of taxi terminals in Arada Sub City, capturing quantitative data for statistical analysis and qualitative insights for a deeper understanding of the issues and potential solutions.

Table 9. Data collection technique

Respondent's stakeholders	Data collection technique
Addis Ababa city transport authority	Interview
Public transport users/taxi	Questioner
Taxi drivers	Interview

3.8.5 Data Management

Once the data have been acquired by one or more of the above-described methods and technologies they are stored in various formats and storage media. data formats include; paper format, electronic databases, and geo-referenced database systems (such as Geographic Information Systems, GIS).

3.8.6 Data Integration

Spatial (geographic) and non-spatial data are often collected at different times, by different entities, using various methods, and stored in diverse formats and media. As a result, there is a critical need for data integration. This process is essential for transforming raw the data into meaningful information that can support decision making at the various organizational levels. For Transportation agencies must organize the available data into suitable forms for applications at the different organizational levels of decision making. This venture presents a big challenge, as data integration is far from easy to implement (Flinch and Briyant,2006).

According to the Federal Highway Administration (FHWA, (2001 (b)), there are two primary approaches to data integration: the fused database model and the interoperable databases model. In the first case the integration strategy leads to the creation of one database that contains all integrated data; in the second case existing or newly created databases are linked together and the integration of the data is achieved with the use of queries that provide a view of the linked data. The choice among the two integration strategies depends on many factors and is clearly a judgment call for the agency officials.

The key factors must be considered when selecting a data integration strategy. These include:

- The intended use of the integrated data (by whom and for what purpose);
- The characteristics of the already existing databases/information systems;
- The volume and type of the involved.
- The availability of technology infrastructure.
- The resource and technical skills allocated to the integration process, and the organizational structure-including departmental responsibilities and data requirements are critical considerations that influence the feasibility and effectiveness of the chosen integration approach.

One of the most effective platforms for transportation data integration is location. Because nearly all transportation assets, activities, and infrastructure are tied to specific geographic locations, spatial data serve as a common reference point for integration. For example, various

state department of transportation (DOT) offices of the US have used GIS and other geospatial tools for data integration (Flinch et al,2004). GIS software and related functionalities can alternatively be incorporated in the databases as external software that enhances the analytical and reporting capabilities of the system. FHWA, (2001) (f)).

In addition to spatial tools, standardization of data definitions and formats plays a crucial role in achieving effective integration. A standard data dictionary or global standard for data definition, representation, storage and communication could be of vital help to the effort of data integration, regardless of the integration strategy implemented. However, agencies often face challenges identified by agencies that have tried to develop and implement data standards and that have attempted to converting existing or legacy data in to these new formats. These challenges include reaching consensus on suitable data formats, establishing common data models, and managing the technical and institutional complexities associated with system migration. In the case of this study, integrating spatial data (such as the location of taxi terminals) with non-spatial data (such as land use, population density, and user feedback) is essential for analyzing both the distribution and accessibility of taxi services in Arada Sub-City Utilizing GIS as the integration platform allows the various data layers to be overlaid and analyzed in a unified framework, offering insight that are critical for urban mobility planning and infrastructure development.

3.9 Methods Data Analysis

This study will analyze the spatial distribution and accessibility of taxi terminals in Arada sub-city using Geospatial and Accessibility Analysis techniques. these methods are essential for identifying spatial patterns, evaluating service coverage, and detecting potential gaps in taxi terminal infrastructure. Accordingly, this section outlines the data processing and analysis methods employed to achieve the objectives of this study.

3.9.1 Spatial Concentration

This section examines the spatial concentration of taxi terminals across different woredas(districts) within Arada sub-city, the aim is to assess inequality of service provision among the woredas. To achieve this, the distribution of taxi terminals was analyzed in relation to the population distribution across the area. the Location Quotient (LQ) method as proposed by Jahan & Oda [20] was employed. The LQ method quantifies how the number of taxi terminals in each woredas compares to the overall sub-city. Offering a measure of relative concentration. specifically, it allows for benchmarking and identifying areas with ether an over-or under concentration of taxi terminals relative to their population size.

The Location Quotient was calculated using Equation.1, which provides a standardized measure to support the spatial localization analysis.

$$LQ = \frac{\left(\frac{n}{p}\right)}{\left(\frac{N}{P}\right)} \qquad (1)$$

Where:

n = number of taxi terminals in a specific woreda.

p = population of the specific woreda

N = Total number of taxi terminals in the sub-city

P = Total population of the Sub-city.

- LQ > 1 the concentration of taxi terminals in woreda exceeds that of the sub-city as whole.

- LQ = 1, the concentration of taxi terminals in the woreda is proportional to the population of the woreda relative to the whole sub city of Arada.
- LQ < 1, The woreda has fewer taxi terminals than expected based on its population relative to the entire sub -city.

3.9.2 Spatial Distribution pattern

Geospatial Analysis**:** the analysis of the spatial distribution of taxi stations in Arada Sub-City was conducted using various secondary data sources. These included geographic coordinates (latitude and longitude) of taxi terminals, Woreda(administrative) Boundaries, spatial Weights matrix: neighbors based on geographic proximity population density, land use data, and gas station locations. To ensure accuracy and determination of the coordinates of taxi station and gas station were accomplished verified using Google Earth pro. Following this, the data were transformed into Geographic information systems (GIS) formats using ArcGIS10.8, incorporating both spatial (coordinate) data and attribute information. After the transformation, imported into the ARCGIS 10.8 Software for further analysis of spatial distribution patterns.

Land use data: land use data for Arada Sub-City, were obtained from Addis Ababa city plan and development Bureau. to effectively analyze this data, the entropy model, introduced by Zhang et al. (2012) was employed. This model facilitated the calculation of the land use mix index for each of the eight administrative districts(woredas) in Arada Sub -City, helping to assess the diversity of land use within each area. using GIS Spatial analysis tools such as buffer analysis, and overlay analysis, relationships between taxi station distribution and other spatial factors like land use, population density, and proximity to service facilities were examined. This allowed for a comprehensive understanding of how various elements influence the location and density of taxi stations within the Sub-city.

Data Preprocessing: Preprocessing of taxi terminals data is critical to effectively analyze the spatial distribution and accessibility of taxi terminals, leading to data-drive insights and informed decision-making. These preprocessing steps, including Attribute Value: analyze the number of taxi terminals per neighborhood, Spatial Weights Matrix, clean data: ensure data accuracy and coherence: remove duplicates, fill missing values, and standardize format. Integrate data: combine geospatial and demographic datasets into a single GIS layer for analysis.

Spatial Statistics: spatial Auto correlation

The study will analyze the spatial distribution and accessibility of taxi terminals in Arada Sub-City using Geospatial and Descriptive Spatial statistics.by applying statistical tests to measure spatial autocorrelation. to identify significant spatial patterns. Spatial statistical tests were applied, focusing on the concept of spatial autocorrelation. a valuable tool for investigating the spatial connections between the positions of taxi stations by applying LISA analysis. LISA statistics break down global spatial patterns into local patterns, providing into how a particular spatial phenomenon is distributed across space, whether it's geographically clustered or dispersed. LISA is typically based on the Moran's I Statistic, but it is applied at a local level rather than globally. It involves computing a spatially weighted average for each location and comparing it. Spatial Autocorrelation: use spatial Autocorrelation (Moran" s I, local indicators of Spatial Association-LISA) to determine if the spatial relationships at specific locations of taxi terminals is random or clustered

The formula for Moran's I is a spatial statistic used to measure the degree of spatial autocorrelation in a dataset. calculated using the formula:

$$I_i = \frac{(x_i - \bar{x}) \sum_j w_{ij}(x_j - \bar{x})}{S_0}$$

Where:

Ii = Local Moran's I for location

Xi = Attribute value at location I,

S = Standard deviation of the attribute values across all location

Wij = Spatial weight between location I and j

Interpreting Result

Interpreting the clusters and outliers computed by Local Moran's I for each woredas districts.

Interpretation:

- I < 0: Indicates a tendency toward dispersion (negative spatial autocorrelation)
- I = 0: Implies complete spatial randomness (no autocorrelation)

- I > 0: Suggests clustering (positive spatial autocorrelation)

Statistical significance (z-scores and p-values) the LISA cluster maps. These maps highlights areas where spatial clustering is statistically significant based on local Moran's statistics. While a p value is a common threshold for significance, when conducting spatial statistics, you 'll often find significant results at p=0.05 so it is good to look at the results for more restrictive p-values. Z-score measures how many standard deviations a data point (or a sample statistic) is away from the mean of the distribution or datasets.

Formula for Z-score:

$$Z = \frac{X - \mu}{\sigma}$$

Where:

X is the observed value (e.g., sample mean or data point

μ is the population mean (or hypothesized mean)

σ is the standard deviation of the population

interpretation of Z-score:

- Z = 0: The observed value is exactly at the mean of the distribution.
- Z > 0: The observed value is above the mean.
- Z < 0: The observed value is below the mean.

Large Z-Scores (e.g., > 2 or < -2) indicate that the observed value is far from the mean, suggesting that it is unusual or unlikely under the null hypothesis. P-value: the p-value is the probability of obtaining a result at least as extreme as the one observed, if the p-value is smaller than the significance level (usually 0.05), we reject the null hypothesis and conclude the result is statistically significant. If the p-value is larger, we fail to reject the null hypothesis.

Mapping and Visualization

Using a geographic Information System (GIS), such as ArcGIS can visualize the results: cluster map. ArcMap: first examine the data generally to determine if median in taxi terminal is clustered or dispersed in Arada sub -city, then you will run local statistical test to see where clusters exist. you used the Moran's I tests in Geoda and will use the Getis-Ord tests in ArcMap.

Creating a spatial Weights matrix using this tool: **spatial Statistics>Modeling>spatial relationships>Generate spatial weights Matrix.**

3.9.3 Spatial Accessibility Analysis

In this study, accessibility to taxi terminals is evaluated based on walking distance, which is a commonly used and practical measure in urban transport planning. The threshold for accessibility was defined as 500 meters, which represents approximately a 10 -15-minute walk for the average pedestrian under normal conditions. This bench mark aligns with global standards used in transport and urban planning studies, where a 400- 500-meter distance is considered the maximum acceptable walking distance to access public transport facilities (Litman,2021).

This threshold was applied during the service area (buffer) analysis using GIS tools o delineate the areas within a 500-meter radius around each taxi terminals. Areas falling outside this buffer zone were identified as underserved or having poor accessibility, forming the basis for spatial equity assessments and recommendations for new terminal locations.

Justification Based on Planning Standards

- **World Bank** and **UN-Habitat** recommend ≤500m as acceptable walking distance to access public transport in cities
- Ethiopian urban planning directives emphasize walkable access within 5–10 minutes (approx. 300–500m)
- Literature supports shorter thresholds for disadvantaged or mobility-limited populations (Parker & McMillan, 2018)

Accessibility analysis is a powerful tool for planners, to assess how mobility measures enable people to travel to various destinations, by using accessibility analysis, planners get deep understanding of what works, and what are the barriers to better connectivity.

Network Analysis: Routing and service Areas: use network analysis tools to create service areas around taxi terminals. Analyze accessibility based on road networks, can construct a spatial weights matrix based on road network using the Generate Network spatial weights tool. Travel

time Analysis: calculate the travel time from various point in the study area to the nearest taxi terminal using network distance

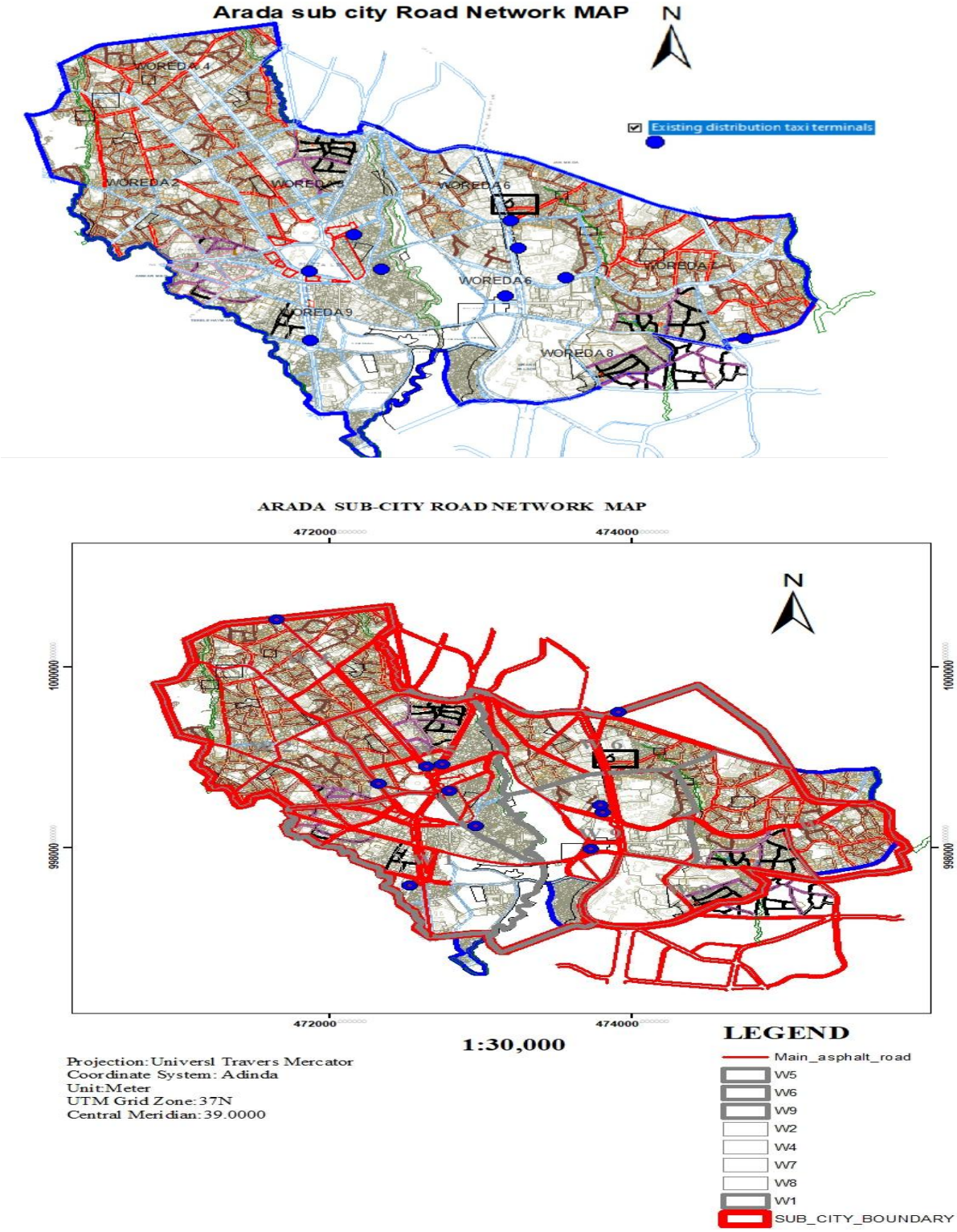


Figure 12. :-Road network and structural plan road by hierachy

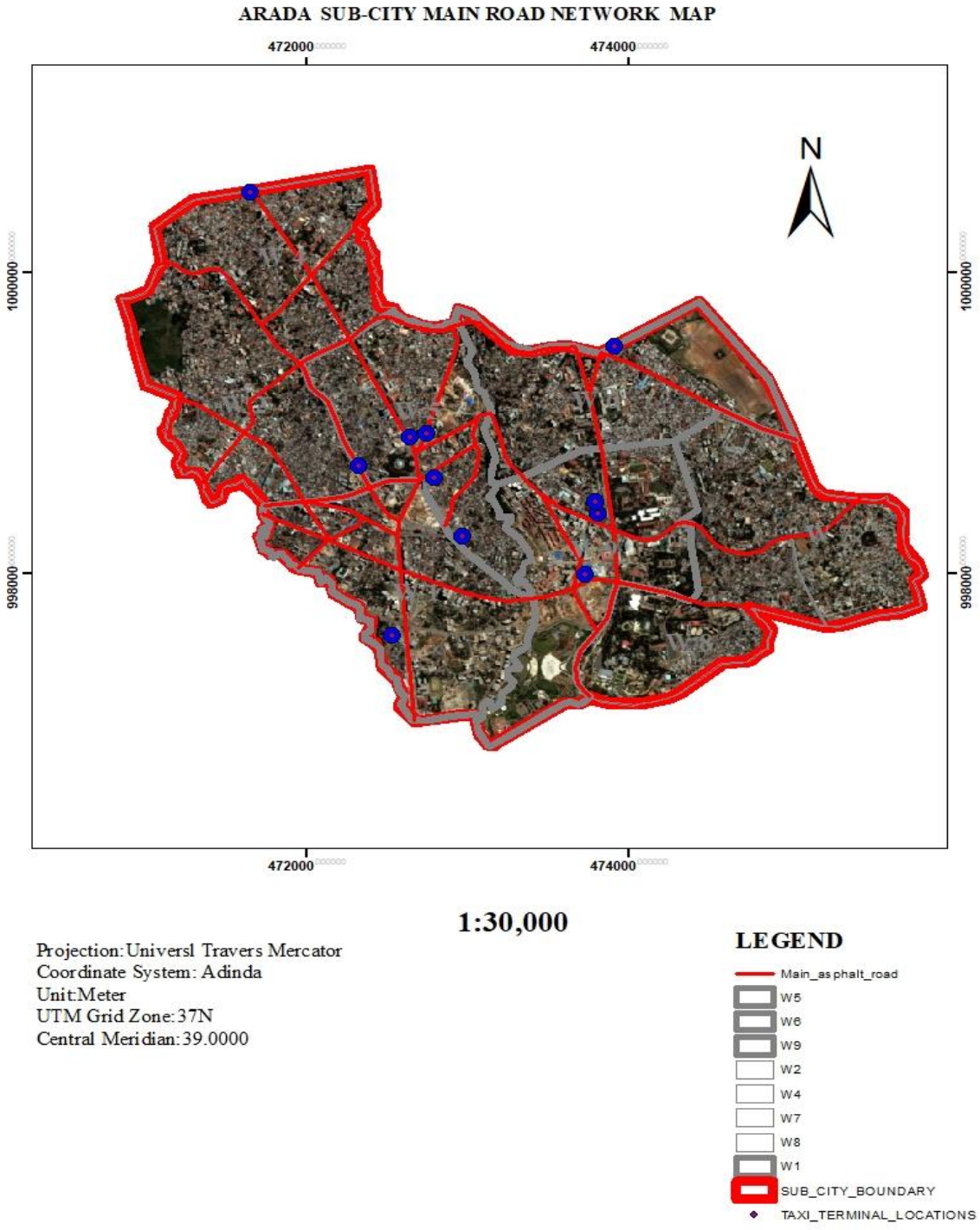


Figure 13. Spatial distribution of taxi terminals in Arada Sub -City, overlaid on 2014 and with the main road network.

3.10 Privacy

In the data collection process, the privacy and confidentiality of all respondents were strictly respected, from different acts such as recording or photographing individuals in a way that could compromise their personal privacy.

3.11 Respect for Diversity

Public taxi terminals are diverse spaces that serve people from various backgrounds. To ensure inclusivity, the research was conducted in a way that respected and represented all segments of the population, with sensitivity to differences in age, gender, socioeconomic status, and ability.

3.12 Transparent Communication

I try to communicate the purpose and goals of the research were clearly communicated to the public and authorities to ensure transparency, build trust, and support informed participation.

3.13 Research Design

The Research design is the structured blueprint that guides the systematic conducting scientific studies. It outlines the overall strategy for data collection, analysis, and interpretation. Ensuring In the Study to address the research Question and objectives.

This study employs a quantitative research approach, as it involves the use of geospatial and descriptive statistical Techniques to map, visualize, and analyze the spatial distribution and accessibility of taxi terminals in Arada Sub-City. The Quantitative methodology is particularly well-suited for this type of spatial analysis, as it allows for precise measurements of the spatial autocorrelation of taxi terminal clustering, spatial analysis, and predictive modeling, ensuring objective and replicability of results.

The use of Geographic Information Systems (GIS) Software are used as the core tool to conduct spatial mapping, proximity analysis, and service area delineation.in addition to GIS-based analysis the study applies the Local Indicators of Spatial Association (LISA) to examine spatial autocorrelation and identify statistically significant clusters and spatial outliers of taxi terminal location. These spatial statistics provide insight into whether the distribution of terminals is random, dispersed, or clustered.

Moreover, the location Quotient (LQ) method is employed to assess the relative concentration of taxi terminals across different areas within the sub-city.

In general, procedure used to carry out this study are summarized in fig.14.below.

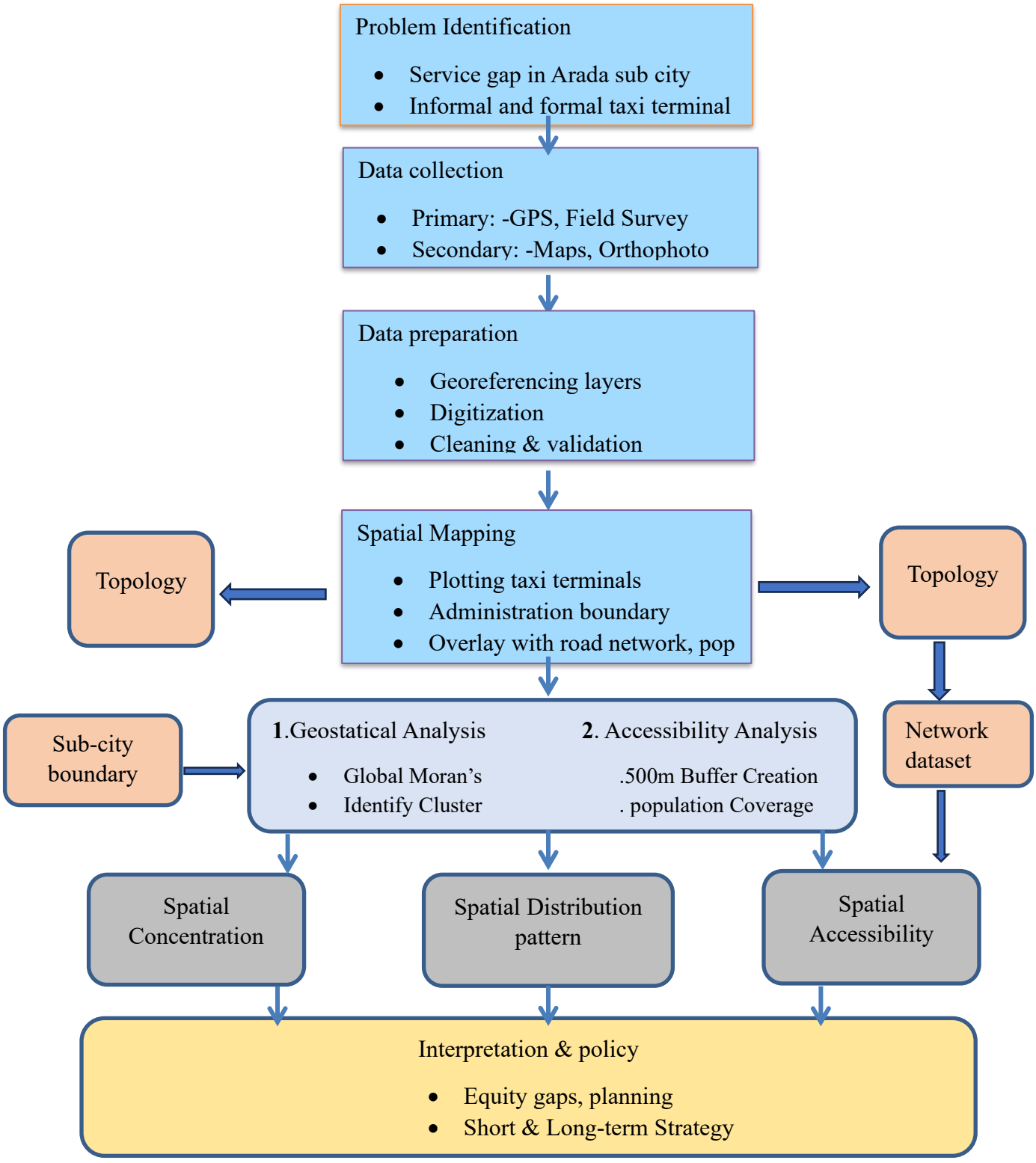


Figure 14. Flowchart of the Methodology used in the study

CHAPTER 4. RESULTS AND DISCUSSIONS

4.1. General

This chapter Presents the results and analysis of the information's gathered from questionnaire, desk study, and interviews, structured according to the research objective and questions. The transport infrastructure particularly the distribution patterns of taxi terminals in Arada Sub City, Addis Ababa.

The desk study involved reviewing existing data sources such as urban transport policies, planning documents, maps, satellite imagery, aerial photographs academic literature, and government reports relevant to public transport systems. These materials helped establish a contextual foundation for understanding the current status of taxi terminal distribution and planning practices.

In addition, semi-structured interviews were conducted with key information's from urban transport planning public service administration, and local governance, these interviews enriched the research findings by providing practical insights and validating the observations from both the desk review, interpretation and discussions would be presented on the basis of the findings and limitations observed.

4.2 The Spatial Concentration of Taxi Terminals

The compute value of spatial concentration measure using equation1. is shows in Table.10 alongside with the number of taxi terminal and population is respective woredas. overall, at sub city scale, the proportion of taxi terminals to the total population is about 1 to 27690 which is not acceptable as compared to the standard set by the government (1:5000) in terms of population. Service provision at the woreda level remains below the required standard in all five woredas. this includes three woredas that currently have no taxi terminals, However, there is significant disparity in the distribution of taxi terminals across the woredas. woreda 5 hosts the highest number of terminals, in contrast to woreda1,2,7, and 8, which lack any form of taxi terminal infrastructure. this uneven distribution highlights critical gaps in local transport development.

In addition, the computed LQ values demonstrate that the concentration of taxi terminals across the woredas in the sub-city significantly. the results reveal three district categories of service distribution:(Under normal Concentration, self-sufficient, and above normal concentration) with the maximum value (3.79) in woreda 5 and woreda 9 indicating a substantial over concentration of taxi terminals relative to their population sizes. In contrast to other woredas 5 and 9 exhibit LQ values exceeding 1, indicating a relative higher concentration of taxi terminals. The remaining woredas show LQ values significantly below 1.0, reflecting a lower-than-average provision of transport infrastructure, suggesting an under provision of taxi terminals in those areas.

These findings suggest that the spatial distribution of taxi terminals is un even with considerable disparity in accessibility and service provision among the woredas.

Further, to investigate the relationship between population and number of taxi terminals, the Pearson product-moment correlation coefficient was applied to the data, the result depicted in figure 16. shows that there is imbalance relationship between the number of taxi terminals and population of woredas. The line of best fit is linear, while the coefficient of correlation (r) in this case 0.2163 is significant at 0.05(95%) significant level.

The coefficient of determination(R-square) value of 0.0468 indicates that about 4.68 % of the variance in the number of taxi terminals is moderately influenced by the population size of the respective woredas.

Table 10. Spatial Concentration of taxi terminals in woredas of Arada sub city as of 2023

Woreda Name	Pop. No	No of Taxi terminals	LQ	Remark
Woreda 1	44482	**1**	0.62	
Woreda 2	42027	0	0	
Woreda 4	34662	**1**	0.79	
Woreda 5	36504	5	3.79	

Woreda 6	40493	1	0.68	
Woreda 7	34049	0	0	
Woreda 8	28525	0	0	
Woreda 9	43868	3	1.89	
Total	**304610**	**11**		

LQ, Location equation

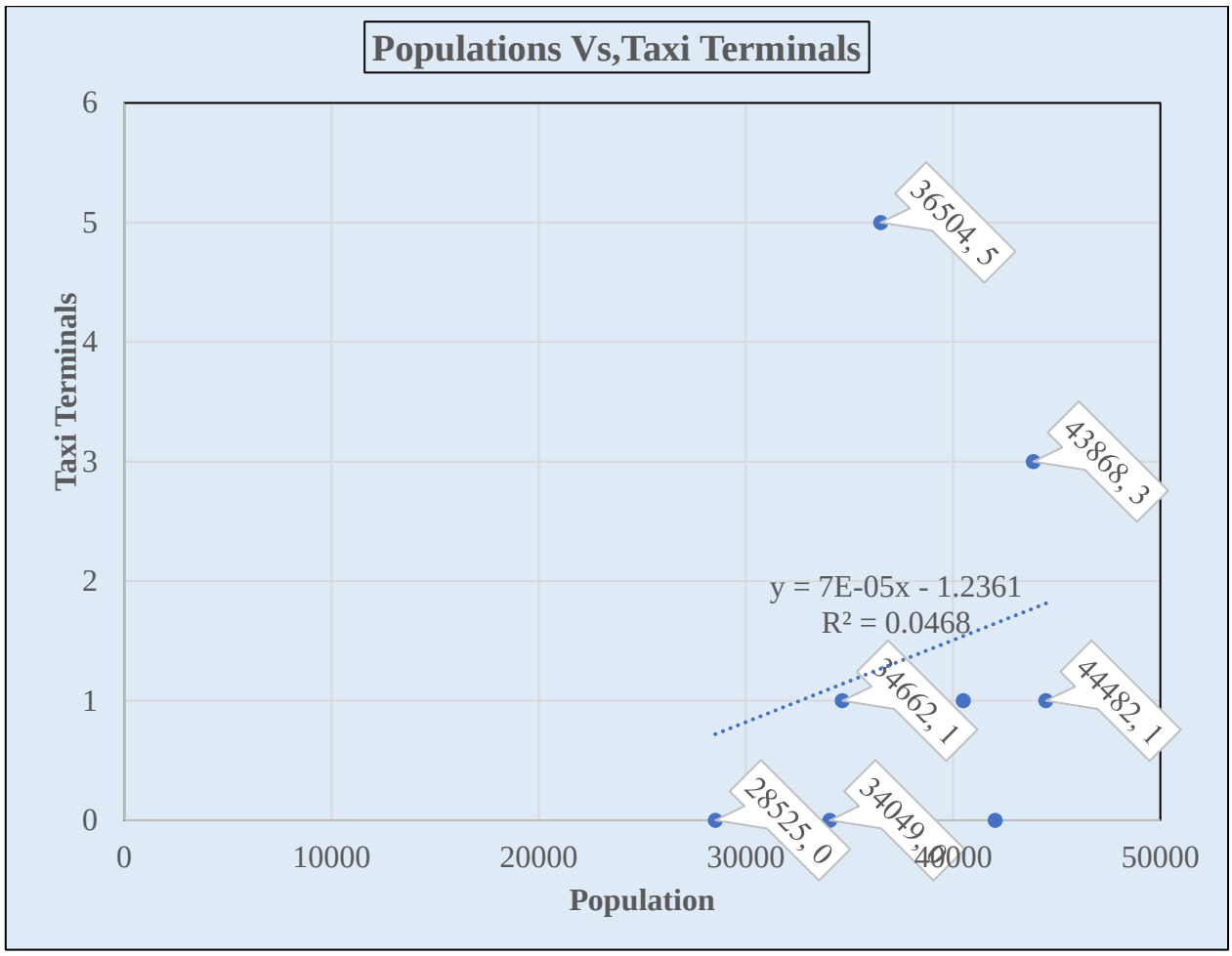


Figure 15. correlation between the number of population and Taxi Terminals in Arada sub-city as of 2023

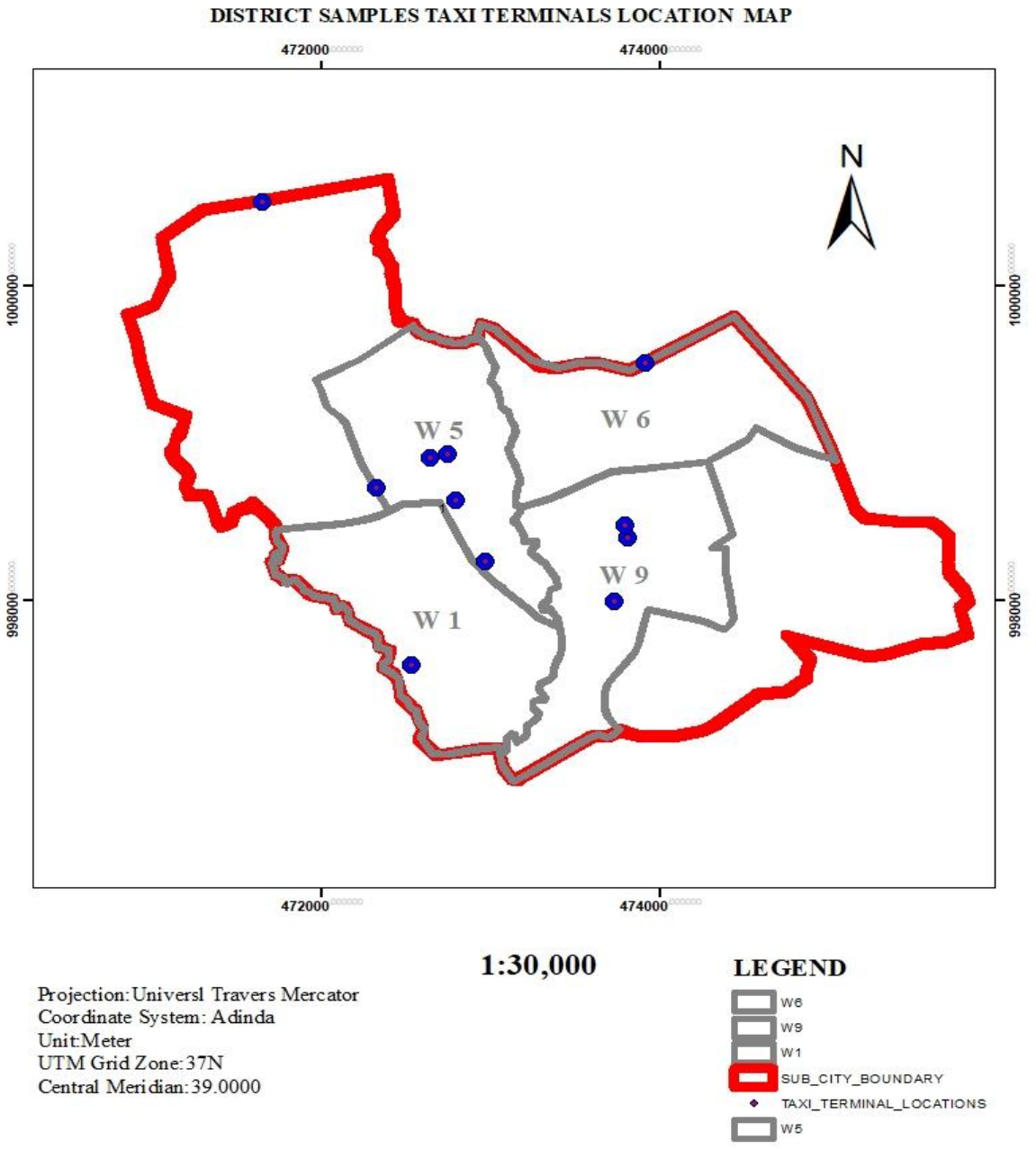


Figure 16: The Taxi Stations Distribution of taxi stations According to selected woredas

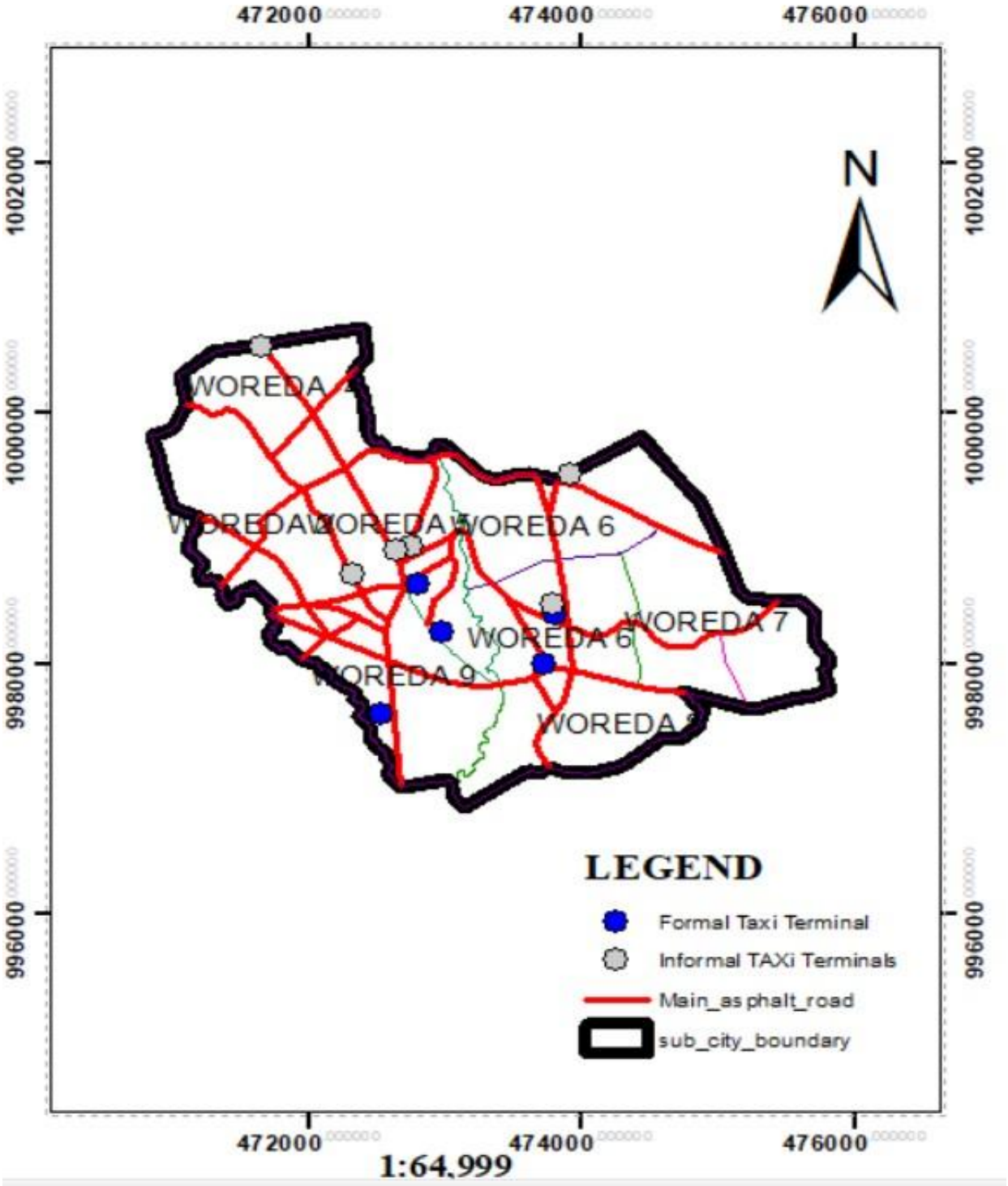


Figure 17: The location of formal and informal taxi stations in Arada Sub City.

4.3. Spatial Distribution pattern

The spatial distribution of taxi terminals in Arada Sub City was Analyzed using GIS based mapping techniques. The result is illustrated in figure 20, which demonstrates that the majority of taxi terminals are concentrated in the central part of the Sub City, particularly around major commercial and transport corridor such as Arat Killo, Piazza, and Merkato.

The spatial pattern reflects that the demand-driven nature of taxi services, as these areas attract high passenger volumes due to their economic, administrative, and cultural significance.

Based on spatial clustering analysis, the following conclusions can be drawn:

Clustered Areas (Hotspots)

- woreda 9 and 5 are identified as High-high clusters, indicated in red colored on the map. These are zones where high taxi terminal density and surrounded by by similar woredas. These are hot spots where taxi services are more concentrated, suggesting that these areas may already have adequate coverage.

Outlier Area:

- Woreda 6, appears as a low-high outlier, marked in orange. This indicate that relatively lower internal densities are adjacent to high density areas. This may suggest a spillover effect or potential inefficiency in taxi terminals placement in this woreda.

Low - Density Areas (Cold spots):

- woreda 1, fall within a low cluster, show in blue. This signifies areas with low taxi terminals density, surrounded by other similarly underserved woredas. These cold spots are indicative of spatial service gaps and highlight the need for targeted terminal development to enhance equity in accessibility

The spatial analysis reveals a clear imbalance in the distribution of taxi terminals, favoring central commercial zones while leaving residential and peripheral areas underserved. This pattern underscores the need for strategic redistribution of terminals and the integration of accessibility criteria into future planning efforts.

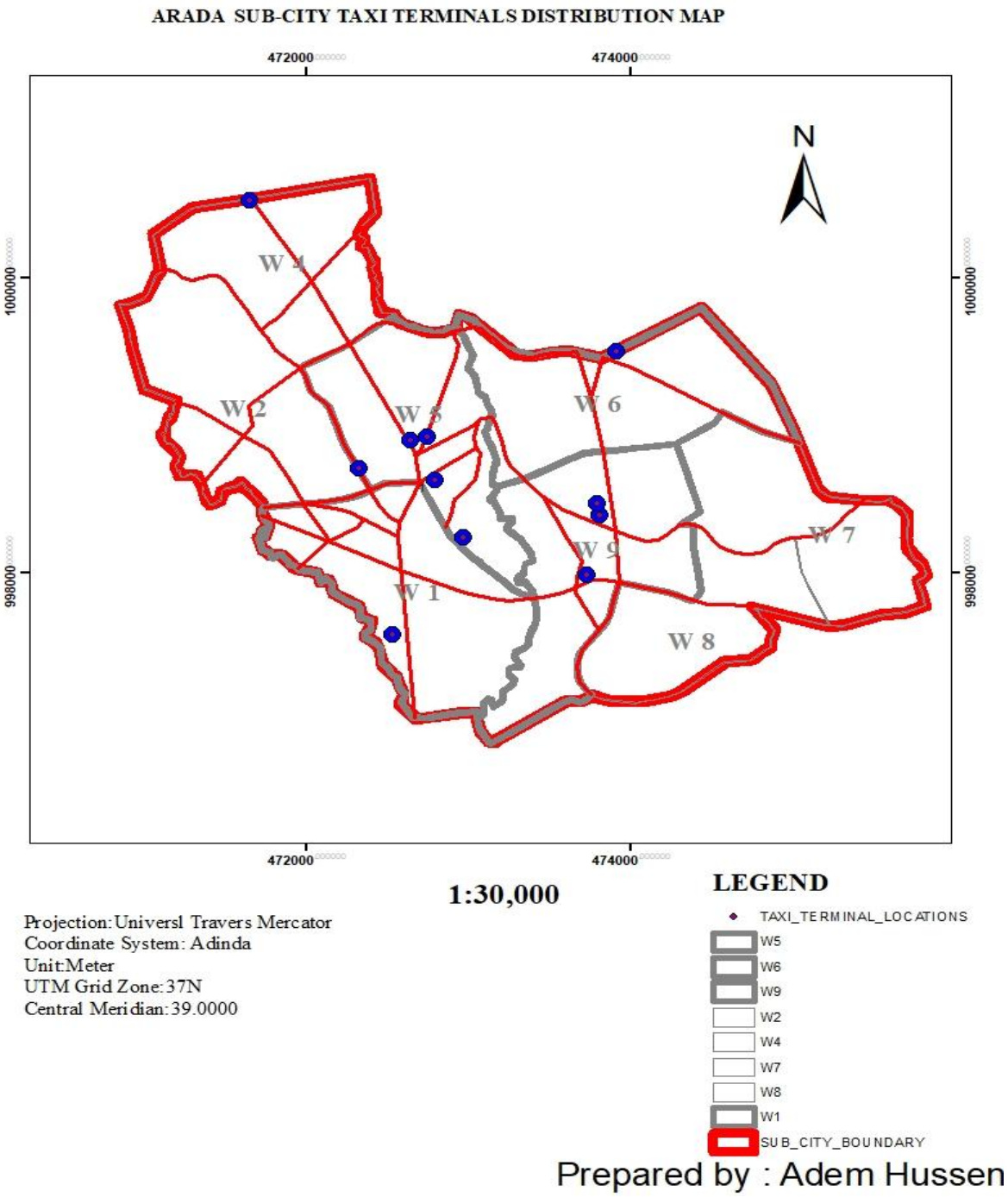


Figure 18. Spatial distribution of Taxi Terminal in Arada Sub City with overlaid with the main road

Spatial autocorrelation global Moran's I showing Analysis result of taxi terminal in Arada sub city. This dispersed pattern, with Moran's I =-0.36 and a-p-value<0.05, implies that taxi terminals are not spatially clustered and may be unevenly distributed across woredas.

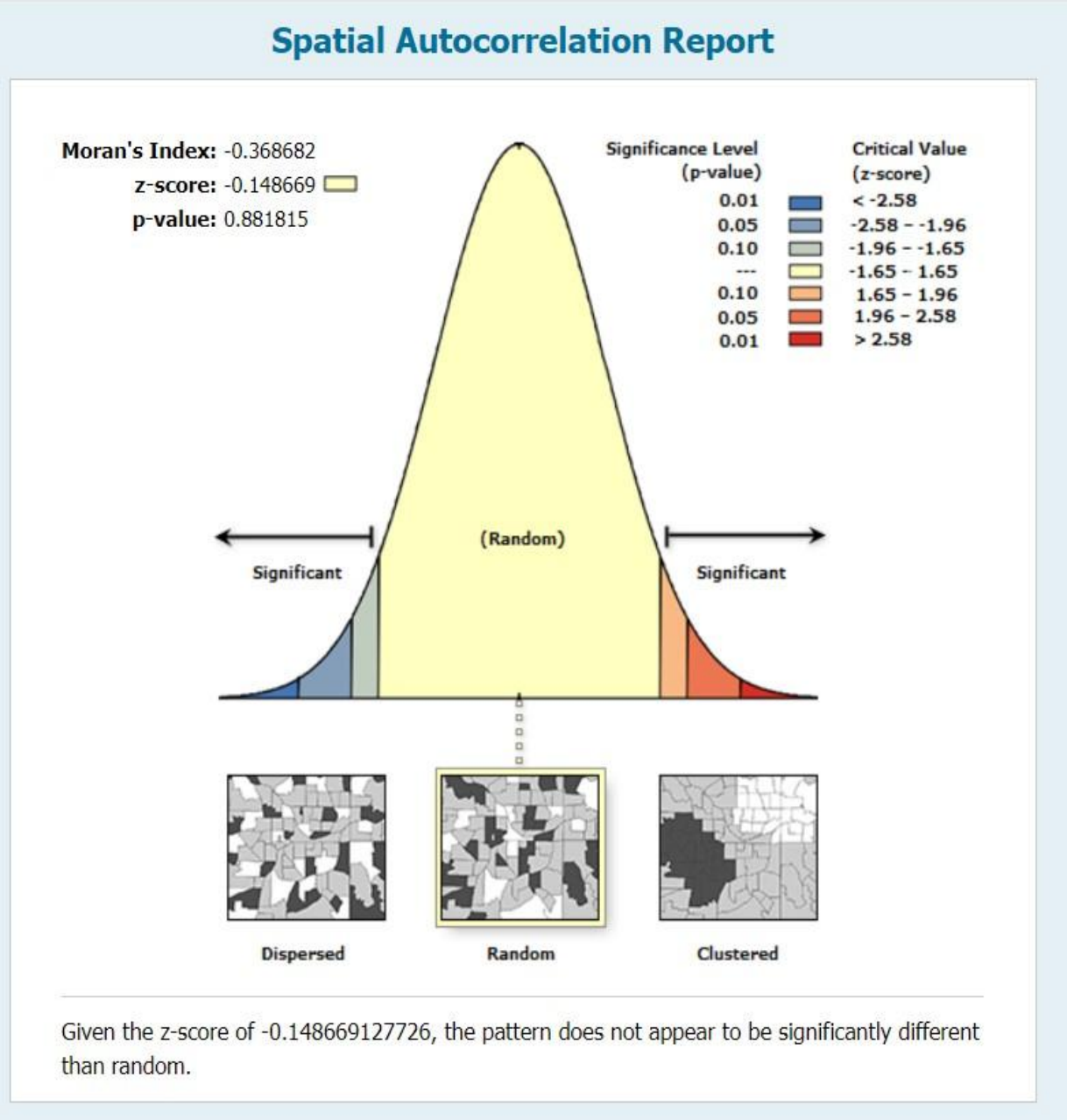


Figure 19: Moran's, I scatter plot showing spatial dispersion of taxi terminals in arada sub-city (Moran's I=-.36, P<0.05).

Global Moran's I Summary

Moran's Index:	-0.368682
Expected Index:	-0.333333
Variance:	0.056532
z-score:	-0.148669
p-value:	0.881815

Dataset Information

Input Feature Class:	Export_Output_7
Input Field:	TAXI TERMINAL PROPORTION.CSV.P_VALUE_PROPORTION
Conceptualization:	INVERSE_DISTANCE
Distance Method:	EUCLIDEAN
Row Standardization:	False
Distance Threshold:	1360.2490 Meters
Weights Matrix File:	None
Selection Set:	False

Figure 20. Global Moranis I analysis result summary report.

The spatial dispersion of taxi terminals in Arada sub-city, as indicated by the Global Moran's I result (-0.36, $p<0.05$), suggests that taxi terminals in Arada sub city reveals a statistically significant pattern of scattered terminal location rather than concentration.

4.4. Spatial Accessibility of Taxi terminal

The result of spatial accessibility analysis of taxi terminals is depicted in fig4.3. accessibility was computed using a 500-meter buffer around each selected taxi terminal, representing a reasonable walking distance based on urban mobility standards. The map shows concentric buffer zones overlaid on the Arada sub-city base map, highlighting areas that fall within and beyond the service radius. The analysis reveals that while central neigh hoods are generally well-served, significant accessibility gaps exist in the outer and informal areas of the sub-city, leaving portions o the population particularly vulnerable groups outside the 500-meter threshold.

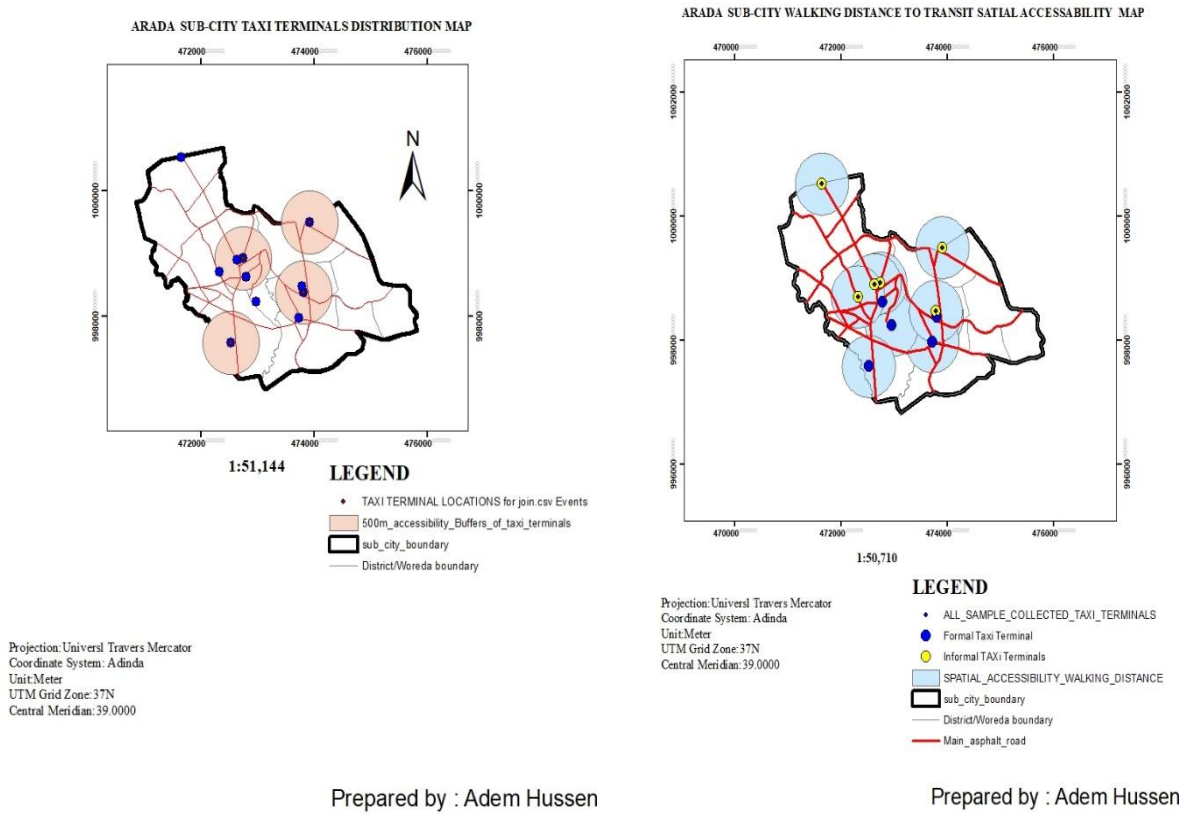


Figure 21: Spatial Accessibility of taxi terminals Walking distance to transit

4.5. Discussion

This study used a variety of analysis techniques, the Impact of clustering or Dispersion on service Delivery in Arada Sub-City was taxi terminals distribution it was highly uneven. The spatial analysis conducted in Arada Sub City revealed a notable clustering of taxi terminals around central commercial zones such as Pissa, Mercato, and Arat killo, while peripheral areas remain underserved. This was confirmed by the Global Moran's I result of -0.36($p<0.05$), which indicates a negative autocorrelation suggesting an uneven, non-random distribution of taxi terminals.

This clustering of taxi terminals has led to high service frequency and convenience in the urban core, benefiting areas with high economic activity. however, it also contributes to localized traffic congestion, terminal overcrowding, and inefficiencies in taxi queuing and loading. In contrast, the outer zones of Arada Sub City, especially residential neighborhoods with growing populations, experience reduced accessibility, requiring long walking distances often exceeding the 500-meter acceptable threshold for users to reach the nearest terminal.

Such spatial disparities limit inclusive mobility, particularly for low-income residents and vulnerable groups who rely heavily on informal transport systems. The absence of well distributed terminals restricts their access to jobs, services, and social opportunities. moreover, the current terminal layout lacks integration with land use planning, leading to reactive, demand-driven clustering rather than proactive service provision.

The finding underscores the need for strategic redistribution of taxi terminals using GIS-based multi-criteria evaluation to improve coverage, efficiency, and equity, redistributing terminals to underserved areas and improving road access to existing terminals. Addressing this imbalance will enhance the performance of the entire transport system in Arada Sub City and support broader smart city development goals.

This spatial analysis would guide decision makers in improving taxi service distribution, ensuring that under-served neighborhoods receive better access while avoiding an overconcentration of taxis in areas that are already well-served.

Spatial Factors Influencing the Clustering of Taxi Terminals

Several Spatial factors contribute to the clustering of taxi terminals in specific areas of Arada Sub City:

1. **Proximity to Commercial Hus**: Central commercial areas such as piazza and Merkato naturally attract more taxi terminals due to the higher volume of foot traffic and demand for transportation. These hubs are focal points for both local residents and tourists, making them prime locations for taxi services.
2. **Population Density:** Areas with higher population density, particularly in the central regions, tend to have more taxi terminals. Higher numbers of potential passengers increase the demand for taxis, which leads to the clustering of terminals in these areas.
3. **Public Infrastructure and transport Link:** Areas with better urban infrastructure, including bus stations, main roads, and pedestrian- friendly streets, tend to have a higher concentration of taxi terminals. Thes areas often designed to facilitate the flow of passengers, king them more accessible and convenient for taxi services to operate.
4. **Economic Activity:** The Clustering of taxi terminals near business districts and markets is a result of the high levels of economic activity. The presence of businesses, markets, and informal commerce crease continuous demand for transportation, encourage more taxi operators to congregate in these areas.
5. **Land use regulations and Zoning**: in some case local zoning regulations may either encourage or

CHAPTER 5. CONCLUTION AND RECOMMENDATIONS

5.1. Conclusion

This study examined the spatial distribution and accessibility of taxi terminals in Addis Ababa Arada sub city, using Geographic information system (GIS) and field observations. the findings revealed that the majority of taxi terminals are unevenly distributed across the sub city, with a significant concentration in central districts such as Aratkillo, Piazza, Mercato, and Addisu Gebeya, while peripheral areas remain underserved. many terminals operate informally and lack basic amenities such as shelters, lighting, and signage, furthermore, accessibility analysis showed that a considerable portion of the urban population, particularly in rapidly growing residential zones, has limited access to well-functioning taxi terminals within a walkable distance. The lack of integration with other transport modes and the absence of planning frameworks for terminal location were also identified as major contributors to inefficiencies and user dissatisfaction.

The result highlights the urgent need for a comprehensive spatial and policy-based approach to taxi terminal planning in Arada sub city. this includes not only improving existing terminal infrastructure and management but also leveraging spatial data and GIS tools to guide the placement of new terminals that better serve the population's mobility needs.

5.2. Recommendation

Based on the output this research, the following recommendations have been forwarded for use by pertinent policy makers at Arada sub city as well at government level.

- Solving the problem of GIS based analysis on spatial distribution and accessibility of taxi terminals is important for promoting equitable access to transportation, GIS plays an important role in decision making process of taxi terminal transport infrastructure service in Arada sub city to be easier, accurate and time effective.
- Data collection methods should be done based on international experience, individual management system data need and standard automated equipment's need to be used to analyze the severity of the deterioration.

- A centralized, GIS-based database should be developed to store and track this over time, enabling transport authorities to monitor infrastructure performance, identify service gaps, and informed decision regarding upgrades or relocation.
- Increasing the coverage of public taxi terminal services be expanded, particularly in peripheral or underserved neighborhoods with limited accessibility.
- Top-level management in the organization and municipal transport agencies should be committed in support and consistent commitment to transport infrastructure planning, particularly in the case of taxi terminals.
- Up-to-date condition of transport infrastructure at taxi terminals should be systematically surveyed and inventoried. And data base should be created to know the history of terminal distributions across the urban landscape.

5.2.1 Strategic Interventions for taxi terminals:

Short-Term Actionable steps:

In the short term, quick and cost -effective improvements can be made by installing essential amenities according to Cervero and Golub (2007), such as shelters, lighting, benches, and signage at informal or under -equipped taxi terminals. enhancing operational management through improved queuing and routing practices can further streamline terminal efficacy.

Long-Term Strategic Intervention:

In the long-term strategic interventions in sustainable urban mobility prioritize the redesign of taxi terminals to support seamless multimodal connectivity. Unlike short-term solutions, these strategies involve structural and, policy-level transformations that integrate taxi services into the wider transportation network. Strategic interventions often involve infrastructure redevelopment, fillet electrification, and data-drive planning tools to align with smart city goals (Litman,2019). these interventions require coordinated governance, interventions require coordinated governance, investment, and regulatory support, but are essential for creating resilient and inclusive transport systems.

5.2.2 Recommended sites for taxi Terminals in Arada Sub-City

The recommended sites Based on the Spatial Analysis and field observations, five key locations have been identified as recommended sites for the development or enhancement of taxi terminals in Arada Sub-City, Addis Ababa. These sites were selected based on their strategic importance, population density, current lack of service coverage, and proximity to key social and economic functions. The goal is to improve accessibility, reduce congestion in over-served areas, and promote equitable transport services across the sub-city.

These new taxi terminals will serve as to improve accessibility, reduce congestion in over served areas, and promote equitable transport services between various parts of the sub-city and improving transport options for underserved communities. these terminals will serve as both origin and destination points and enhance connectivity for underserved communities.

1. Addisu Gebeya Area
2. Addis Ketema (long distance bus station)
3. Kebena Area
4. Gojam Berenada
5. Pastor Square

Addisu Gebeya Area:

Addisu Gebeya is a central transportation hub that serves as a connection point for four major transportation routes. This makes its one of the busiest areas in Arada Sub City with high foot traffic and vehicle congestion. The high mobility in this area leads to frequent taxi jams and delays, affecting the efficiency of public transportation.

Despite its importance as a transportation focal point, Addisu Gebeya currently lacks a dedicated transportation terminal for taxis, which results in disorganized queuing and inefficient service.

Establishing a well-planned taxi terminal here will provide a structured and safe environment.

Addis Ketema (Long-Distance Bus Station

Addis ketema is already a well-known commercial area and is home to the major long-distance bus station that connects Addis Ababa with other parts of Ethiopia. With its centrality and high passenger turnover, this area is a prime location or additional taxi terminals.

Currently, taxi services are highly concentrated in the core commercial zones, creating heavy traffic congestion and in efficient loading/unloading at the bus station. the establishment of a dedicated taxi terminal at Addis ketema will improve transportation coordination, ease passenger flow, and reduce waiting times for passengers traveling to and from the bus station.

Kebena Area

Kebena is a densely populated neighborhood with close proximity to schools, hospitals, and government institutions, despite its centrality and importance, the area lacks a structural taxi terminal. establishing a terminal in kebena would provide safer, more efficient transport access for residents, students, and commuters, while reducing congestion caused by informal taxi stops. This site would also serve as a vital last mile connector for surrounding institutions and residential zones.

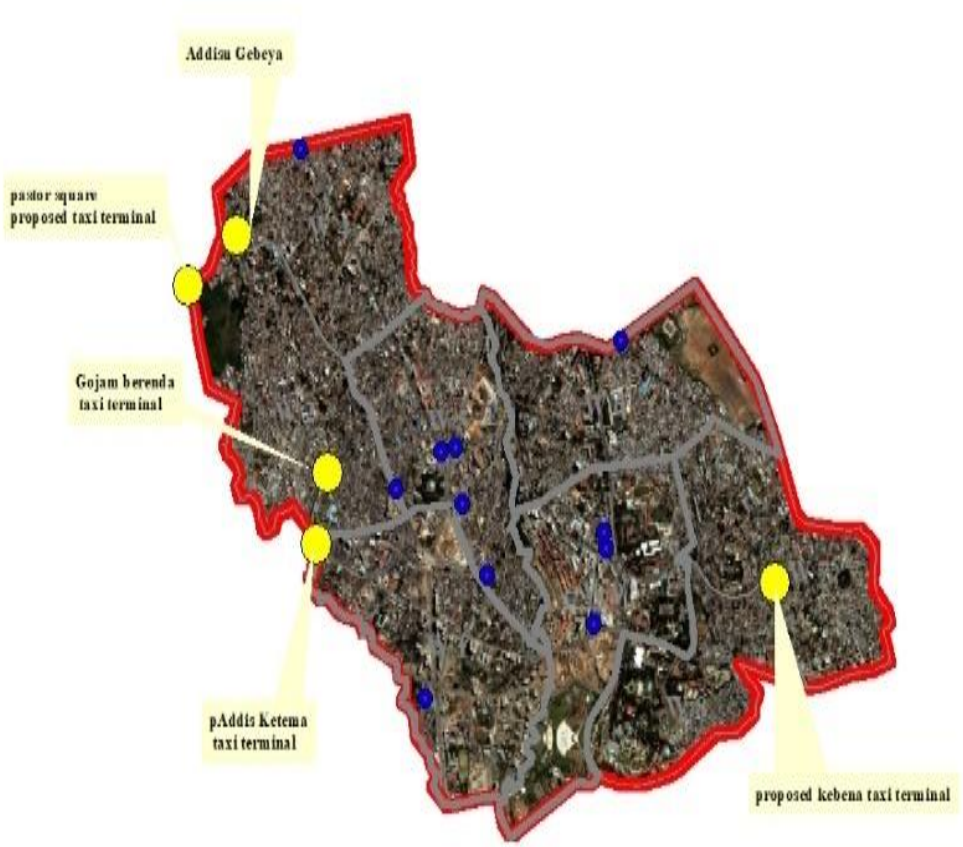
Gojam Berenda

Gojam Berenda is a transitional area between the more densely populated central zones and the suburban outskirts of Arada sub city. It is characterized by growing residential neighborhoods, increasing traffic, and an emerging commercial center. Daspit this, taxi access is limited, and residents often face long walking distances to the nearest terminals.

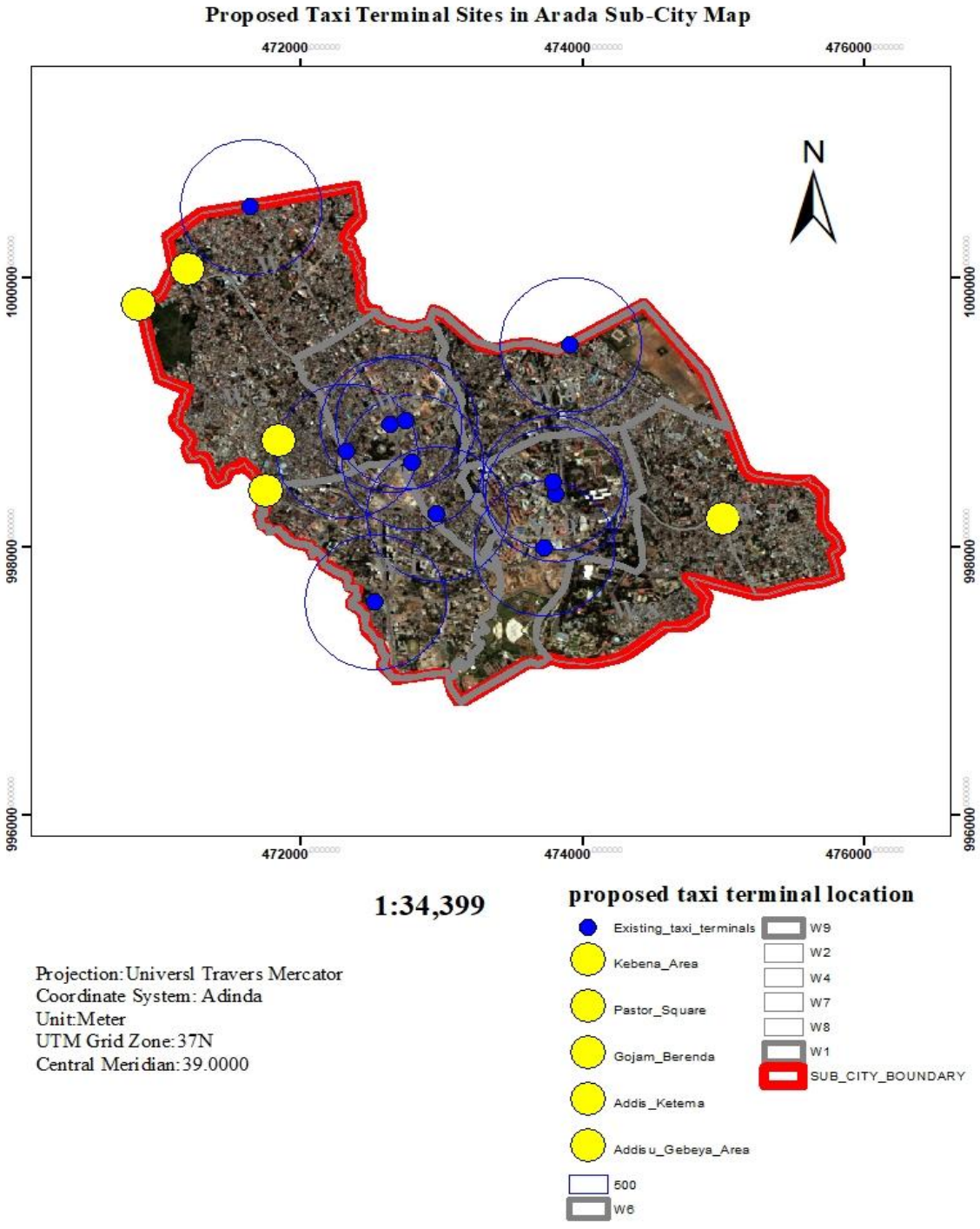
Pastor Square

Pastor Square is located in an area with a mix of commercial and residential zones and is known for being a major crossroads within Arada sub city. The square has a high concentration of pedestrian traffic due to the presence of shops, markets, and businesses. however, it currently lacks a dedicated taxi terminal, leading to disorganized taxi operations and delays.

A well-designed taxi terminal at pastor Square would not only improve passenger flow and reduce congestion but also enhance safety for passengers and taxi drivers alike.



(a) Existing and Proposed Taxi terminal's location in Arada Sub-City.



(b)500m buffer walking distance

Figure 22. (a) Proposed Taxi Terminal Sites (b) 500m buffer walking distance Arada Sub-City.

5.3. Importance and Limitation of the Study

There is an increasing global consensus that taxi terminals serves as an effective and practical tool for integrating urban design and transport planning, ultimately enhancing efficiency and spatial equity in terminal placement. however, the study on analyzing the spatial distribution and accessibility of taxi terminals in Arada Sub City, Addia Ababa reveals several limitations that may impact its findings and implications. These limitations include:

1. **Data gaps**: many urban taxi terminals, particularly in developing regions, operate without formal systems for data collection or record-keeping. Which can introduce bias limit the precision of analysis.
2. **Informality of terminals**: within Arada sub city, the widespread presence of taxi terminal presents a significant challenge. Numerous taxi terminals are not officially designated or regulated, resulting in spontaneous setups by drivers and passengers. This informality complicates efforts to create standardized assessments or apply formal planning methodologies
3. **Accessibility threshold assumptions**: the use of a fixed 500-meter buffer for accessibility may oversimplify real world conditions such as terrain difficulty, safety, or walkability. Which can vary widely across neighborhoods.
4. **Representation of stakeholders**: due: to informal nature of the terminals, taxi drivers, passengers, and other key stakeholders such as a local authorities or transport planner are not always easy to engage in formal data collection processes
5. **Rapid urban changes**: in Addis Ababa, particularly in Arada Sub-City, pose a change for longitudinal studies. With ongoing urbanization, informal settlements, and infrastructure development, the characteristics of taxi terminals and their operations can change rapidly.

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