GEO-SPATIAL TECHNOLOGIES FOR INFRASTRUCTURE ACCESSIBILITY IN SMART CITY DEVELOPMENT: CASE OF BISHOFTU CITY, OROMIA, ETHIOPIA

Eshetu Mekonen Gurmu

Thesis submitted to the Department of Architecture

College of Civil Engineering and Architecture (CoCEA),

Office of Graduate Studies

Adama Science and Technology University

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Adama, Ethiopia

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Under the Supervision of

Roba Gemechu (Phd)

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DECLARATION

I hereby declare that this research entitled "**Geo-Spatial Technologies for Infrastructure Accessibility in Smart City Development: Case of Bishoftu City, Oromia, Ethiopia"** is my original work. That is, it has not been submitted to any other university. All materials used for this thesis have been duly acknowledged through citation.

Eshetu Mekonen	______________________	_______________
Name of student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read this thesis entitled "**Geo-Spatial Technologies for Infrastructure Accessibility in Smart City Development: Case of Bishoftu City, Oromia, Ethiopia"** prepared under my guidance by **Eshetu Mekonen**. Therefore, I recommend the submission to the department following the applicable procedures.

Roba Gemechu (PhD)	__________________	__________________
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APPROVAL PAGE OF THE THESIS

I, the advisor of this thesis entitled "**Geo-Spatial Technologies for Infrastructure Accessibility in Smart City Development: Case of Bishoftu City, Oromia, Ethiopia"** and developed by **Eshetu Mekonen** hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by **Eshetu Mekonen** have read and evaluated the thesis entitled "**Geo-Spatial Technologies for Infrastructure Accessibility in Smart City Development: Case of Bishoftu City, Oromia, Ethiopia"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted.

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LIST OF ABBREVIATION AND ACRONYMS

Abbreviation/Acronym	Full Form
ICT	Information and Communication Technology
IoT	Internet of Things
AI	Artificial Intelligence
GIS	Geographic Information System
GPS	Global Positioning System
SDG	Sustainable Development Goals
SCADA	Supervisory Control and Data Acquisition
CPS	Cyber-Physical System
API	Application Programming Interface
LBS	Location-Based Services
UAV	Unmanned Aerial Vehicle
5G	Fifth-Generation Wireless Technology
ITS	Intelligent Transportation Systems
UN-Habitat	United Nations Human Settlements Programme
IoE	Internet of Everything

ABSTRACT

Urban infrastructure is one of the strongest drivers for sustainable urban development and living standards in urbanizing towns like Bishoftu. Despite urbanization advancing very rapidly, most of the towns in Ethiopia lack uniform access to basic facilities. The objective of the analysis was to identify the extent in coverage and accessibility of the major urban infrastructure in Bishoftu City using the tool geo-spatial technology. Satellite images in high resolution, OpenStreetMap (OSM) data, and official infrastructure record data were principal sources of primary data for analysis. Preprocessing the data involved the digitizing the infrastructure layers (health center, road, school, water point) and cleaning the attribute table for consistency and geographic accuracy. Spatial analysis and network analysis were applied in GIS tools and accessibility models such as proximity analysis and service area mapping through road networks. The analysis revealed deep-rooted urban infrastructure disparities in delivery and availability in Bishoftu City. It revealed that the greater part of infrastructure facilities like schools, medical facilities, and road infrastructure is mostly in the center and western part of the city, while the residential peripheral areas, specifically the eastern and southeastern parts, remain mostly underdeveloped. Network analysis, in addition, revealed that up to 40% of the peripheral population is beyond 3 to 5 kilometers away from core facilities, with limited access through all-weather road networks and public transport. Overlay of the population density on the infrastructure layers provided an extreme mismatch between the availability of the service versus the population demand in high-growth peripheral areas. All these suggest the requirement for an equitable spatial strategy in infrastructure planning. The research foresees the application of geo-spatial technology in planning the urban area in the midst of the plans for data-informed, inclusive, and smart city master plans, filling gaps and anticipating the development of the city in advance. The research concludes that the distribution of infrastructure in Bishoftu compromises the uniformity in the availability of the same, posing threats towards inclusive urban development. Inferences drawn from the study, the paper suggests special infrastructure development in the under-developed areas, application of geo-spatial analysis in urban planning, and the implementation of smart city concepts towards punctual delivery of the same.

Keywords: Geo-spatial technology, Smart city, urban development, accessibility

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Urban development has entered a new era through smart cities which combine technology and data systems for raising the operational efficiency and sustainability of urban living spaces. The performance of urban services through information and communication technologies (ICT) stands as a core element of smart city development which includes transportation, energy, healthcare, water and waste management (Batty et al., 2012). Smart cities around the world serve as primary sources of innovation and economic growth especially when dealing with fast urban expansion and environmental issues and rising demands for infrastructure and public services (Chourabi et al., 2012). The expansion of cities makes it essential to guarantee fair access to infrastructure and services for all people because this is fundamental to reach smart urban development objectives.

The development of smart cities aims to enhance urban living conditions through the integration of advanced technology which improves the operational efficiency of essential systems and promotes environmental sustainability and social development. The integration of information and communication technologies in urban spaces allows cities to develop smart solutions for enhancing their essential systems which include transportation, healthcare, energy and waste management (Batty et al., 2012). Smart cities have established themselves as vital sources of economic growth and innovation worldwide because

To achieve effective smart city programs infrastructure accessibility serves as a vital success factor. Urban quality of life and economic opportunity improvement requires proper access to basic infrastructure elements including roads, schools, healthcare facilities and clean water. Spatial inequality along with poor service delivery and social exclusion stem from inaccessibility according to UN-Habitat (2020). The analysis of infrastructure service spatial distribution and accessibility holds essential importance to establish smart cities that combine technological advancement with social inclusiveness and spatial integration.

Urban planning and management now heavily depend on Geo-Spatial Technologies (GSTs) because they include Geographic Information Systems (GIS) and Remote Sensing (RS) and Global Positioning System (GPS). Through the integration of spatial data collection and analysis systems GSTs enable the visualization of spatial information which delivers crucial insights about land use patterns and infrastructure distribution and transportation systems and population changes (Longley et al., 2015). GIS technology provides urban planners with the capability to perform complex spatial analysis through which they create models for urban development and infrastructure evaluation and service delivery coverage (Yeh & Li, 1998). The implementation of GSTs provides the best results when identifying and resolving infrastructure deficiencies. These tools help urban planners by creating infrastructure maps which reveal accessibility trends so they can select underserved areas for service delivery system optimization (Ahmed et al., 2021). The functionality of GSTs extends to scenario analysis and simulations which helps decision-makers examine future development patterns and create sustainable urban expansion strategies.

The current urbanization rate in Ethiopia stands as one of the fastest among Sub-Saharan Africa countries. The rural nation of Ethiopia has converted into an urbanized country at an accelerated rate over the past two decades because of rural-to-urban migration and natural population growth alongside the administrative reclassification of rural regions into urban areas according to the World Bank in 2020. The urban population of Ethiopia expanded from 10.8 million in 2002 to 28 million in 2022 which transformed urban residents from 15% to 23% of the total population according to UN-Habitat 2020. The cities of Hawassa, Bahir Dar, Adama, and Dire Dawa have experienced both geographical and population growth. Hawassa experienced a population surge of 180% from 2007 to 2023 which demonstrates the severe strain placed on city infrastructure and administrative systems according to Woldegerima et al. 2018. The current urban growth rate indicates a path toward reaching 40% of the national population living in cities by 2040 according to data from CSA 2021.

Although urbanization in Ethiopia is rich in potential for economic growth and social advancement, it has, however, presented some issues, the most notable being in the area of infrastructure and public utilities. The most significant among the challenges is the absence of basic infrastructure such as roads, provision for water, sanitary facilities, electricity, and waste treatment systems, for instance. Poor planning for infrastructure in the large urban towns in Ethiopia is rampant, hence the disconnected provision of services and inefficiency in the running of urban towns (Fekade, 2019). In the urban towns that are rapidly increasing in population, infrastructure development falls behind the rates of increase in population, hence congestion, poor drainage, and limited access for the provision of clean water and electricity (UN-Habitat, 2020).

Furthermore, the lack of low-income housing has led to the proliferation of informal settlements, mainly in urban peripheries. Substandard living, insecure land ownership, and inadequate access to education, health, and waste disposal characterize informal settlements (Alemayehu & Alemu, 2021). Such settlements not only aggravate urban poverty but lead to enormous public health and environmental risks. Urban sprawl and unplanned development have further led to encroachment onto environmentally sensitive land such as wetlands and forests, leading to land degradation and climate hazard exposure (Teshome et al., 2020).

Pressure on current public services is yet another urgent issue. Schools, healthcare facilities, and public transport networks are being stretched by the increasing urban population, most times to provide below-par service delivery and access. Such issues of urban development need more active urban governance and investment in strong infrastructure networks. Geospatial technology like Remote Sensing and GIS integration into urban planning practice offers promising opportunities to tackle such challenges through enhancing data gathering, spatial analysis, and decision-making (Ahmed et al., 2021).

1.2. Statement of the Problem

Ethiopia is pursuing the intense urbanization of cities, but for Bishoftu and its likes, provision of good infrastructure on equal terms faces far greater impediments. Services such as roads, healthcare, schools, or water supply are relative in an uneven manner, especially between fast-growing localities on the one hand, and the long-established neighborhoods, on the other. Such pattern of development in residential neighborhoods in Bishoftu has not been complemented with an adequate level of infrastructure development, thereby engendering disparities in access to infrastructure and quality of life (Woldegerima et al., 2020). Generally, residents of outlying areas or informal settlements have to go for miles for reaching basic services, posing a disconnect in urban expansion and the provision of key services.

The accessibility gaps are indicative of the spatial inequality that describes an unfair favoritism of some neighborhoods, usually the richest centers, in infrastructure provision: the other neighborhoods remain underserved or even totally excluded (Teferi & Abraha, 2021). This, of course, also goes against the effort to promote inclusive urban development and is responsible for social and economic marginalization. With regard to Bishoftu, urban growth has become increasingly difficult to manage due to the absence of integrated and update spatial planning frameworks. With weak land management and weak regulation, informal settlements proliferate further, thereby complicating infrastructure expansion and delivery of some urban services (UN-Habitat, 2020). Traditional planning approaches based on outdated maps and fragmented datasets simply cannot predict and attempt to address such issues.

In increasing towns such as Bishoftu, city infrastructure is a key aspect in figuring out sustainable improvement and great of existence. Even with Ethiopia's speedy urbanization, many towns still struggle to offer equal get admission to to primary offerings. With the use of geospatial technology, this look at sought to evaluate the accessibility and spatial distribution of important urban infrastructure in Bishoftu City. The evaluation's important records resources had been government infrastructure statistics, OpenStreetMap records, and excessive-resolution satellite tv for pc imagery. Roads, schools, hospitals, and water stations have been a number of the infrastructure layers that have been digitized as a part of the information preprocessing system. Additionally, characteristic tables had been wiped clean to assure uniformity and spatial accuracy.

Moreover, the failure to incorporate spatial intelligence into infrastructure planning limits the city's ability to identify service gaps, prioritize high-need areas, and plan for future growth. Urban infrastructure is often developed reactively rather than proactively, resulting in short-term fixes instead of long-term, sustainable solutions (Ahmed et al., 2021). Given the availability of free and open-source geospatial tools and satellite imagery, this underutilization represents a critical missed opportunity for improving urban infrastructure delivery. Cities like Bishoftu could greatly benefit from embracing geo-spatial technologies to enhance decision-making, improve transparency, and foster more inclusive development.

Around the world, geo-spatial technologies have increasingly become central tools in urban infrastructure planning and monitoring. Countries such as India, Brazil, and China have made significant advances in integrating Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS) into the development of urban infrastructure (Kuffer et al., 2016). In India, GIS-based infrastructure mapping has improved the allocation of roads, water supply, and sanitation services in cities like Bangalore and Hyderabad (Mahalingam et al., 2013).

In Brazil, geo-spatial tools have been employed to address infrastructure disparities in informal settlements through participatory mapping and infrastructure audits (Menezes et al., 2020).

In developed nations, smart cities such as Singapore, Amsterdam, and Barcelona leverage real-time spatial data for dynamic traffic control, optimized utility management, and predictive infrastructure maintenance (Batty et al., 2012). These examples highlight how spatial data can enable evidence-based planning, reduce service delivery costs, and improve urban residents' quality of life. They also illustrate the importance of integrating institutional frameworks with technological infrastructure for successful geo-spatial implementation.

In Ethiopia, several studies have demonstrated the potential and growing application of geo-spatial technologies in urban and infrastructure planning. For example, Teferi and Abraha (2021) used GIS-based spatial analysis to evaluate disparities in urban infrastructure services in Bahir Dar, identifying clear patterns of inequity between inner-city and peri-urban areas. Similarly, Gebeyehu and Desta (2019) assessed the spatial distribution of schools and health services in Addis Ababa using GIS, revealing uneven accessibility and underscoring the need for spatial data integration into planning.

Despite such efforts, the use of geo-spatial technologies remains limited and largely academic in nature. Institutional adoption by urban planning offices is minimal, with most city administrations relying on manual or paper-based planning systems. A key challenge is the lack of trained personnel, budgetary constraints, and weak data-sharing policies across government departments (Alemayehu & Alemu, 2022). This has resulted in fragmented planning processes and uncoordinated infrastructure development across many Ethiopian urban centers.

Although Bishoftu is one of the fastest-growing secondary cities in Ethiopia and strategically located near Addis Ababa, it has received limited academic or policy attention in terms of geo-spatial infrastructure assessment. Urban growth in Bishoftu is rapid and uncoordinated, particularly along the city's peripheries, yet no comprehensive geo-spatial assessment has been conducted to evaluate accessibility to infrastructure such as roads, schools, and health facilities (Woldegerima et al., 2020). Existing urban development plans are often outdated, and spatial planning lacks integration with real-time data sources.

Thus, there is a pressing need to conduct a geo-spatial assessment of infrastructure accessibility in Bishoftu. Such research would fill a critical empirical gap, offer data-driven insights to planners, and align the city with Ethiopia's broader digital transformation and smart city ambitions.

1.3. Research objectives

1.3.1. General Objective

The general objective of this research is to assess the role of geo-spatial technologies in assessing infrastructure accessibility to support smart city development in the case of Bishoftu City.

1.3.2. Specific Objective

- To assess the spatial distribution of existing urban infrastructure in Bishoftu City using geo-spatial technologies.
- To evaluate the accessibility of key infrastructure services across different parts of the city through spatial and network analysis.
- To identify gaps and inequalities in infrastructure accessibility and propose geo-spatially informed strategies for improving equitable service delivery in the context of smart city development.

1.4. Research Questions

- What is the current spatial distribution of urban infrastructure in Bishoftu City as revealed through geo-spatial technologies?
- How accessible are key infrastructure services (e.g., roads, schools, health facilities) across different parts of Bishoftu City based on spatial and network analysis?
- What spatial gaps and inequalities exist in infrastructure accessibility, and how can geo-spatially informed strategies be used to improve equitable service delivery within the smart city development framework?

1.5. Significance of the study

One of the primary significances of geo-spatial technology in Bishoftu is its ability to provide detailed insights into land use patterns and urban infrastructure. By utilizing Geographic Information Systems (GIS) and remote sensing technologies, city planners can identify areas that require development or improvement. For instance, geo-spatial data can reveal underserved neighborhoods lacking essential services such as healthcare or transportation. This information enables planners to make informed decisions about where to allocate resources effectively, ensuring that all residents have access to necessary amenities.

The implementation of geo-spatial technology also supports economic growth by fostering an environment conducive to business development. Accurate mapping and location data can attract investments by providing potential investors with critical insights into market opportunities within Bishoftu. Furthermore, the digital addressing system **(eDAS)** recently inaugurated in Bishoftu enhances logistical efficiency for businesses by facilitating precise deliveries and improving customer service through accurate location identification.

1.6. Scope of the study

This research focuses on the integration of geospatial technology within smart city systems to enhance property taxation accuracy specifically within the context of Bishoftu City, Ethiopia. Geospatial technology used in this research encompasses tools and techniques used to collect, analyze, and visualize spatial data. This includes Geographic Information Systems (GIS), remote sensing, and Global positioning systems (GPS) technologies. These tools provide essential insights into urban planning by enabling stakeholders to understand spatial relationships and patterns within the city. The scope encompasses framing of how geospatial technology can integrate in smart city development and contribute to sustainable urban development in Bishoftu City.

1.7. Operational terms of definition

Church: A building used for Christian worship and related community activities, serving as a key religious and social institution (Smith, 2003).

Mosque: A place designated for Muslim worship, religious education, and communal gatherings, playing a central role in Islamic community life (Khan, 2011).

Administrative Buildings: Facilities housing governmental offices responsible for policy implementation, public administration, and provision of civic services (Healey, 2006).

Schools: Institutions offering formal education across primary, secondary, and higher levels, essential for human capital development (UNESCO, 2015).

Health Centers: Local healthcare facilities providing primary medical services including preventive care, diagnostics, and treatment (World Health Organization [WHO], 2010).

Community Centers: Public venues designed to support social, cultural, and recreational activities, fostering community engagement and social cohesion (Putnam, 2000).

Markets: Designated spaces or buildings for commercial exchange of goods and services, vital for local economies and livelihoods (Porter, 1995).

Parks and Recreational Facilities: Open public spaces and amenities that promote leisure, physical activity, and social interaction, contributing to urban well-being (Carmona et al., 2010).

Public Utilities: Infrastructure systems that provide essential services such as water, electricity, sanitation, and waste management, critical for urban functioning (Fay et al., 2015).

CHAPTER TWO

2. LITRATURE REVIEW

2.1. Theoretical literature review

2.1.1. Smart City Theory

The concept of a smart city has gained substantial attention in both academic and policy circles over the last two decades, emerging as a pathway toward sustainable urban development and improved quality of life for residents. While definitions vary, a commonly accepted description characterizes smart cities as urban areas that leverage information and communication technologies (ICTs) and other advanced technologies to enhance the efficiency of city operations, foster sustainable economic growth, and provide high-quality services to citizens (Batty et al., 2012; Nam & Pardo, 2011). In essence, a smart city integrates physical infrastructure, digital technologies, and human capital to create interconnected systems capable of real-time data collection, analysis, and informed decision-making (Hollands, 2008).

The key characteristics of smart cities include ubiquitous connectivity, intelligent infrastructure, data-driven governance, sustainable resource management, and citizen engagement (Caragliu, Del Bo, & Nijkamp, 2011). These elements enable smart cities to optimize urban service delivery, reduce environmental impact, and enhance urban resilience. Importantly, smart cities emphasize not only technological innovation but also social inclusivity and environmental sustainability as foundational pillars (Angelidou, 2015).

Several theoretical frameworks have been proposed to explain smart city development, focusing on the interplay between technology, governance, and urban infrastructure. One prominent framework is the Triple Helix Model, which highlights the collaborative roles of government, academia, and industry in driving innovation and smart urban development (Carayannis & Campbell, 2011). Another framework, the Urban Informatics Model, stresses the role of data and analytics in transforming urban governance and citizen services (Kitchin, 2014). These frameworks underscore the multidimensional nature of smart cities, where infrastructure, digital technologies, and institutional arrangements must work synergistically to achieve smart outcomes.

Central to all smart city frameworks is the importance of infrastructure accessibility. Infrastructure, encompassing transportation networks, utilities, health, education, and communication systems, forms the backbone of urban life. Accessibility to these services is crucial for economic participation, social equity, and overall well-being. In the context of smart cities, infrastructure accessibility is enhanced through the deployment of geo-spatial technologies that enable precise mapping, monitoring, and management of infrastructure assets (Hashem et al., 2016). This spatially aware infrastructure facilitates optimized service delivery, reduces disparities, and supports inclusive urban growth. As such, improving infrastructure accessibility is not only a technical challenge but also a key social objective of smart city initiatives (Angelidou, 2014).

2.1.2. Infrastructure Accessibility Theory

Infrastructure accessibility refers to the ease with which individuals and communities can reach and effectively use essential services such as transportation networks, healthcare, education, water supply, and energy (Geurs & van Wee, 2004). It is a multidimensional concept encompassing physical proximity, affordability, availability, and quality of infrastructure services (Litman, 2017). Accessibility is not just about geographic distance but also includes factors such as travel time, cost, and social inclusion, making it a fundamental determinant of urban residents' quality of life (Beyer et al., 2017). Importantly, infrastructure accessibility is closely linked to the principle of equity, which demands that all segments of society regardless of socioeconomic status, gender, or location—have fair and just access to urban services (Lucas, 2012).

Urban infrastructure plays a critical role in achieving sustainable development, which seeks to meet present needs without compromising the ability of future generations to meet theirs (UN, 2015). Infrastructure systems—such as transport, water, sanitation, and energy—are the backbone of economic productivity, social well-being, and environmental protection (Fay et al., 2015). Sustainable urban infrastructure promotes efficient resource use, reduces environmental footprints, and enhances resilience to climate change and disasters (Satterthwaite, 2016). Accessibility to such infrastructure, therefore, is essential not only for economic inclusion but also for sustainable urban growth and poverty alleviation (World Bank, 2017).

Theories on spatial inequalities and urban service provision address the uneven distribution of infrastructure and its impacts on different social groups and geographic areas. The Spatial Mismatch Theory (Kain, 1968), originally developed to explain labor market disparities, has been extended to highlight how the location of infrastructure services relative to marginalized populations can exacerbate social exclusion. Similarly, the Urban Political Economy Theory focuses on how power dynamics and policy decisions lead to uneven investment in urban infrastructure, often privileging affluent neighborhoods over low-income or peripheral areas (Harvey, 1973). Moreover, Central Place Theory (Christaller, 1933) explains how urban services tend to cluster in central areas, creating accessibility challenges for peripheral communities. These theoretical perspectives emphasize the importance of equitable spatial planning and targeted interventions to reduce accessibility gaps (Wang & Liu, 2017).

2.1.3. Geo-Spatial Technology Theories

Geo-spatial technologies encompass a range of tools and methods designed to capture, store, analyze, and visualize spatial and geographic data. At the core of these technologies are Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS). GIS is a computer-based system that enables the management and analysis of spatial data through layering and mapping, allowing users to interpret complex geographic relationships (Goodchild, 2010). Remote sensing involves acquiring information about the Earth's surface using sensors mounted on satellites or aircraft, which collect data across various electromagnetic spectra to monitor land use, environmental changes, and urban dynamics (Lillesand et al., 2015). GPS technology provides accurate geolocation information by triangulating signals from satellites, facilitating precise positioning essential for mapping and navigation in urban planning (El-Rabbany, 2002).

The theoretical foundation of spatial analysis in urban planning lies in understanding the patterns, relationships, and processes that occur in geographic space. Spatial analysis uses mathematical and statistical techniques to examine the distribution and interaction of urban features such as infrastructure, population, and land use (Longley et al., 2015). One key aspect is network analysis, which models the connectivity and accessibility of urban infrastructure such as roads, public transport routes, and utility networks (Miller, 2017). Network analysis applies graph theory and optimization algorithms to solve problems like shortest path, service area determination, and flow analysis, thereby aiding planners in assessing infrastructure efficiency and accessibility (Shen et al., 2016). These analyses are critical for smart city development as they enable the identification of gaps and bottlenecks in service provision and inform strategies for optimal resource allocation.

Integration of geo-spatial data supports decision-making in urban governance by providing a comprehensive spatial framework that enhances transparency, efficiency, and responsiveness.

Geo-spatial decision support systems (Geo-DSS) combine spatial datasets, analytical models, and visualization tools to assist policymakers in evaluating urban scenarios and making evidence-based decisions (Malczewski, 2006). This integration is especially important for smart cities, where real-time data streams from sensors, IoT devices, and mobile platforms are fused with traditional spatial databases to monitor urban systems dynamically (Batty, 2013). Such integration facilitates participatory planning by making complex spatial information accessible to stakeholders and supports adaptive governance by enabling scenario modeling and impact assessment (Kumar & Tiwari, 2020). In developing countries like Ethiopia, the growing adoption of geo-spatial technologies holds promise for improving urban management, enhancing service delivery, and fostering sustainable urban development (Amede et al., 2019).

2.2. Conceptual literature review

2.2.1. Conceptual Framework for Geo-Spatial Technologies in Smart Cities

Geo-spatial technologies play a pivotal role in managing urban infrastructure within the broader framework of smart city development. Conceptually, these technologies are positioned as key enablers that support the collection, integration, and analysis of spatial data to improve the efficiency, accessibility, and sustainability of urban services (Hashem et al., 2016). In smart cities, urban infrastructure management involves complex layers of spatial information—ranging from road networks and public utilities to healthcare and educational facilities—that need to be dynamically monitored and optimized. Geo-spatial technologies facilitate this by providing real-time spatial intelligence and visualization tools that enhance situational awareness and planning accuracy (Ahvenniemi et al., 2017).

Frameworks that link spatial data to infrastructure accessibility and smart city objectives generally emphasize the integration of three main components: data acquisition, spatial analysis, and decision support. First, spatial data acquisition includes the collection of multi-source geospatial datasets such as satellite imagery, GPS data, sensor networks, and crowdsourced information (Batty et al., 2012). Second, spatial and network analyses process these data to evaluate the distribution, connectivity, and accessibility of infrastructure across urban landscapes. Techniques such as accessibility modeling, service area delineation, and gap analysis allow urban planners to identify underserved areas and inefficiencies (Zhang et al., 2018). Finally, decision support systems utilize these insights to align infrastructure development with smart city goals such as sustainability, inclusiveness, and resilience (Kumar & Tiwari, 2020). This integrative approach ensures that infrastructure planning is not only reactive but anticipatory, addressing future urban demands through data-driven strategies.

The components of geo-spatial integration in urban planning involve several interconnected processes. Data integration is fundamental, combining diverse spatial datasets into unified platforms that support interoperability and comprehensive analysis (Yigitcanlar et al., 2018). Analytical tools, including spatial statistics, predictive modeling, and network analysis, empower planners to simulate urban scenarios, forecast impacts, and optimize resource allocation (Batty, 2013). Visualization interfaces, such as interactive maps and dashboards, promote stakeholder engagement and transparency in decision-making (Wang et al., 2019). Furthermore, geo-spatial integration supports continuous monitoring of urban infrastructure, enabling adaptive governance essential to smart city development (Angelidou, 2014). Together, these components form a cohesive conceptual framework that highlights how geo-spatial technologies contribute to more equitable, efficient, and sustainable urban infrastructure management.

2.2.2. Concepts of Infrastructure Accessibility and Spatial Equity

Infrastructure accessibility refers to the ease with which individuals or communities can reach and utilize essential urban services such as healthcare, education, transportation, and utilities. Accessibility is often measured using spatial metrics that account for both physical proximity and functional availability of services (Geurs & van Wee, 2004). These metrics include Euclidean distance, travel time, service density, and network connectivity. For example, travel time is a common metric in urban transportation planning, while service coverage maps are used to identify underserved areas (Liu & Zhu, 2004). These measurements help evaluate how equitably infrastructure is distributed across different urban zones.

Spatial equity and justice in infrastructure provision concern the fair allocation of services and resources to all urban residents, regardless of socioeconomic status, geographic location, or demographic characteristics (Talen, 1998). In many rapidly urbanizing regions—especially in the Global South inequitable access to infrastructure leads to persistent disparities in health, education, and economic opportunity. Spatial justice requires that infrastructure investments actively address these inequalities by prioritizing marginalized neighborhoods and populations (Soja, 2010).

Therefore, accessibility is not just a technical concern but also a social and ethical one, aligning with the goals of sustainable and inclusive urban development.

Various conceptual models have been developed to measure and analyze accessibility. The proximity model evaluates how close a service is to users, often using buffers or distance thresholds. Cumulative opportunity models count the number of services accessible within a given time or distance. Gravity-based models incorporate both the attractiveness of a service and the impedance (e.g., time or cost) of reaching it. Finally, network-based models analyze accessibility along actual transportation networks, offering more realistic insights into urban mobility and service reach (Hansen, 1959; Páez et al., 2012). These models serve as foundational tools for spatial analysis in urban planning and can be effectively implemented using geo-spatial technologies like GIS and Remote Sensing.

In the context of smart city development, measuring and enhancing infrastructure accessibility through spatially explicit approaches ensures that urban services are delivered in a manner that is efficient, equitable, and responsive to population needs (Neutens, 2015). Geo-spatial data and analytical tools help to visualize disparities, simulate infrastructure scenarios, and support evidence-based decision-making. Integrating these concepts into planning processes can significantly improve the capacity of cities like Bishoftu to address service gaps and promote spatial equity in line with sustainable development goals.

2.2.3. Conceptualizing Infrastructure Challenges in Developing Countries

Urbanization in developing countries has been rapid and often unplanned, leading to complex infrastructure challenges. Unlike the gradual urban transitions experienced in developed nations, urban growth in the Global South is frequently characterized by informal settlements, unregulated land use, and overstretched infrastructure systems (UN-Habitat, 2020). Many secondary cities, such as Bishoftu in Ethiopia, are experiencing increased pressure due to migration from rural areas and natural population growth. These urbanization dynamics have outpaced infrastructure investment, leading to significant gaps in service delivery and land-use management (Angel et al., 2011).

Infrastructure development in these contexts faces multiple challenges, including inadequate planning capacity, financial constraints, lack of updated spatial data, and institutional fragmentation (Pieterse & Parnell, 2014). In secondary cities like Bishoftu, road networks may not expand in proportion to the growing urban footprint, and essential services like schools, health centers, and water supply systems may be unevenly distributed. These spatial disparities result in socio-economic inequalities, inefficient mobility, and declining urban livability. Moreover, the lack of coordination between urban development actors contributes to fragmented decision-making and reactive planning approaches (World Bank, 2017).

Geo-spatial tools such as GIS, Remote Sensing, and spatial analysis software offer critical support in managing these challenges by enabling evidence-based planning and monitoring. These technologies allow for mapping urban growth patterns, analyzing land use changes, modeling infrastructure accessibility, and identifying underserved areas (Cheng & Adepeju, 2014). In secondary cities, where up-to-date urban data is often limited, satellite imagery and geospatial analysis provide cost-effective alternatives to traditional survey-based data collection. Moreover, by integrating spatial datasets with demographic and socioeconomic information, planners can develop equitable and efficient urban infrastructure strategies that align with smart city goals and sustainable development objectives (Yeh & Li, 2001).

2.3. Empirical literature review

2.3.1. Global Empirical Studies on Geo-Spatial Technologies and Infrastructure Accessibility

Geo-spatial technologies have become integral tools for analyzing and improving infrastructure accessibility in urban environments globally. In developed countries, the application of Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS) has been extensive in infrastructure planning and service optimization. For example, in the United States and Europe, GIS has been used for mapping public transportation networks, identifying underserved areas, and optimizing emergency service locations (Murray, 2001; Wiggins et al., 2009). These studies demonstrate that spatial analysis can significantly enhance equity and efficiency in urban infrastructure delivery.

In developing countries, although the adoption of geo-spatial technologies is more recent, several empirical studies have shown promising results. In India, Kumar et al. (2018) applied GIS to evaluate healthcare accessibility in urban slums, identifying service gaps and proposing facility reallocation to improve equity. In Nigeria, Adepoju and Oni (2012) used spatial techniques to assess road network connectivity and accessibility in Lagos, revealing significant disparities that hinder mobility. Similarly, in Kenya, Githiria et al. (2020) employed satellite imagery and GIS to map informal settlements and guide infrastructure interventions in Nairobi. These studies underscore how spatial technologies can inform pro-poor infrastructure strategies in rapidly growing cities.

Success stories from Latin America, such as Medellín, Colombia, further highlight the role of geo-spatial technologies in integrated urban planning. Medellín leveraged GIS to plan its urban transport corridors and social housing projects, resulting in improved accessibility for marginalized populations (Brand & Dávila, 2011). These global cases reveal that when geo-spatial data is combined with participatory planning and governance reforms, it can help achieve more inclusive and sustainable urban infrastructure outcomes.

However, cross-cutting lessons emphasize the importance of institutional capacity, data availability, and inter-agency coordination. While technological tools are powerful, their effectiveness depends on local planning institutions' ability to interpret and use spatial data in decision-making (UN-Habitat, 2016). In many cases, challenges such as limited technical expertise, lack of open-access spatial data, and fragmented planning systems hinder the full utilization of these technologies.

2.3.2. Empirical Evidence from Ethiopia

In recent years, several studies in Ethiopia have begun to apply geo-spatial technologies to assess urban infrastructure accessibility and support urban planning. For instance, in Addis Ababa, Abebe and Megento (2016) utilized GIS to analyze the spatial distribution of public service facilities, revealing disparities in access to schools and health centers, particularly in peri-urban areas. Their study highlighted how spatial analysis can guide equitable allocation of urban services. Similarly, in Bahir Dar, Teferi and Abraha (2020) employed GIS and remote sensing to evaluate accessibility to transportation and water infrastructure, noting that unplanned urban expansion was contributing to service inefficiencies and access inequalities.

Other cities such as Hawassa and Mekelle have also been the focus of infrastructure accessibility studies using geo-spatial methods. For example, Nigussie et al. (2019) conducted a spatial accessibility analysis of healthcare services in Hawassa using network analysis in GIS, identifying service deserts and recommending priority areas for facility development. These studies demonstrate the growing recognition of geo-spatial tools as effective instruments for diagnosing urban infrastructure challenges and optimizing service delivery in Ethiopian urban centers.

Despite this progress, the adoption of geo-spatial technologies in Ethiopian urban planning remains limited and uneven. A study by Worku and Hailu (2021) noted that most municipalities lack the institutional capacity, trained personnel, and infrastructure to fully leverage spatial technologies for planning and decision-making. Moreover, urban planning processes in secondary cities like Bishoftu often rely on outdated maps and manual methods, which restrict the ability to analyze spatial patterns and address infrastructure gaps effectively. According to the Ethiopian Ministry of Urban Development and Infrastructure (MoUDI, 2020), only a few cities have integrated GIS into their master planning efforts, and even fewer use real-time spatial data to support ongoing service monitoring or future planning.

Furthermore, limited coordination between national and local planning bodies, low awareness of spatial technology benefits, and inadequate data-sharing frameworks further hinder the effective use of geo-spatial data (UN-Habitat, 2017). These institutional and technical barriers point to a clear need for enhanced capacity-building, investment in digital infrastructure, and the integration of spatial data systems into Ethiopia's broader urban governance framework. Such improvements are essential to enable data-driven urban development, especially in fast-growing towns like Bishoftu, where spatial inequalities in infrastructure provision persist but remain underexplored.

2.4. Summary

This chapter reviewed theoretical, conceptual, and empirical literature on smart cities, infrastructure accessibility, and geo-spatial technologies. Theoretically, smart city frameworks emphasize the integration of digital technologies, human capital, and infrastructure to enhance urban sustainability and livability, with models like the Triple Helix and Urban Informatics highlighting collaboration and data-driven governance. Infrastructure accessibility theory underscores equitable access to essential services as a driver of social inclusion and sustainable development, while geo-spatial theory focuses on tools like GIS, remote sensing, and network analysis to support spatial decision-making. Conceptually, geo-spatial technologies are framed as critical enablers of smart infrastructure planning through data acquisition, spatial analysis, and decision support. Infrastructure accessibility and spatial equity concepts highlight the importance of fair service distribution, especially in rapidly urbanizing areas. Empirical studies from both global and Ethiopian contexts demonstrate how spatial technologies are being applied to analyze and address infrastructure gaps, though adoption in Ethiopia remains limited due to institutional, technical, and data-related challenges—particularly in secondary cities like Bishoftu, where planning often lacks real-time spatial data integration.

2.5. Identified Gaps

Bishoftu City, one of the rapidly urbanizing secondary cities in Ethiopia, has seen significant demographic and spatial growth in recent decades, yet research specifically focused on its infrastructure accessibility remains limited. While a few local planning documents and regional urban development reports (MoUDI, 2020) mention Bishoftu in broader urban contexts, there is a noticeable absence of detailed academic studies that assess its urban infrastructure through the lens of geo-spatial technologies. Unlike Addis Ababa or Bahir Dar, which have benefited from spatial studies informing infrastructure planning (Abebe & Megento, 2016; Teferi & Abraha, 2020), Bishoftu lacks a systematic, spatially-explicit assessment of infrastructure accessibility.

Preliminary observations and reports from local government sources and field assessments suggest that Bishoftu faces growing spatial inequalities in access to critical infrastructure, including road networks, healthcare services, educational facilities, and clean water supply (Oromia Urban Planning Institute, 2021). These gaps are more pronounced in peripheral and newly developing neighborhoods where urban expansion often precedes infrastructure provision. The city's reliance on conventional, non-digital planning methods further exacerbates the problem, as urban planners are unable to visualize or model spatial distribution and service coverage effectively. Without geo-spatial analysis tools, infrastructure decisions often fail to consider location-based demand patterns, travel distances, or population density—leading to misallocation and underutilization of resources.

Moreover, Bishoftu's rapid growth has outpaced the capacity of existing urban infrastructure, creating congestion in core areas while new settlements remain underserved. The lack of integrated geo-spatial planning frameworks means that municipal authorities are unable to systematically monitor infrastructure provision or simulate future development scenarios based on spatial data. This presents a missed opportunity for utilizing tools such as GIS-based network analysis, accessibility modeling, or service catchment mapping—tools that have proven effective in similar contexts globally (Geertman et al., 2019; Batty, 2013).

The identified gaps in both research and practice highlight the urgent need for geo-spatially informed strategies tailored to the specific spatial dynamics of Bishoftu. Addressing infrastructure inequalities and promoting inclusive urban development in the city will require integrating spatial technologies into urban planning workflows. Such integration can enable evidence-based decisions, support real-time infrastructure monitoring, and align with Ethiopia's broader smart city aspirations (UN-Habitat, 2017). Therefore, this study aims to fill the existing knowledge and practice gaps by providing a spatial assessment of infrastructure accessibility in Bishoftu and proposing geospatial strategies for sustainable and equitable urban development.

CHAPTER

3. RESEARCH MATERIAL AND METHODOLOGY

3.1. Description of the Study Area

Bishoftu, formerly known as Debre Zeit, is a rapidly urbanizing city located in the Oromia National Regional State of Ethiopia. Geographically, it lies approximately 47 kilometers southeast of the capital city, Addis Ababa, making it part of the Addis Ababa-Djibouti development corridor, which is a critical economic and transport axis for the country. The city is situated within the administrative boundary of the East Shewa Zone, specifically in Ada'a Woreda. Its astronomical coordinates extend between 8°45′ to 8°47′ North latitude and 38°56′ to 39° East longitude, positioning Bishoftu within the central highlands of Ethiopia.

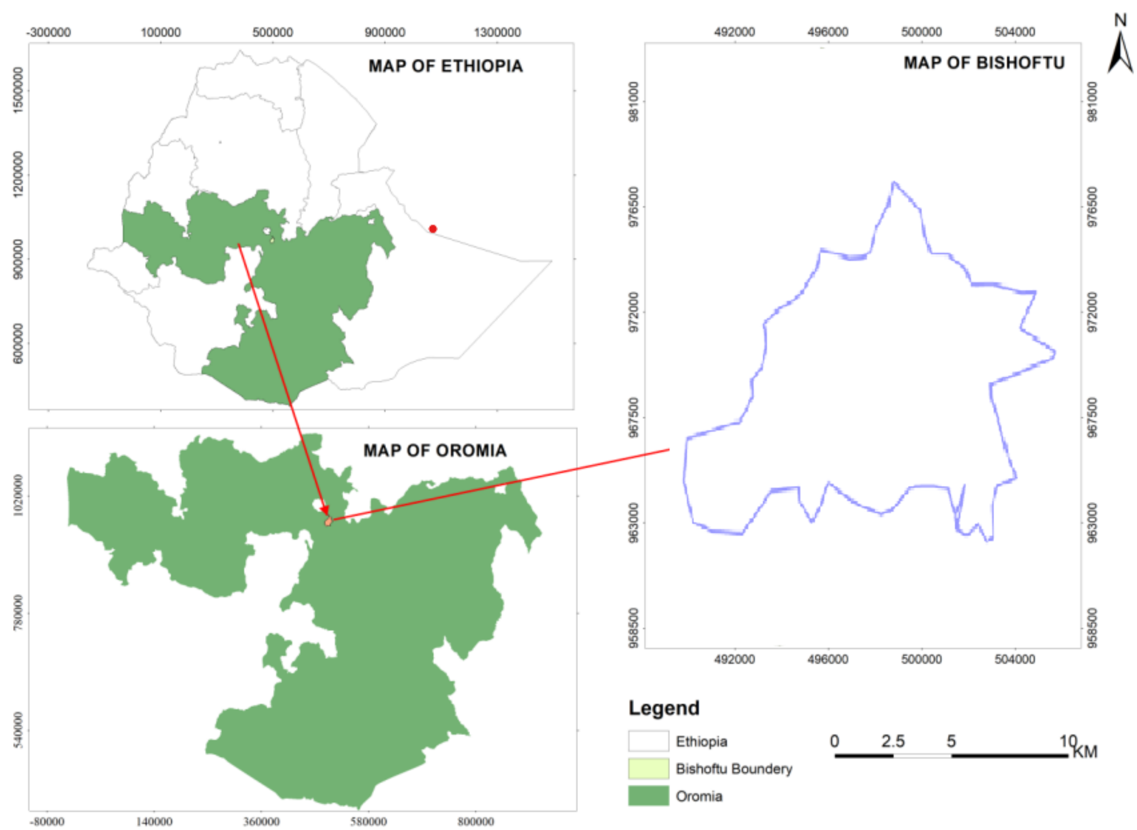

Figure 3-1: Location map of the study area

3.2. Research Approach

This study adopts a mixed-methods research approach, combining both qualitative and quantitative techniques to provide a comprehensive understanding of infrastructure accessibility in Bishoftu

City within the context of smart city development. The quantitative aspect primarily involves spatial analysis using geo-spatial technologies such as GIS (Geographic Information Systems), Remote Sensing, and GPS. These tools enable the extraction, visualization, and analysis of spatial data related to the distribution and accessibility of key urban infrastructure such as roads, health centers, schools, and other public services.

3.3.Research Design

The research follows a descriptive and analytical research design. The descriptive aspect is used to map and document the current spatial distribution of infrastructure facilities in Bishoftu City using geo-spatial data. This includes identifying existing road networks, educational institutions, health facilities, water points, and other essential infrastructure.

3.4.Data type and source

The study primarily utilized secondary spatial and non-spatial data, supplemented by GPS-based primary data collection. Administrative and infrastructure-related GIS shapefiles, such as roads, schools, health centers, and kebele boundaries, were sourced from key government institutions including the Bishoftu Municipality or Urban Planning Office, the Oromia Urban Planning Institute, the Ethiopian Central Statistical Agency (CSA), and the Ethiopian Mapping Agency (EMA). Additionally, population and demographic data covering household size, population distribution, and related socioeconomic indicators were extracted from CSA resources, such as the 2007 Population and Housing Census and the 2016 Demographic and Health Survey (DHS). These data supported spatial equity analysis and service gap assessments.

Table 3-1: Data type and source

Data Type	Description	Source/Institution
GIS Shapefiles	Roads, schools, health facilities, kebele boundaries	Bishoftu Municipality, Oromia Urban Planning Institute, EMA
Demographic Data	Population distribution, household size, socioeconomic indicators	Ethiopian Central Statistical Agency (CSA) – 2007 Census, 2016 DHS
Urban Planning Documents	Structure plans, infrastructure development strategies, smart city frameworks	Bishoftu Municipality, Oromia Urban Planning Institute
GPS Data	Ground-based coordinates of infrastructure features	Collected by the researcher during fieldwork

3.5.Software Used

This research employed ArcMap, a widely used Geographic Information System (GIS) software developed by Esri, for spatial data processing, analysis, and visualization. ArcMap provided robust tools for managing, analyzing, and displaying geographic information, which were crucial for tasks such as spatial distribution mapping, service area analysis, and spatial overlay operations. Its capabilities in handling complex spatial queries and network analysis enabled the evaluation of infrastructure accessibility across Bishoftu City effectively. Additionally, AutoCAD software was utilized for precise drafting and editing of infrastructure layouts and urban planning maps. AutoCAD's computer-aided design functionalities supported the preparation and refinement of infrastructure schematics, ensuring the integration of accurate spatial data in the planning process.

3.6.Data Pre-processing

The collected spatial datasets, including administrative boundaries, roads, health facilities, and schools, underwent thorough pre-processing to ensure accuracy and compatibility for analysis. This process involved standardizing all data layers to a common coordinate reference system (WGS 1984 UTM Zone 37N) to maintain spatial alignment across datasets. Topological errors such as overlapping polygons and disconnected road segments were identified and corrected to ensure spatial integrity. Attribute data associated with each infrastructure layer were carefully verified for completeness and correctness. Additionally, GPS data collected from field surveys were integrated and cross-checked against existing shapefiles to update and validate the precise locations of infrastructure points.

3.7.Data processing and analysis

3.7.1. Spatial distribution of existing infrastructure

To assess the spatial distribution of existing urban infrastructure in Bishoftu City, various geo-spatial datasets were processed and analyzed using Geographic Information System (GIS) tools such as ArcGIS or QGIS. The shapefiles collected from relevant agencies were first pre-processed through projection standardization, topology checks, and attribute verification. These datasets, which include roads, health facilities, schools, and administrative boundaries, were then spatially visualized to examine the current distribution of infrastructure and identify clustering patterns or under-served zones.

Kernel Density Estimation (KDE) is a spatial analysis technique used to estimate the density or concentration of point features, such as infrastructure locations, across a study area. By applying KDE, areas with high clustering of infrastructure points can be identified, helping to visualize hotspots and reveal patterns of spatial distribution.

The formula for KDE at a location x is given by:

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

where:

- f^(x) is the estimated density at location xxx,
- n is the total number of points,
- h is the bandwidth (smoothing parameter),
- K is the kernel function,
- Xi are the observed point locations.

3.7.2. Infrastructure accessibility

For the evaluation of infrastructure accessibility across different parts of the city, network analysis techniques were applied. Using road network data, service areas were generated to calculate travel times and distances from residential locations to the nearest essential services such as schools and health centers. Buffer analysis and proximity tools were also utilized to assess spatial coverage and identify underserved or peripheral neighborhoods. Accessibility indicators, such as the number of services reachable within a given radius or travel time threshold, were computed and mapped to reflect inequalities in service provision.

Service area analysis utilizes the road network to delineate the geographic zones reachable within a specified travel time or distance from key infrastructure points, such as hospitals or schools. This approach helps to assess the accessibility of services by identifying which parts of the city fall within convenient reach of essential facilities, commonly based on literatures. The network distance d between two points, A and B, is calculated as:

$$d = \sum_{i=1}^{m} l_i$$

where:

- m is the number of road segments connecting points A and B,
- li is the length of each individual road segment along the path.

Table 3-2: standards/criteria for service area analysis based on literature for urban infrastructure accessibility

Infrastructure Type	**Accessibility Measure**	**Threshold/Standard**	**Reference**
Health Facilities	Travel time	≤ 15 minutes	WHO (2010); Wang et al. (2018)
Schools	Travel distance	≤ 5 km	Noor et al. (2006); Tatem et al. (2006)
	Walking distance	≤ 1 km	UNESCO (2014); Geurs & van Wee (2004)
Public Transportation Stops	Travel time	≤ 15 minutes	UNECE (2019); Liu et al. (2020)
	Walking distance	≤ 400 meters	Cervero (1994); Litman (2015)
Road Networks	Maximum network distance	≤ 5 km	Litman (2019); El-Geneidy et al. (2016)
	Travel time	≤ 10 minutes	OECD (2015); Sarkar et al. (2016)
Parks and Recreational Facilities	Walking distance	≤ 400 meters	Giles-Corti et al. (2005); Wolch et al. (2014)

3.7.3. Inequalities in infrastructure accessibility

To identify infrastructure gaps and propose solutions, the study incorporated spatial overlay analysis by integrating population density data with the service area maps. This helped highlight areas with high demand but poor access to essential services. Moreover, spatial equity was assessed using location-allocation models and service gap mapping, thereby quantifying disparities in access to urban infrastructure.

Spatial overlay analysis involves layering different spatial datasets to identify areas where infrastructure accessibility does not meet the population's needs. In this study, population density maps were overlaid with the service areas of existing infrastructure such as schools, hospitals, and roads. This approach allows for the detection of zones with high population density but limited or no access to critical services. By visually and quantitatively examining these overlaps, planners can identify underserved communities where infrastructure investment is most needed.

Location-allocation modeling is a spatial optimization technique used to determine the best locations for new infrastructure facilities to maximize accessibility. This method considers the current distribution of services and population demand to allocate new infrastructure in a way that minimizes travel distances or times for the largest number of residents. Applying this model helps ensure efficient resource allocation and improved equity in service delivery by strategically addressing gaps revealed through spatial analysis.

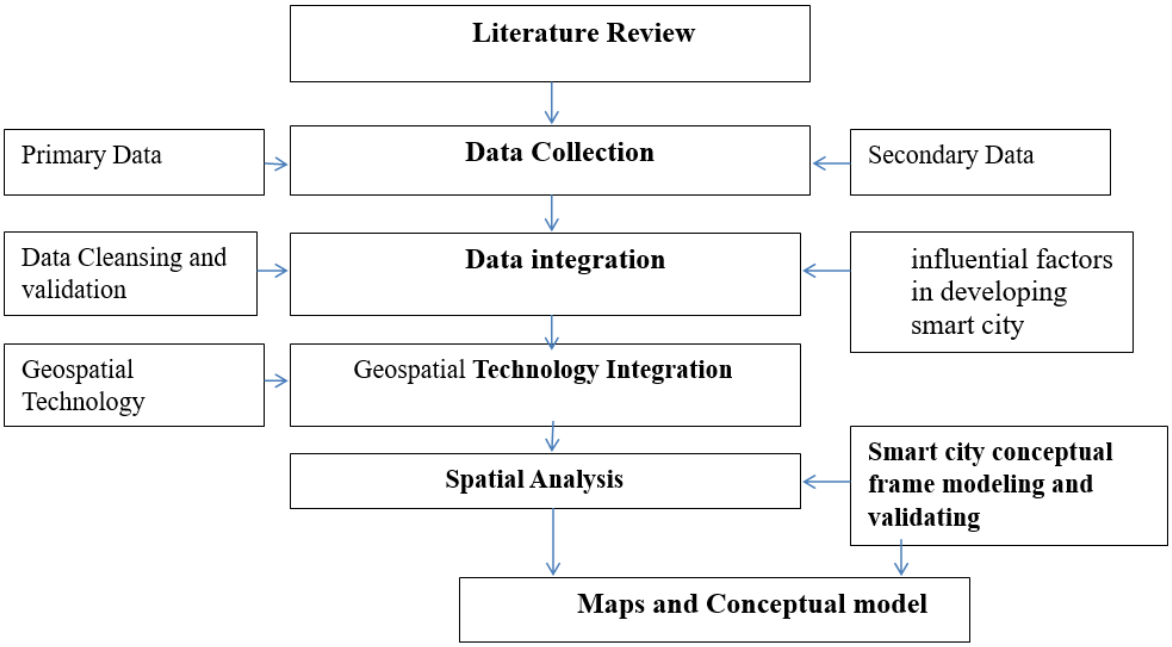

Figure 3-2: Methodological flowchart

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Introduction

This chapter presents the key findings of the study based on the research objectives outlined in the earlier chapters. It integrates the results obtained from spatial and statistical analyses using geo-spatial technologies, focusing on the spatial distribution and accessibility of critical infrastructure services within Bishoftu City. The chapter is organized according to the three main research objectives: (1) assessing the spatial distribution of existing urban infrastructure, (2) evaluating the accessibility of key services such as roads, schools, and health facilities, and (3) identifying spatial gaps and inequalities to propose geo-spatially informed strategies for improved service delivery. The findings are supported by maps, graphs, and tables generated through Geographic Information System (GIS) and spatial analysis tools, including kernel density estimation, service area modeling, and spatial overlay analysis. Each section discusses the implications of the results in the context of smart city development, spatial equity, and sustainable urban planning. Furthermore, comparisons are drawn with similar empirical studies, both globally and locally, to place the findings in a broader context.

4.2. Spatial distribution of infrastructures in the city

The spatial distribution analysis of key urban infrastructures in Bishoftu City, as presented in Figure 4-1, reveals a clear pattern of central concentration across most infrastructure types. The five infrastructure categories analyzed include hospitals, health centers, kindergartens, green areas, and playgrounds. The findings indicate that these essential services are unevenly distributed, with a significant clustering toward the city center.

Hospitals (Figure 4-1d), in particular, are highly centralized, limiting access for residents living on the urban periphery. This centralization reflects a common trend in many developing cities, where high-tier medical services are located in the urban core due to administrative convenience and historical planning biases (Talen, 2001; WHO, 2010). In contrast, health centers (Figure 4-1c) exhibit a relatively better dispersion pattern, offering broader coverage and potentially reducing spatial inequity in basic healthcare access. This aligns with planning principles that advocate for decentralizing primary health care services to enhance spatial equity (UN-Habitat, 2009).

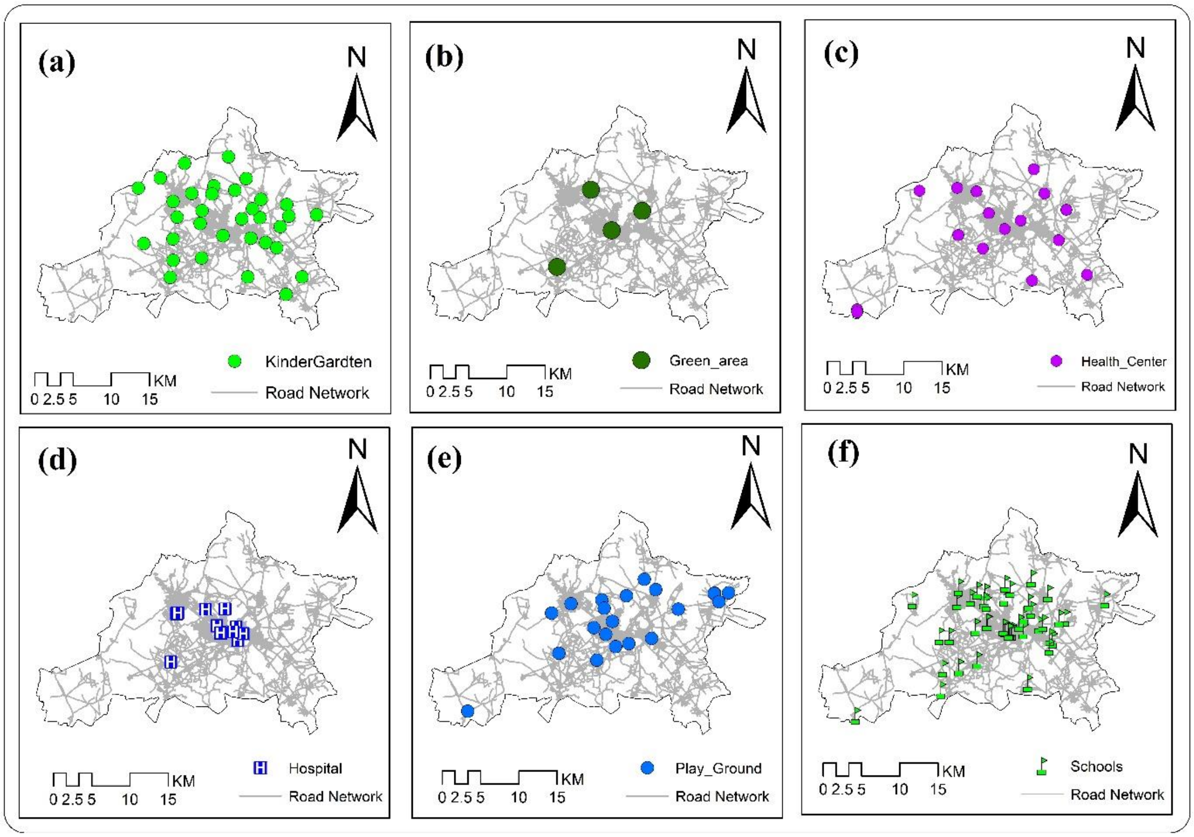

Figure 4-1: Spatial distribution of existing infostructures in the city; (a) Kinder Garden, (b) Green Area, (c) Health Center, (d) Hospitals, (e) Play Ground, (f) Schools

Similarly, the distribution of kindergartens suggests a reasonable spatial spread across the city, which can be attributed to the decentralized nature of early childhood education in Ethiopia, often supported by both public and private sectors (MoE, 2020). On the other hand, green areas (Figure 4-1b) and playgrounds (Figure 4-1e) are notably concentrated in the central zones. This raises concerns about environmental justice and equitable access to recreational spaces, especially for children and elderly populations in peripheral neighborhoods. Research has shown that equitable access to green infrastructure is crucial for public health, urban cooling, and social cohesion (Kabisch & Haase, 2014; Wolch, Byrne, & Newell, 2014).

Overall, the spatial patterns indicate a clear urban-core bias in infrastructure distribution, which may exacerbate inequalities in service access and urban quality of life. Addressing these disparities is central to the principles of smart and inclusive city planning, which emphasize equitable infrastructure provision as a key element of sustainable urban development (Batty et al., 2012; OECD, 2015).

4.3.Infrastructure Accessibility and Inequality Mapping

4.3.1. Service Area Mapping for Green Area in the city

Accessibility to green spaces plays a vital role in enhancing urban residents' well-being by promoting recreational opportunities, improving mental health, and contributing to environmental quality (Wolch et al., 2014; Kabisch & Haase, 2014). In this study, service area mapping for green areas in Bishoftu City was conducted using two primary impedance measures: travel time and distance. This dual approach helps to capture both the physical and temporal dimensions of accessibility, as recommended in urban accessibility studies (Geurs & van Wee, 2004).

As illustrated in Figure 4-2, green area accessibility was modeled based on travel time thresholds of 10 minutes, 20 minutes, 30 minutes, and 1 hour, following standards in the literature (WHO, 2016). These thresholds reflect walking and moderate vehicular access scenarios for various population groups, particularly the elderly and children, who are more sensitive to longer distances and times.

In parallel, a distance-based analysis was carried out using buffers of 1 km, 2 km, 3 km, 4 km, and beyond 5 km. This range reflects international benchmarks that suggest urban green spaces should ideally be within a 300–500 m radius for frequent use, while distances over 2 km tend to discourage regular access, especially in underserved communities (Ståhle, 2010; European Commission, 2013).

The results show that a significant portion of the city falls within the 30-minute or 3 km accessibility zone, especially in central areas. However, peripheral neighborhoods particularly in the south and northeast experience limited access to green spaces, with distances often exceeding 4–5 km and travel times surpassing 30 minutes. These spatial disparities suggest inequitable green space provision, a challenge that undermines sustainable urban development goals and social inclusion (UN-Habitat, 2020).

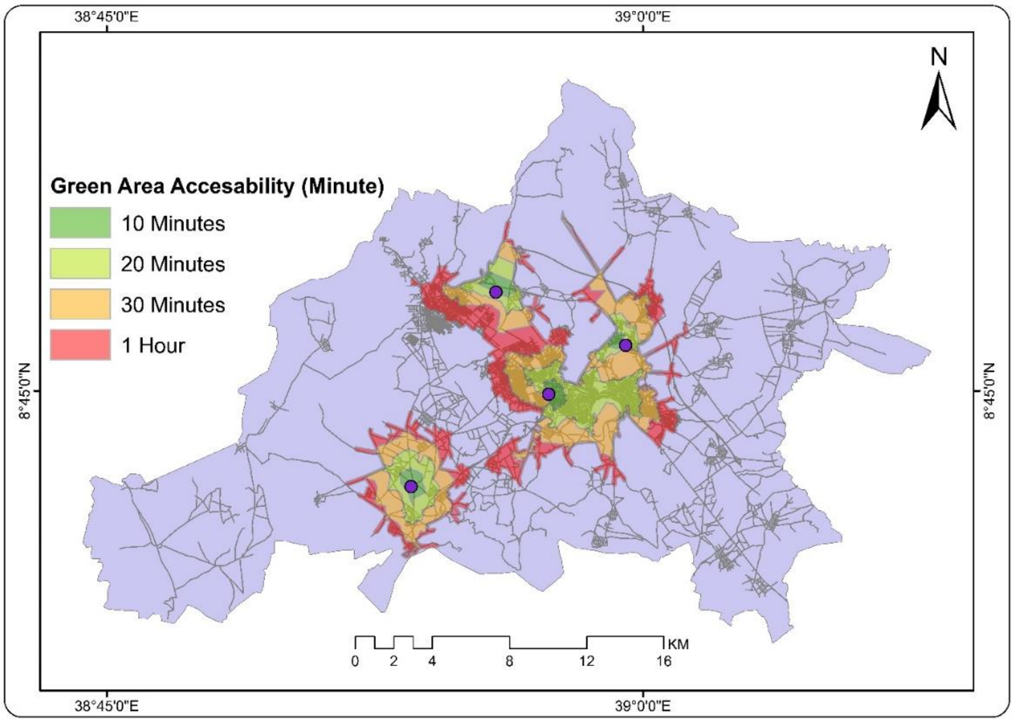

Figure 4-2: Accessibility of green area to the nearby community when the impedance is minute

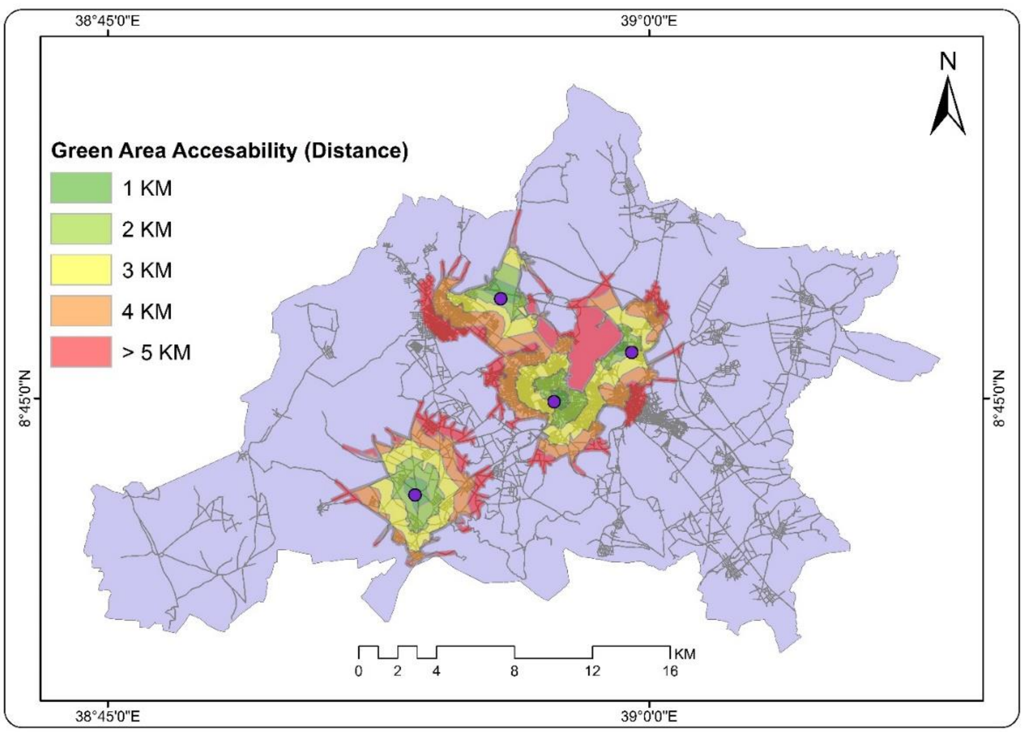

Figure 4-3: Accessibility of green area to the nearby community when the impedance is length

4.3.2. Green area distribution inequalities

As presented in Figure 4-4, the spatial distribution of green area accessibility in Bishoftu City reveals clear inequalities. The green-shaded zones represent residential areas that fall within acceptable accessibility thresholds to green spaces—either in terms of travel time or distance. These thresholds were modeled using a network-based approach, which considers actual road connectivity, transport routes, and barriers, as recommended in contemporary accessibility studies (Geurs & van Wee, 2004; Talen, 2003).

The analysis shows that residential areas near the city center generally enjoy better access to green infrastructure. This pattern is consistent with the "central place bias" observed in many rapidly urbanizing cities of the Global South, where infrastructure development tends to concentrate in core urban zones (Kabisch & Haase, 2014). In contrast, peripheral neighborhoods located outside the green buffer zones remain underserved. These communities face physical and spatial barriers to green space access, often exceeding the 500-meter or 10-minute walking thresholds suggested by the World Health Organization (WHO, 2016) and the European Commission (2013).

Quantitatively, the findings reveal that approximately 7,090 hectares of residential area fall within the good accessibility zone, while a significantly larger 14,564 hectares remain in poor accessibility zones. This spatial disparity suggests a service provision gap, where a substantial portion of the population—especially in suburban and newly developed areas—is deprived of the health, environmental, and social benefits associated with regular access to green spaces.

Such inequities underscore the importance of spatial justice in urban planning and support the call for geo-spatially informed strategies to guide the equitable distribution of green infrastructure. Tools such as location-allocation models and green infrastructure planning frameworks can help optimize future investments by targeting underserved areas and minimizing environmental injustice (Wolch et al., 2014; UN-Habitat, 2020).

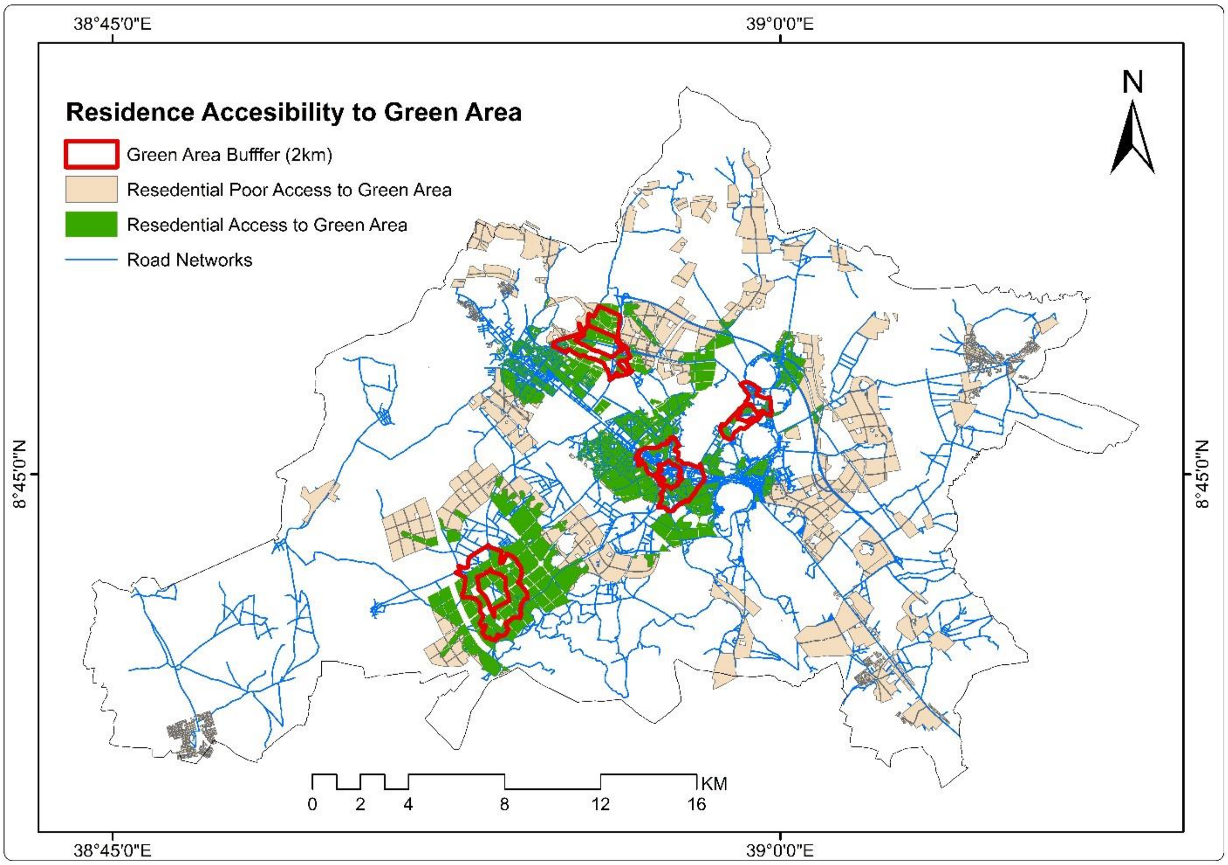

Figure 4-4: Residence accessibility to green area

4.3.3. Health center accessibility

Health center accessibility in Bishoftu City was analyzed using distance-based and network-based approaches, aiming to assess how well the existing facilities serve the urban population. As illustrated in Figure 4-5, service areas were modeled based on distance thresholds of 1 km, 2 km, 3 km, 4 km, and greater than 5 km, which are commonly used in health access studies (Guagliardo, 2004; McGrail & Humphreys, 2009). These thresholds help in identifying spatial disparities in access, with longer distances suggesting underserved populations.

In addition to distance impedance, network analysis was conducted using the Closest Facility tool in ArcGIS, integrating high-density population survey points as incident locations representing demand points. As shown in Figure 4-6, the tool identified three health centers as optimal destinations based on shortest path and least travel cost (i.e., considering actual road network connectivity rather than Euclidean distance). This approach provides a more realistic picture of accessibility in an urban context, particularly in cities with irregular road layouts (Delamater, 2013).

Furthermore, route directionality and travel paths were mapped in Figure 4-7, indicating how residents from densely populated areas reach the nearest health center. The analysis showed that some areas in the city are beyond the acceptable accessibility threshold (typically 2–3 km), especially in outer residential zones. This reflects an uneven spatial distribution of healthcare services, with a concentration near the central urban area, leaving peripheral areas underserved.

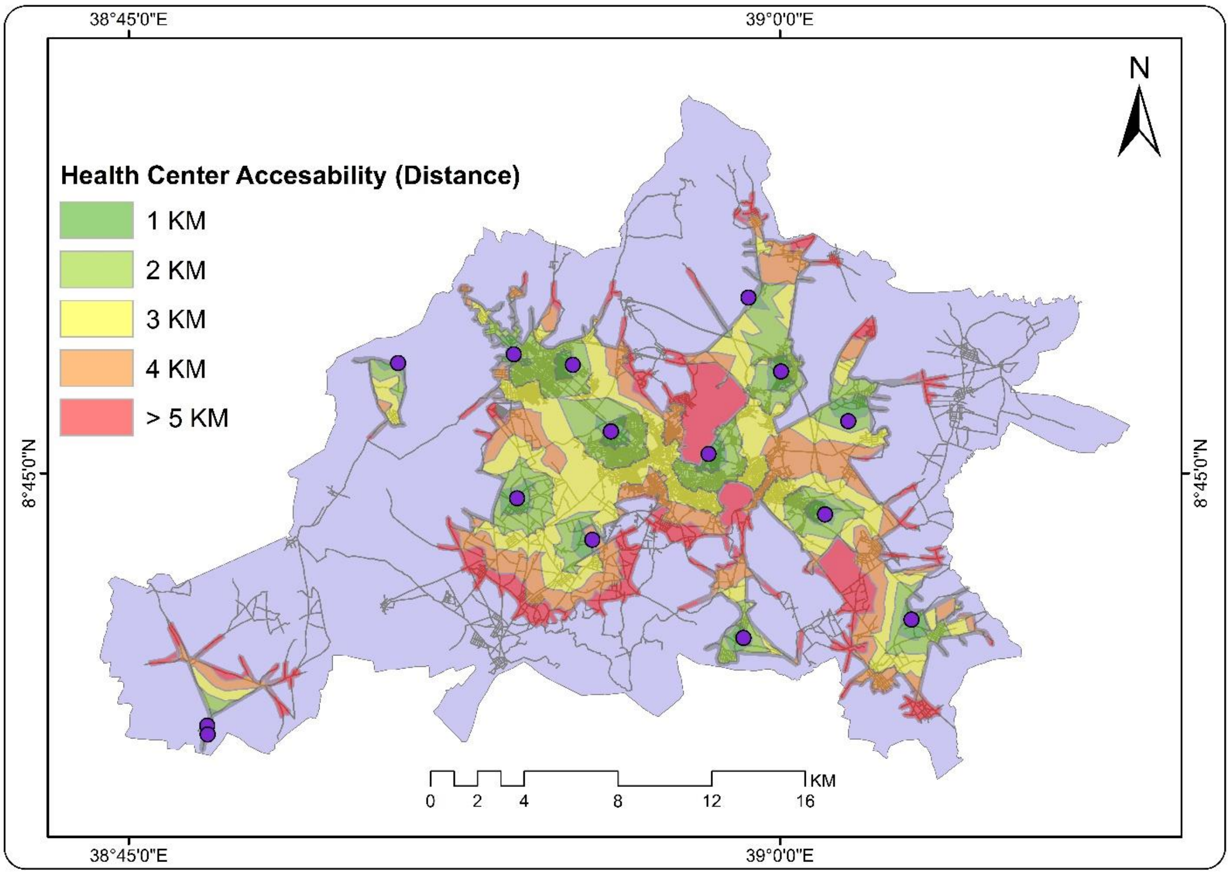

Figure 4-5: Accessibility of health center to the nearby community when the impedance is length

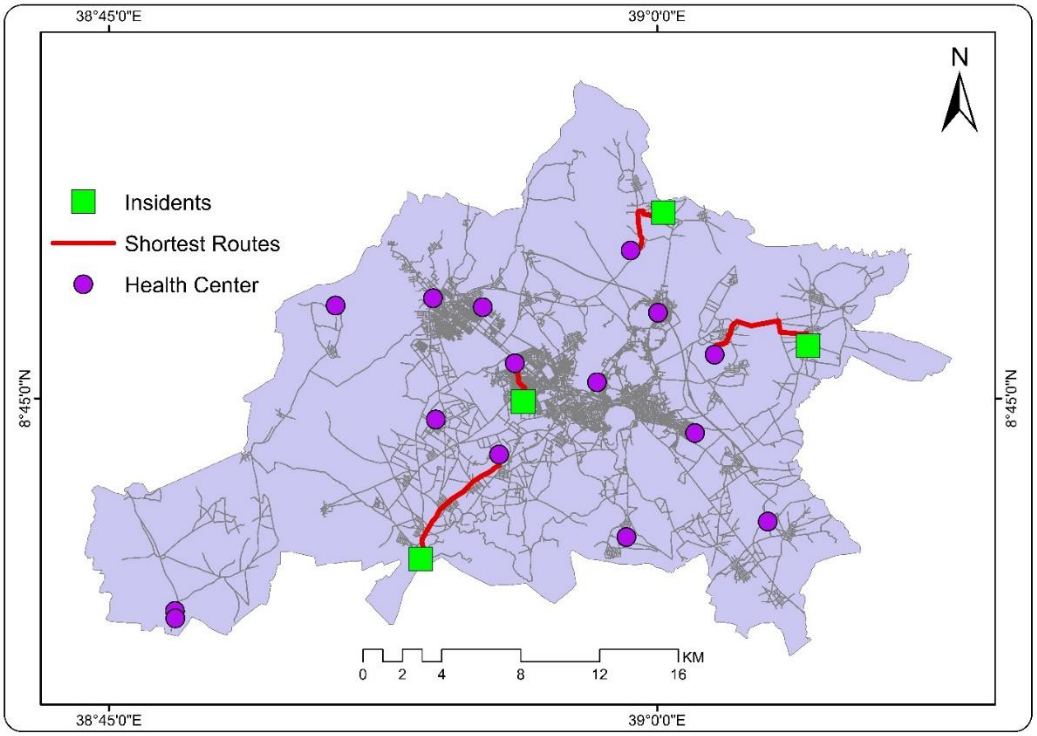

Figure 4-6: Shortest path

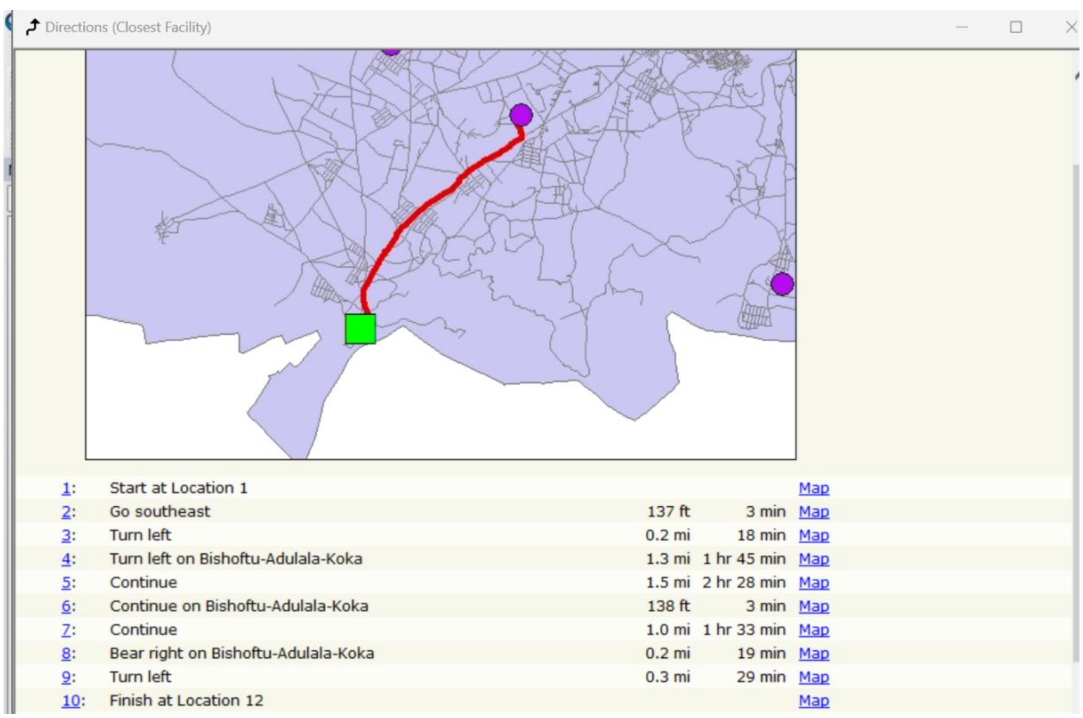

Figure 4-7: Directions

Based on the spatial analysis of existing health centers and population distribution, a location-allocation model was applied to determine the most optimal site for a new health center in Bishoftu City. The model prioritized minimizing travel distance and maximizing service coverage for densely populated yet underserved areas. High-demand zones identified through population density mapping and accessibility deficits served as demand points, while potential facility locations were selected within the periphery where access was poor. The analysis revealed a strategic location in the southeastern quadrant of the city as the most effective placement for a new health center. This site would significantly reduce travel time and increase equitable access, aligning with spatial justice principles and urban health planning standards (Rahman et al., 2019).

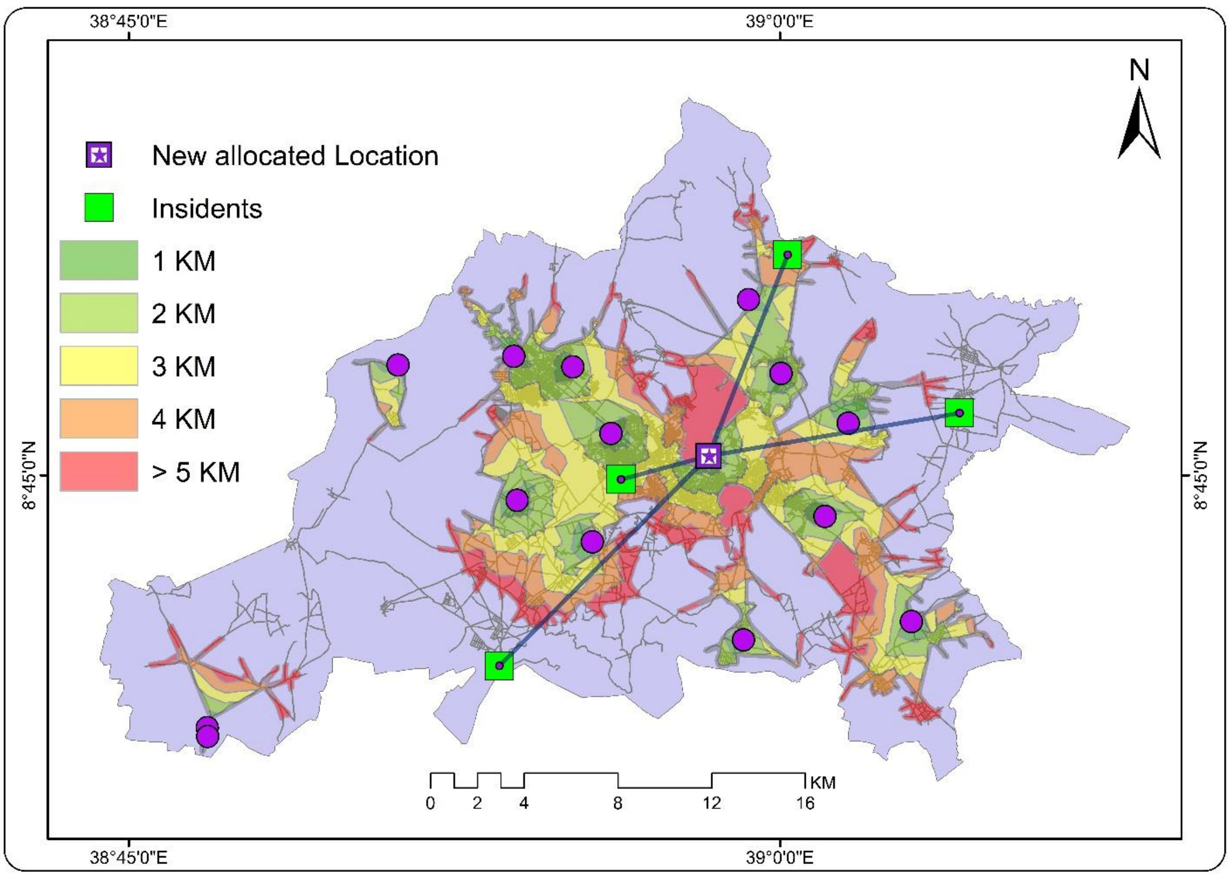

Figure 4-8: New location allocation for health center

Figure 4-9 illustrates the spatial accessibility of residents to health centers in Bishoftu City, using a 2 km buffer zone as the standard threshold for acceptable walking or travel distance. Areas within the 2 km buffer zones (highlighted in green) are considered to have good access to health centers. In contrast, the beige-colored zones represent areas with poor access, falling outside the designated service radius. The map shows that health centers are mainly clustered toward the city center and southeastern parts. Despite multiple facilities, significant gaps in accessibility remain, particularly on the northwestern, southwestern, and peripheral zones of the city. The road network overlay confirms that limited connectivity and sparse road infrastructure in some areas further exacerbate the accessibility issue. This spatial disparity indicates that a considerable portion of the city's population is underserved in terms of health infrastructure. These findings are consistent with studies that emphasize the importance of equitable spatial distribution of health services in urban planning (Talen & Anselin, 1998; Guagliardo, 2004).

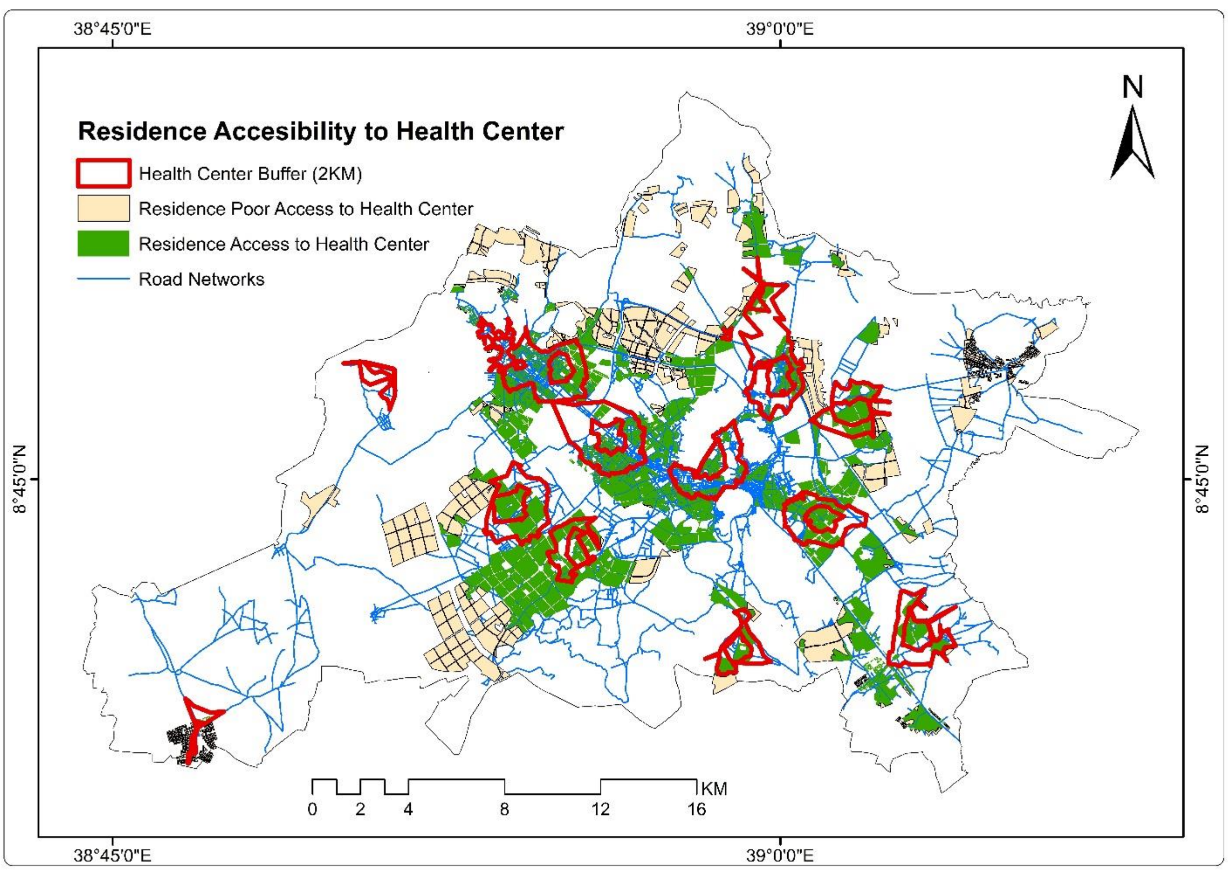

Figure 4-9: Residence accessibility to health center

An in-depth spatial accessibility analysis was conducted to evaluate the extent to which residential areas in Bishoftu City are served by existing health centers. A 2-kilometer service buffer was used as a standard threshold to define adequate accessibility, a benchmark commonly adopted in urban health infrastructure planning (Guagliardo, 2004). Based on the spatial overlay of residential areas and health center buffers, the analysis revealed a distinct inequality in accessibility distribution across the city.

Out of the total residential area analyzed, approximately 13,452.87 hectares representing 74.7% of the residential land are situated within the 2-kilometer buffer zone of existing health centers. This indicates that a significant portion of the city's population has relatively good physical access to healthcare services. However, the remaining 4,545.91 hectares, accounting for about 25.3% of residential land, lie outside the established service area. These regions are classified as underserved or having poor access to health centers.

The underserved areas are predominantly located in the peripheral parts of the city, where rapid urban expansion has not been matched with corresponding public infrastructure investment. Such spatial disparities highlight a critical gap in equitable service delivery, suggesting the need for targeted interventions. Expanding health infrastructure into these underserved areas particularly by using spatial planning tools such as location-allocation modeling would help minimize travel time and optimize health service coverage for the growing urban population.

4.3.4. Hospital Accessibility Analysis

The accessibility of hospital infrastructure plays a crucial role in urban health equity and emergency responsiveness. In this study, the spatial accessibility of hospitals in Bishoftu City was analyzed using a combination of distance-based and travel time-based impedance approaches. This dual-method framework provides a comprehensive understanding of how physical geography and transportation infrastructure affect the public's ability to reach hospital services.

The first layer of analysis was conducted using distance thresholds of 1 km, 2 km, 3 km, 4 km, and greater than 5 km, as illustrated in Figure 4-10. These distance bands were generated using the Euclidean distance tool and supplemented with network-based service area analysis in ArcGIS to account for road connectivity. According to the World Health Organization (WHO, 2010), access to hospital services within 5 km is considered essential in urban settings to ensure timely treatment, particularly during emergencies. The results show that while a substantial portion of the population resides within a 3 km range of hospitals, a significant number of households especially on the peripheries fall beyond the 5 km threshold. These underserved zones highlight spatial disparities in healthcare distribution.

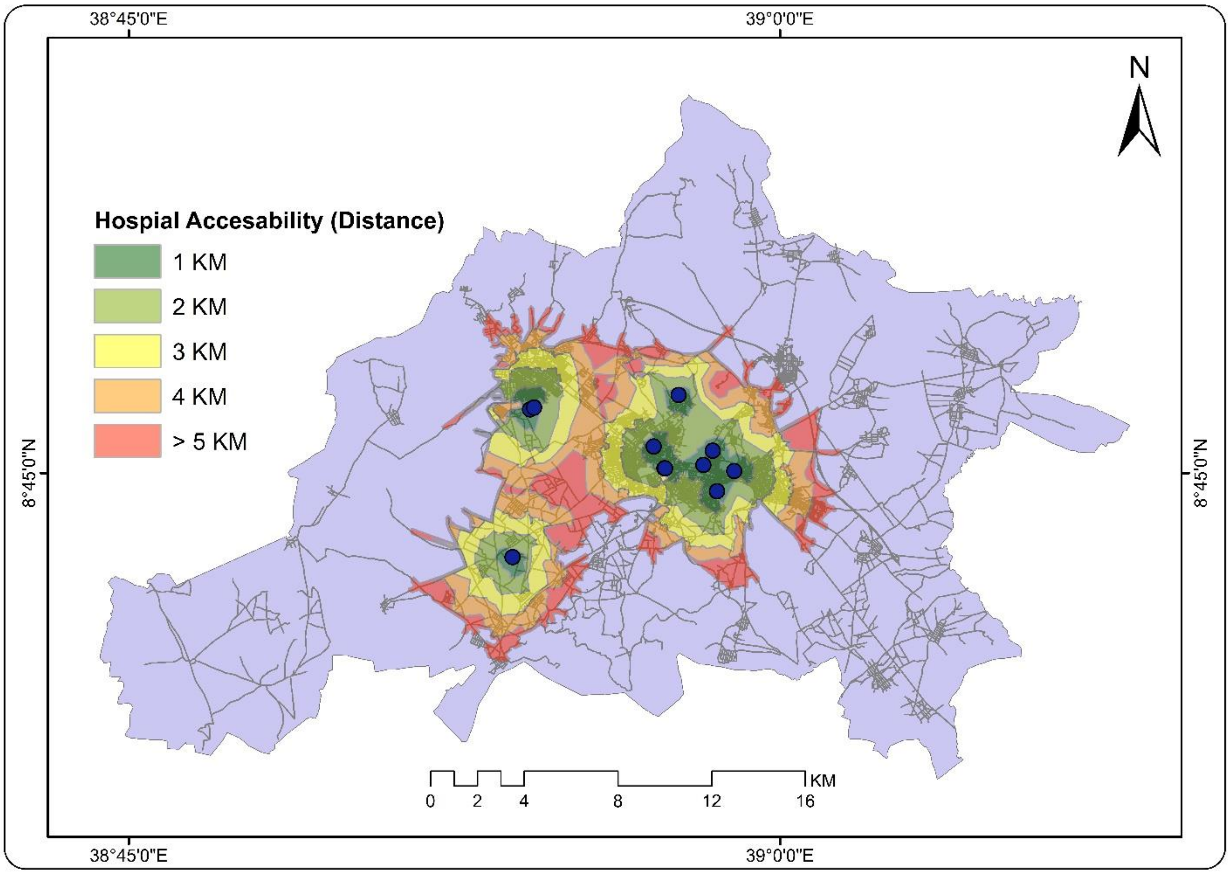

Figure 4-10: Hospital Accessibility with distance impedance

Beyond mere distance, travel time provides a more realistic reflection of accessibility, especially in cities where infrastructure conditions, traffic congestion, and road hierarchy influence mobility. As shown in Figure 4-11, service areas were generated based on travel time intervals of 20 minutes, 30 minutes, 1 hour, 2 hours, and more than 2 hours. This analysis incorporated the city's road network dataset, assigning average travel speeds depending on road type (e.g., primary roads at 60 km/h, secondary at 40 km/h). According to Guagliardo (2004), travel time is a more effective indicator of spatial access to healthcare, particularly in areas where transport networks are inconsistent. The results indicate that while central parts of the city can access hospitals within 20 to 30 minutes, many peripheral areas require up to an hour or more—exceeding the optimal time recommended by health accessibility standards (McGrail & Humphreys, 2009).

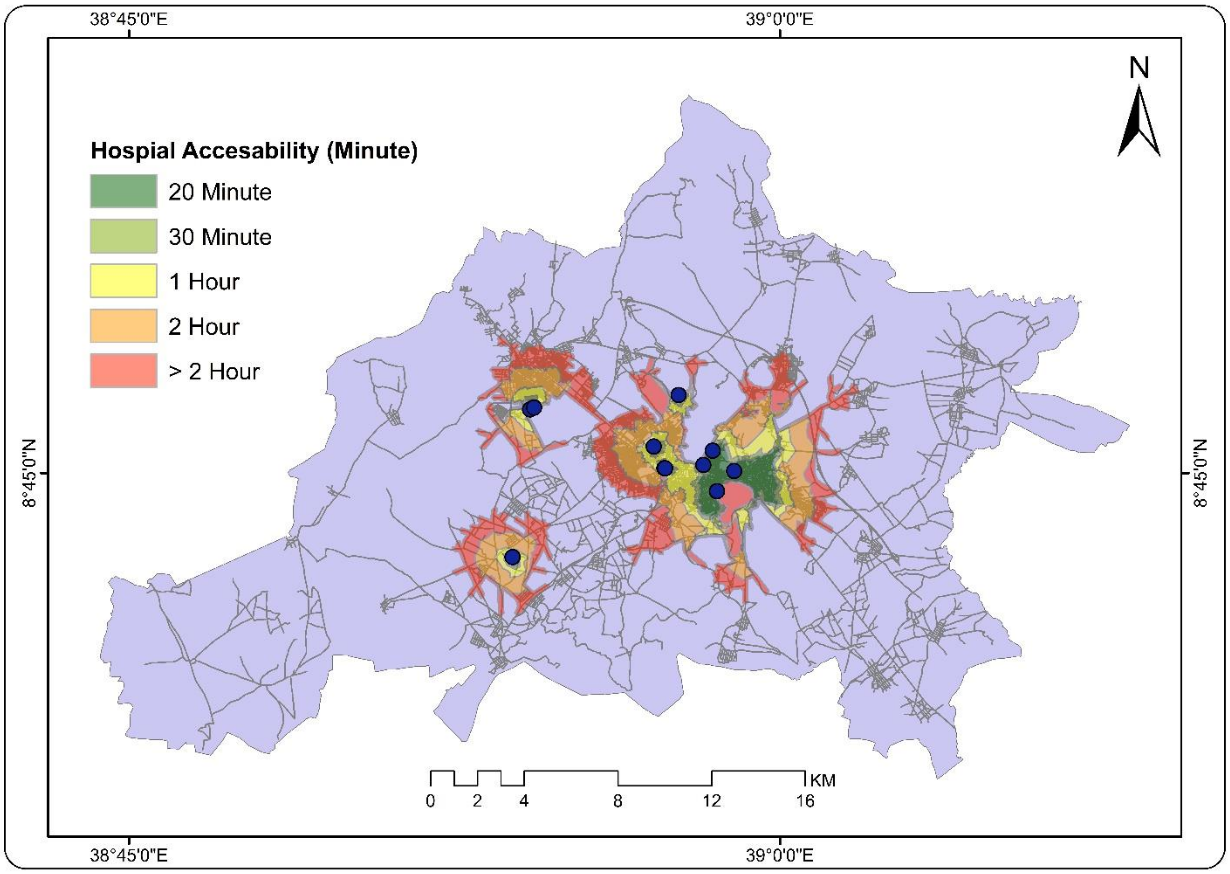

Figure 4-11: Hospital accessibility in terms of Minute

To further assess the strain on hospital infrastructure, a closest facility analysis was conducted using high-density population survey points as demand locations and hospitals as facilities. The network analyst tool in ArcMap was employed to determine the shortest route based on road network distances (Figure 4-12). This analysis not only calculates the most efficient travel paths from populated neighborhoods to nearby hospitals but also reveals which hospitals bear the highest load in terms of catchment population. In urban planning, understanding service burden is essential for future investment and decongestion strategies (Delamater et al., 2012).

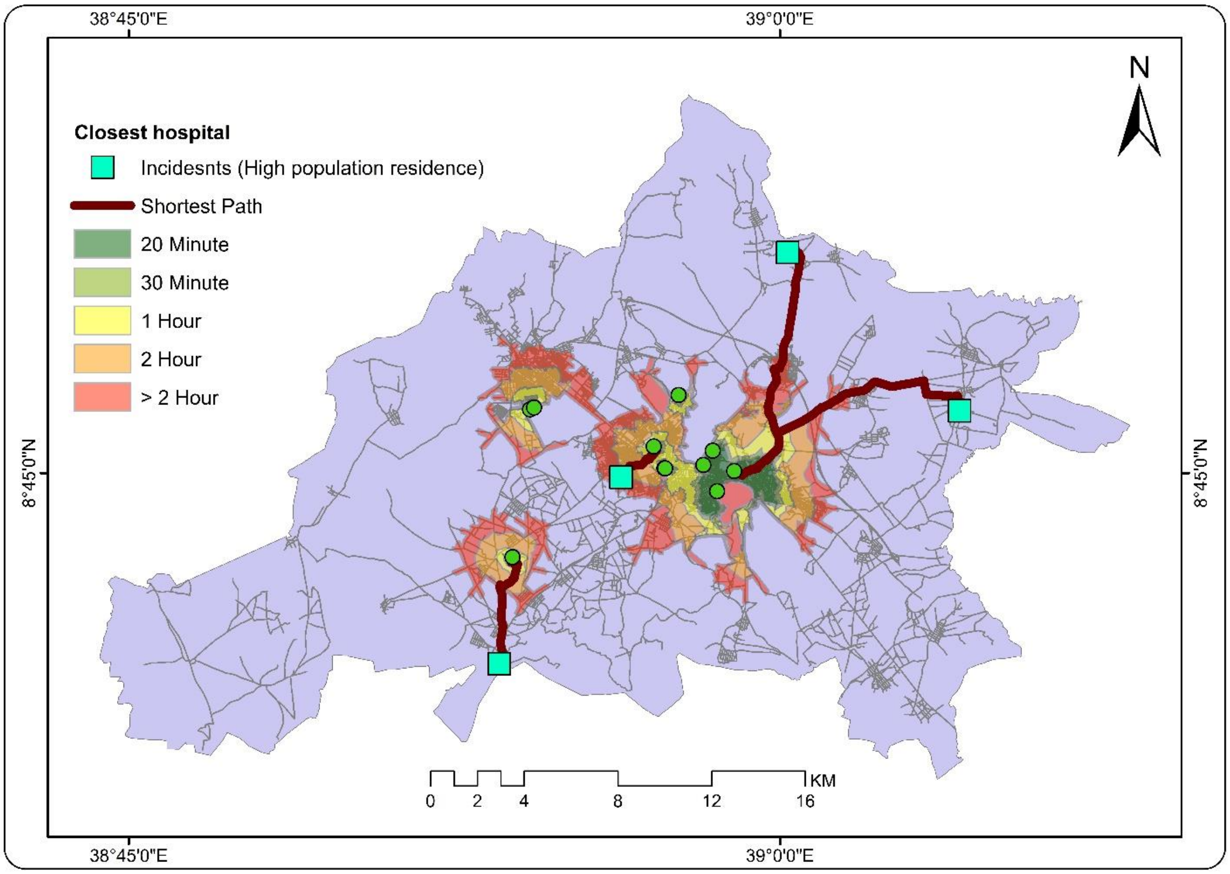

Figure 4-12: Closest Hospital that serves the high population residence areas

Following the identification of service gaps and overloaded hospitals, a location-allocation model was implemented to propose a new site for hospital infrastructure (Figure 4-13). This model seeks to optimize the placement of a new facility by minimizing the overall travel distance from demand points and redistributing service load. The result was the identification of an optimal site in the southeastern part of the city—an area currently characterized by limited healthcare coverage and high residential density. The placement is supported by quantitative thresholds from the literature, which recommend a hospital-to-population ratio of 1:100,000 and maximum access time of 30 minutes in urban environments (Talen & Anselin, 1998; WHO, 2010). The addition of a new hospital is projected to reduce service burden on existing facilities and improve access equity, thereby promoting a more resilient urban healthcare system.

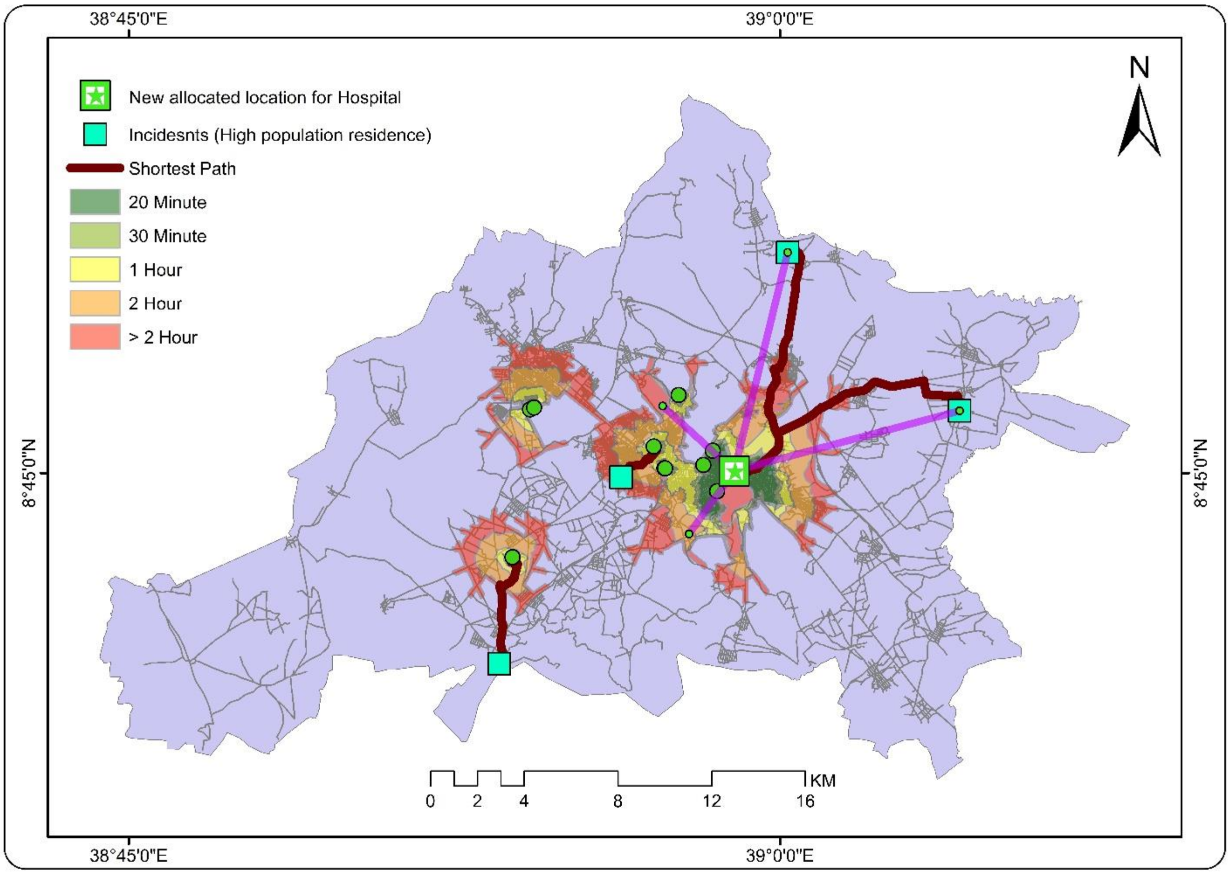

Figure 4-13: New hospital location allocation based on the population residence number

In terms of spatial coverage, the analysis reveals a significant disparity in residential access to hospital services across Bishoftu City. The total residential area with adequate access to hospital services (i.e., within recommended distance or travel time thresholds) amounts to approximately 6,445.25 hectares, while a much larger area about 26,445.25 hectares falls under the category of poor or no access to hospitals. This indicates that only about 19.6% of the residential area is currently served by hospitals under optimal accessibility standards, whereas the remaining 80.4% of the urban residential landscape remains underserved.

This spatial inequity in hospital access raises serious public health concerns, especially in the context of emergency medical situations where time is critical. The findings are in line with global studies which suggest that in rapidly urbanizing areas of developing countries, healthcare facilities often lag behind residential growth, resulting in service bottlenecks (Guagliardo, 2004; Noor et al., 2006). These results also strongly justify the necessity for strategic health facility expansion, including the establishment of a new hospital in the southern and peripheral sections of the city, as identified by the location-allocation model.

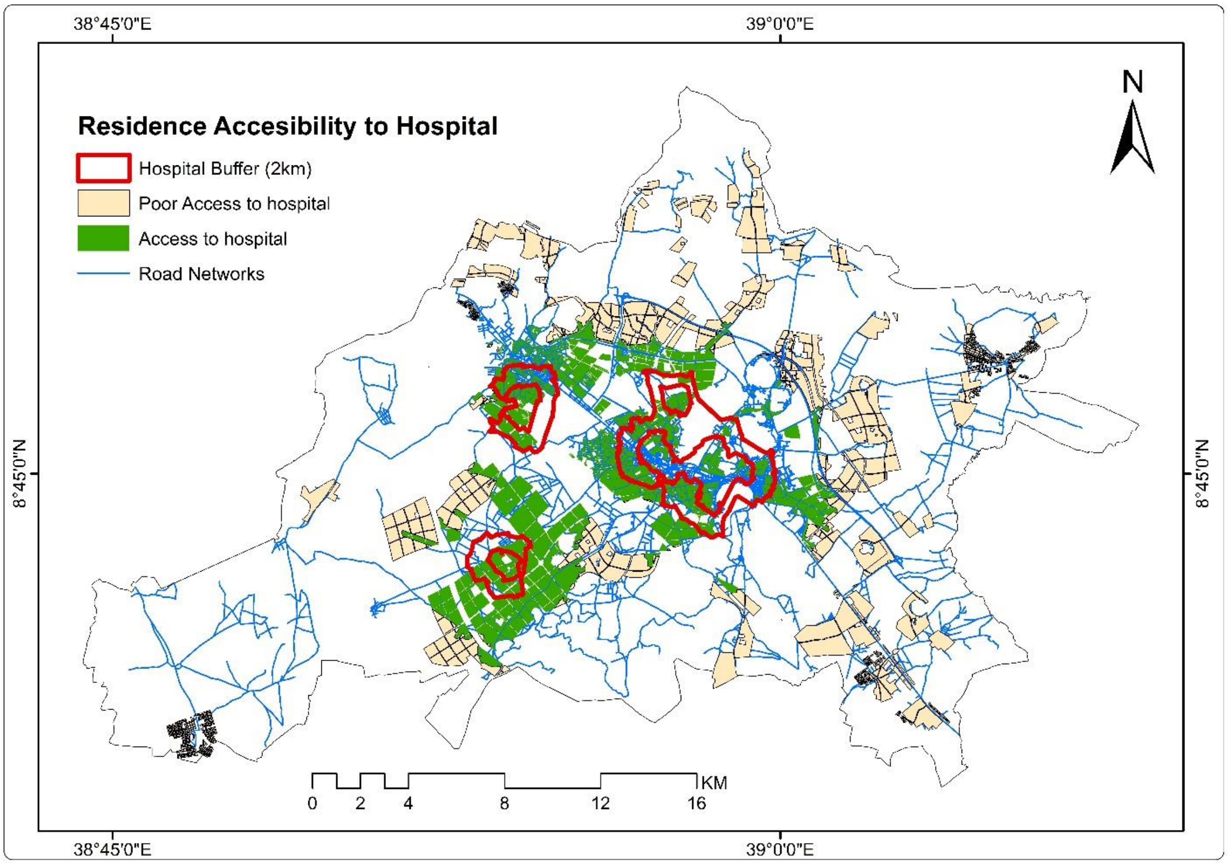

Figure 4-14: Residence accessibility to hospital

4.3.5. Kinder Garden Accessibility

The spatial accessibility of kindergartens in Bishoftu was analyzed using both distance and time impedance parameters to assess how well the facilities serve the residential population. As shown in Figure 4-15, the distance-based accessibility mapping was conducted using buffer thresholds of 1 km, 2 km, 3 km, 4 km, and >5 km. The results indicate that a considerable number of kindergarten facilities are located within the central and moderately dense urban neighborhoods, enabling relatively better proximity-based access for households living within 1–3 km radii. However, several peripheral residential zones particularly in the western and southern parts of the city lie beyond the 4 km threshold, suggesting these areas are underserved in terms of early childhood education facilities.

In addition, Figure 4-16 illustrates the time-based accessibility to kindergartens, analyzed using thresholds of 10, 20, 30 minutes, 1 hour, and >1 hour walking or travel time. The results show that most urban residents can reach a kindergarten within 20 to 30 minutes of travel time, especially those situated near well-connected road networks. However, some residential clusters, particularly on the city's outskirts, fall into the >30 minutes to 1 hour category, reflecting mobility constraints due to poor road conditions, disconnected transport systems, or lack of nearby facilities.

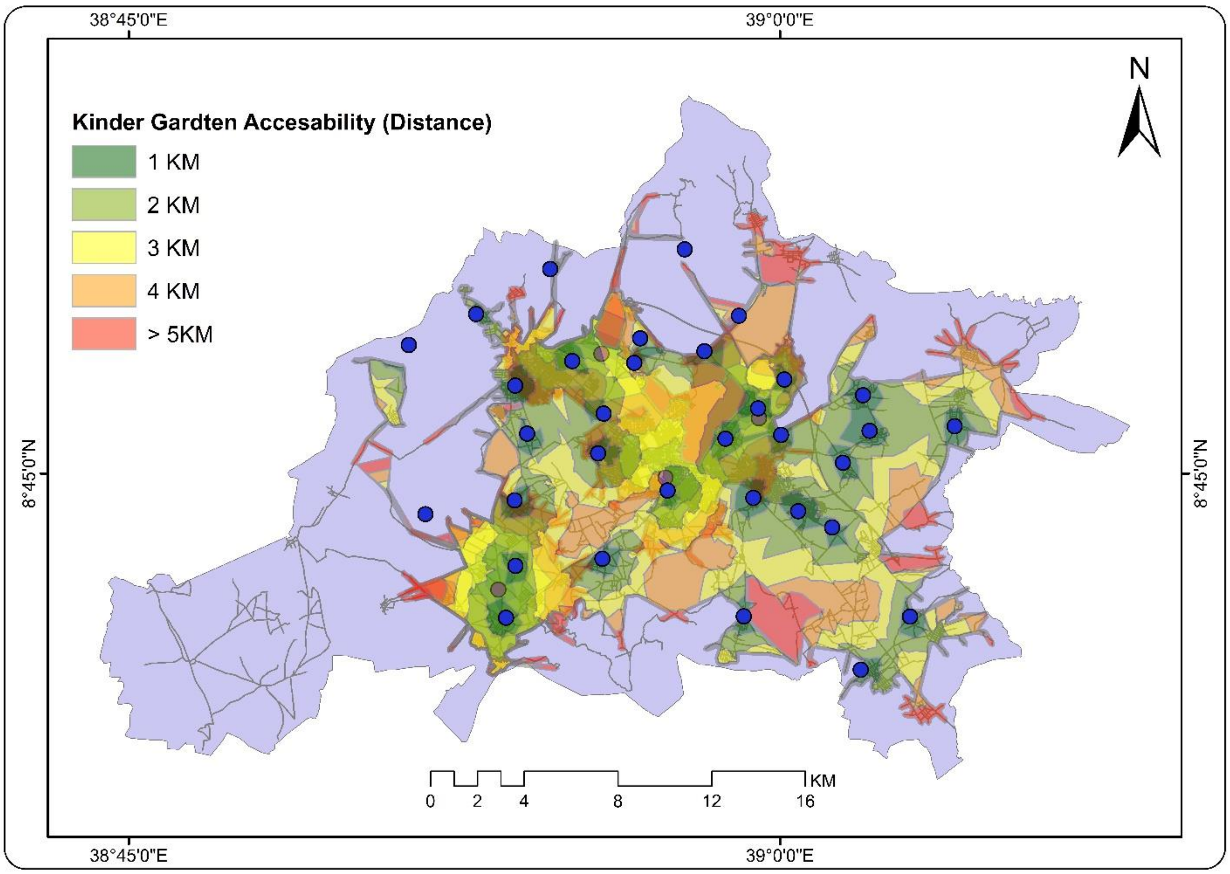

Figure 4-15: Kinder Garden Accessibility in terms of distance

This spatial pattern aligns with existing research that emphasizes how educational infrastructure access is highly dependent on both geographic proximity and transportation efficiency (Talen, 2001; Wu et al., 2014). Moreover, the importance of ensuring access to kindergartens within walking distance is echoed in child-centered urban planning principles, which advocate for facilities to be located within 1–2 km walking distance in urban settings (UN-Habitat, 2013). Therefore, the observed accessibility disparities highlight the need for targeted planning interventions to improve kindergarten coverage in the city's expanding residential zones, especially in newly developed or peri-urban areas.

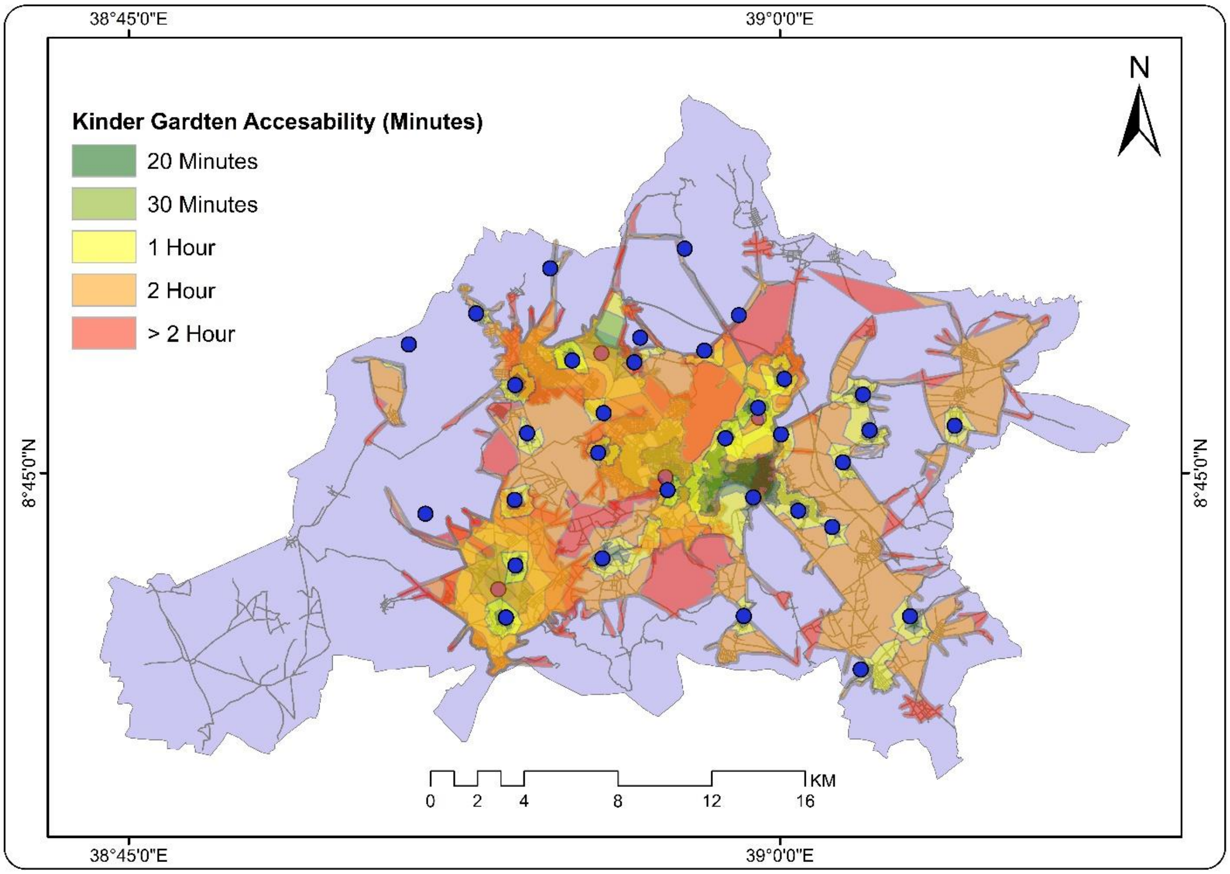

Figure 4-16: Kinder Garden Accessibility in terms of time (minutes)

Based on the accessibility analysis of kindergarten facilities in the study area, the spatial distribution clearly reveals disparities between areas with and without adequate access. The total residential area with access to kindergarten infrastructure amounts to approximately 12,633.93 hectares, while areas without access cover around 2,633.93 hectares.

This result highlights that while the majority of the city's population has reasonable proximity to kindergarten services, a significant portion—roughly 17% of the total residential area—remains underserved. These underserved zones are primarily located on the periphery of the city, where rapid urban expansion has outpaced the provision of public services such as early childhood education.

This spatial inequality is consistent with findings from other urban settings where education infrastructure fails to keep up with horizontal urban growth (Delbosc & Currie, 2011; Talen, 2001).

Furthermore, distance and time impedance modeling reveal that many peripheral households fall beyond the 2 km and 30-minute thresholds that are often cited as standards for walkable access to schools and childcare facilities (UN-Habitat, 2013).

These gaps suggest the need for strategic planning interventions, including the allocation of new kindergarten sites in underserved neighborhoods and improvement of road networks to facilitate better travel efficiency. Doing so would ensure equitable access to early education, which is essential for promoting inclusive urban development and supporting working families, particularly those in low-income, high-density areas.

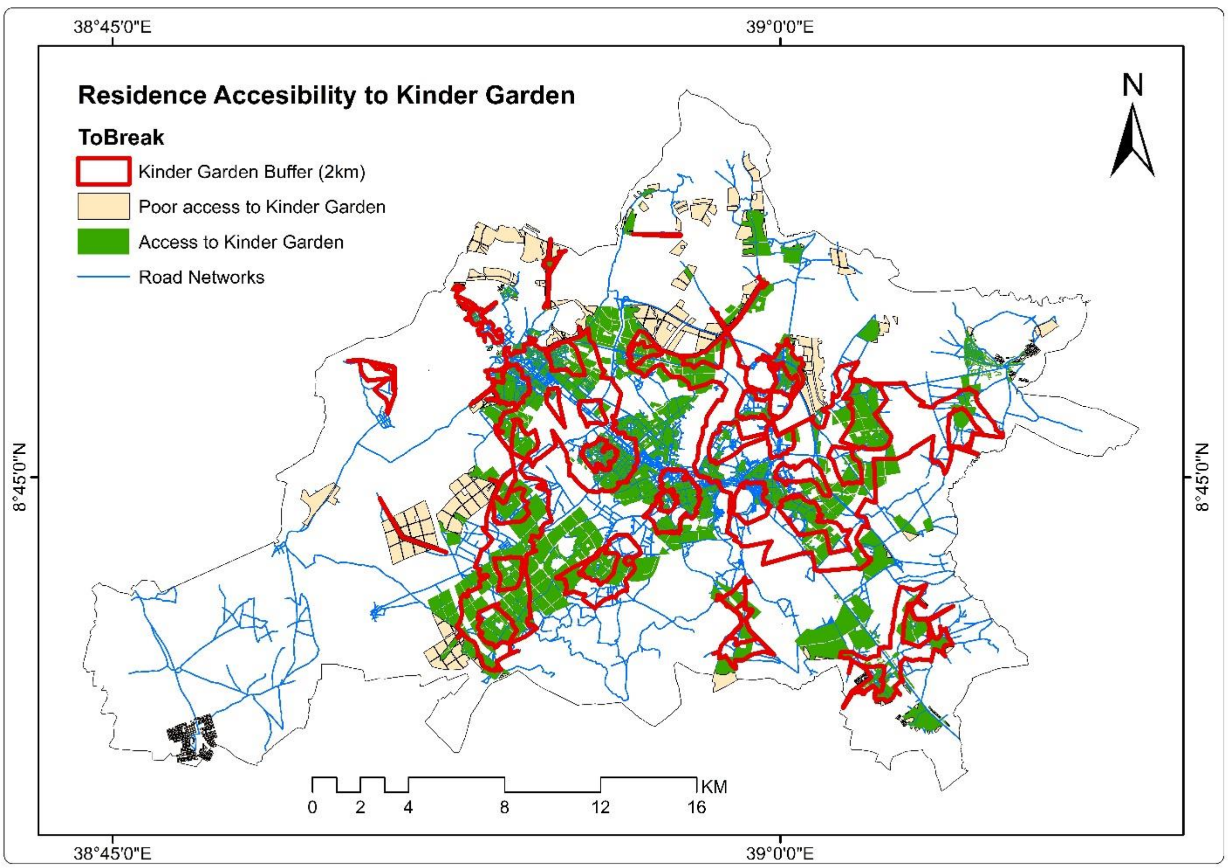

Figure 4-17: Residence accessibility to Kinder Garden

4.3.4. Play Ground accessibility

The accessibility analysis for playgrounds using both distance and time impedance reveals notable disparities in service distribution across the city. As depicted in Figure 4-18, playground access was evaluated using a series of distance thresholds: 1 km, 2 km, 3 km, 4 km, and greater than 5 km. Correspondingly, Figure 4-19 illustrates time-based accessibility, with thresholds set at 10 minutes, 20 minutes, 30 minutes, 1 hour, and >1 hour using the road network.

The spatial pattern shows that most of the playgrounds are concentrated in the central and inner urban areas, providing easy access to residents within a 1–2 km or 10–20 minute travel range. However, a substantial portion of residential neighborhoods, especially in the outskirts of the city, falls beyond the 3 km or 30-minute travel threshold. These zones reflect low accessibility to recreational services, which contradicts urban livability standards that recommend recreational facilities be located within a 10–15 minute walking distance (approximately 800–1,200 meters) (WHO, 2016; Talen & Anselin, 1998).

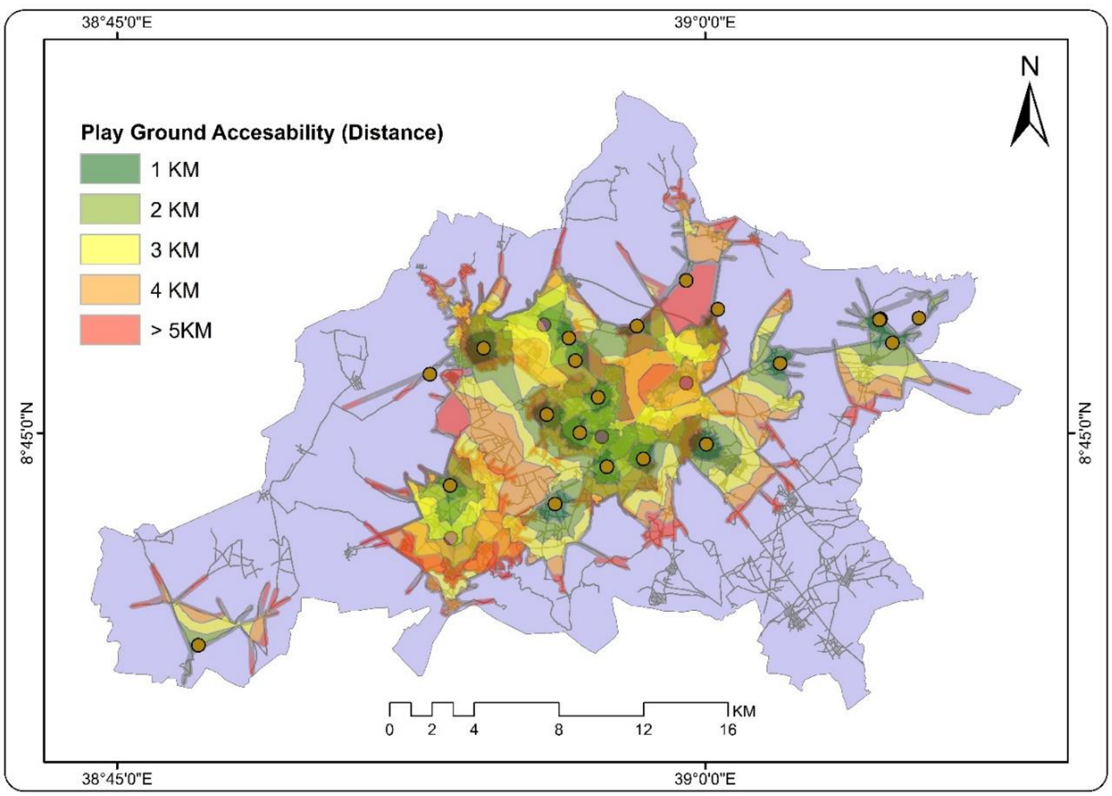

Figure 4-18: Playground accessibility in terms of distance

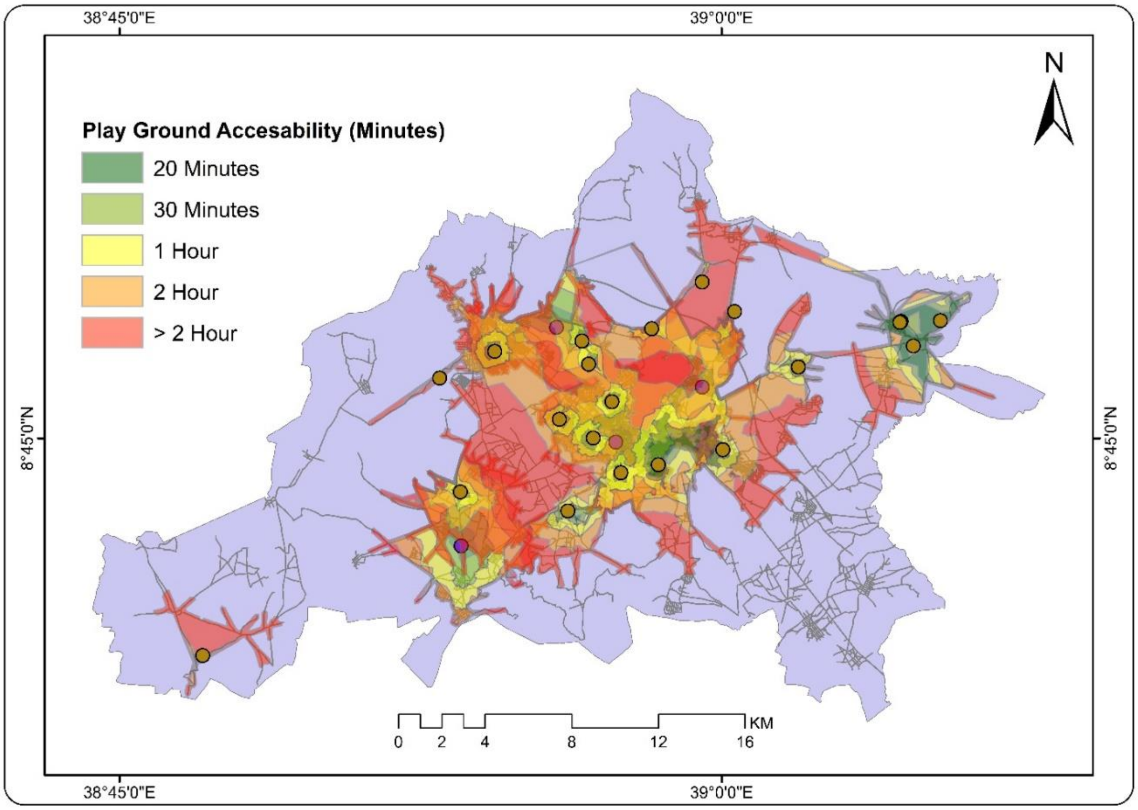

Figure 4-19: Playground accessibility in terms of time (minutes)

The accessibility analysis for playgrounds, based on both distance and time impedance, provides key insights into the spatial equity of recreational services across the city. According to the accessibility data, a total of 14,253.37 hectares of residential area fall within acceptable accessibility ranges to playgrounds either in terms of proximity (distance) or travel time. Conversely, 4,292.58 hectares of residential land are categorized as having poor or no access to playgrounds.

This distribution aligns with the patterns visualized in Figure 4-18 and Figure 4-19. Figure 4-18 shows accessibility based on distance thresholds (1 km, 2 km, 3 km, 4 km, >5 km), while Figure 4-19 uses time thresholds (10 minutes, 20 minutes, 30 minutes, 1 hour, >1 hour) using the urban road network. The figures indicate that playgrounds are mainly clustered in central urban areas, providing short-distance and low-time access to inner-city residents. In contrast, residents in peripheral neighborhoods often lie beyond the 3 km or 30-minute mark, placing them at a disadvantage when it comes to reaching these facilities.

This discrepancy reflects spatial inequality, where urban fringe communities often characterized by lower infrastructure investment experience a deficit in child-friendly and inclusive public spaces. According to Wolch, Byrne, & Newell (2014), lack of access to recreational green spaces like playgrounds can limit children's physical activity, mental well-being, and social development. Similarly, Rigolon (2016) emphasized that spatial accessibility to urban green and play spaces is a key determinant of urban quality of life, particularly for low-income households and children.

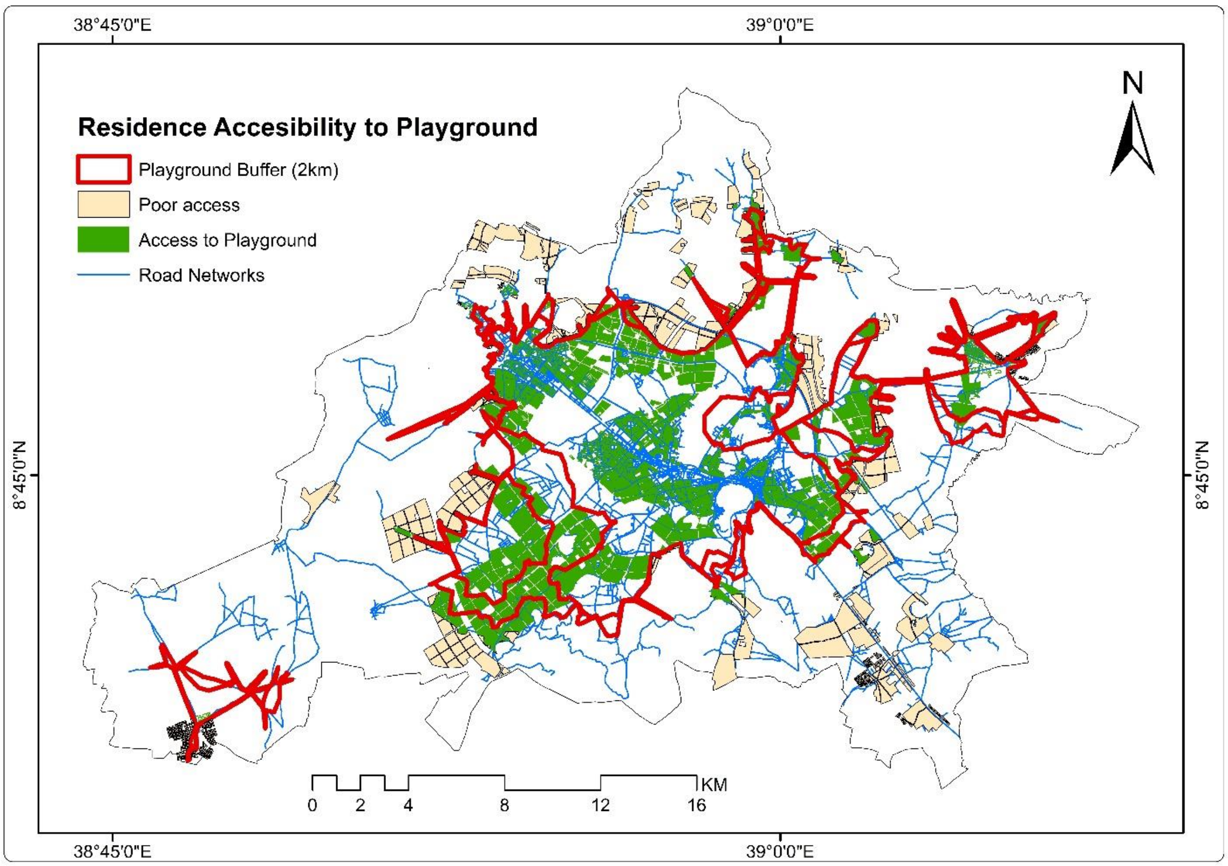

Figure 4-20: Residence accessibility to playground

4.3.5. School accessibility

The accessibility analysis of schools using both distance and time impedance provides important insights into how well educational services are distributed across the city. Based on Figure 4-21, which reflects distance-based accessibility, schools were evaluated in terms of their proximity to residential areas using buffer zones of 1 km, 2 km, 3 km, 4 km, and beyond 5 km. The results show that a majority of the school facilities are concentrated within the central and semi-urban areas of the city. Consequently, residents in the city center typically enjoy good access to educational facilities, with many schools falling within a walkable range of less than 2 km. However, as urban expansion has pushed residential settlements toward the periphery, a considerable number of residents in these areas now fall outside the 3 km and even 5 km buffer zones.

Figure 4-22, which represents time-based accessibility, further highlights the unequal distribution of educational services by mapping travel time to schools. This analysis, which considers the actual road network and travel conditions, categorizes accessibility based on estimated durations of 10, 20, 30 minutes, 1 hour, and over 1 hour. Residents in the central areas generally benefit from short travel times often within 10 to 20 minutes due to the denser road networks and closer proximity of schools. However, the situation is starkly different in peripheral zones, where travel time often exceeds 30 minutes and, in some cases, even reaches over 1 hour.

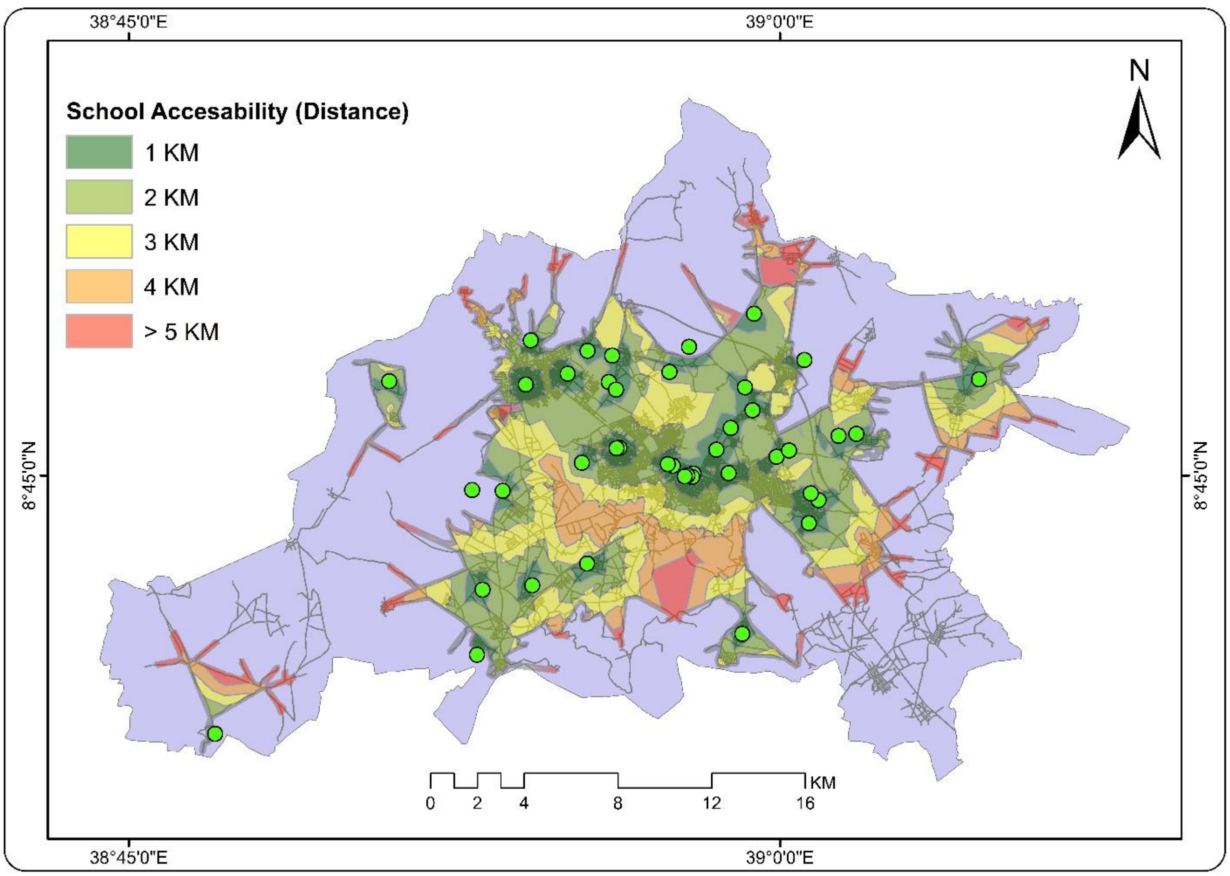

Figure 4-21: School accessibility in terms of distance

The analysis clearly reveals the spatial inequality in access to schools, with a significant proportion of the population particularly those living in the newly developed or less planned outskirts of the city experiencing substantial barriers to accessing education. According to international standards and best practices in urban planning, such disparities are concerning. Literature suggests that lack of nearby schools and long travel times can negatively impact educational outcomes, leading to higher dropout rates and lower academic performance.

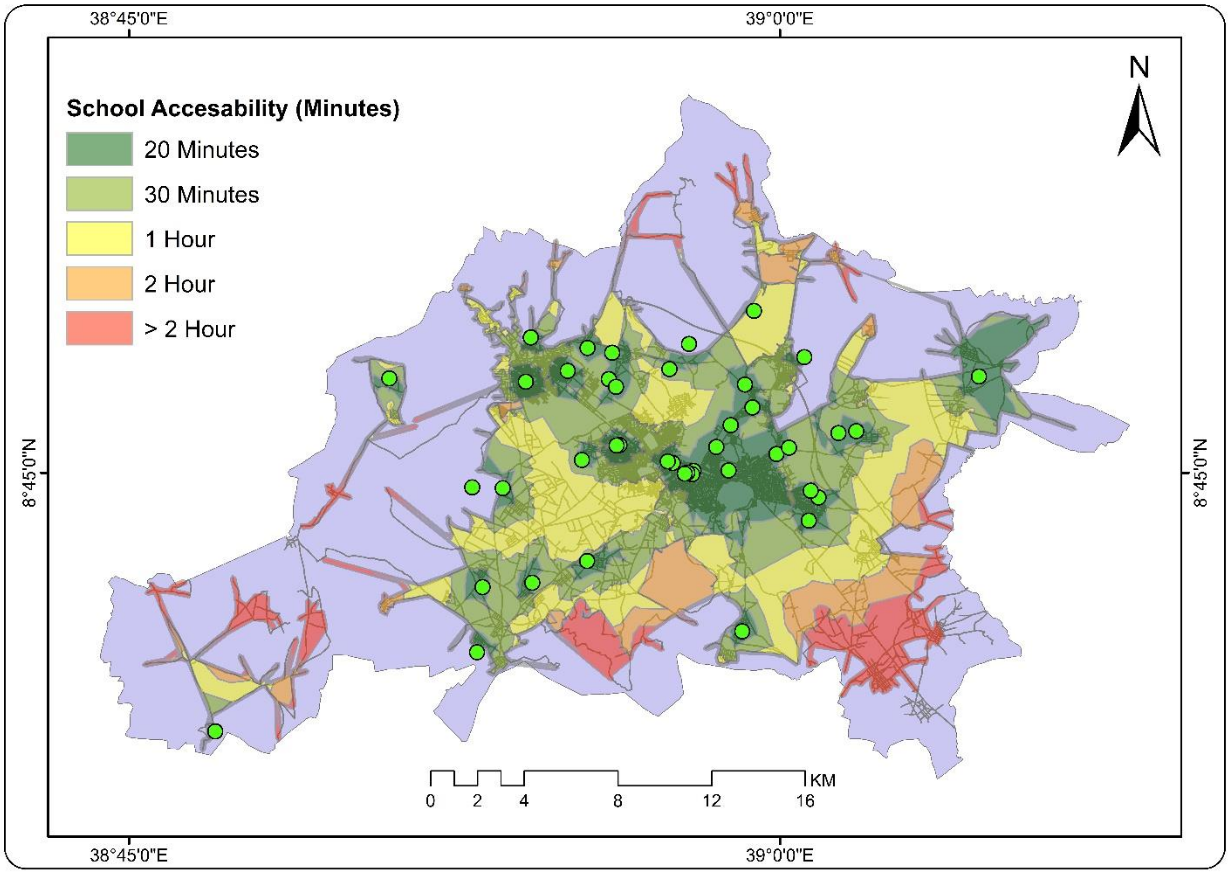

Figure 4-22: School accessibility in terms of time

Based on the accessibility analysis, the spatial distribution of schools within the study area reveals both strengths and gaps in educational service provision. The results show that approximately 16,458.81 hectares of residential areas fall under good accessibility to schools, while about 3,746.47 hectares are categorized as poorly accessible. This disparity reflects significant variation in service availability between central and peripheral parts of the city.

From a distance impedance perspective (Figure 4-21), accessibility was evaluated using buffer zones at 1 km, 2 km, 3 km, 4 km, and >5 km thresholds. The analysis indicates that the majority of schools are situated within a 1–3 km range from residential clusters in the urban core, where educational infrastructure is relatively well-established. However, several residential areas, particularly those located on the city's outskirts, fall outside the 4 km and 5 km buffers. These communities are therefore underserved in terms of proximity to schools, necessitating long-distance travel by students, which may pose logistical and safety challenges, especially for younger children.

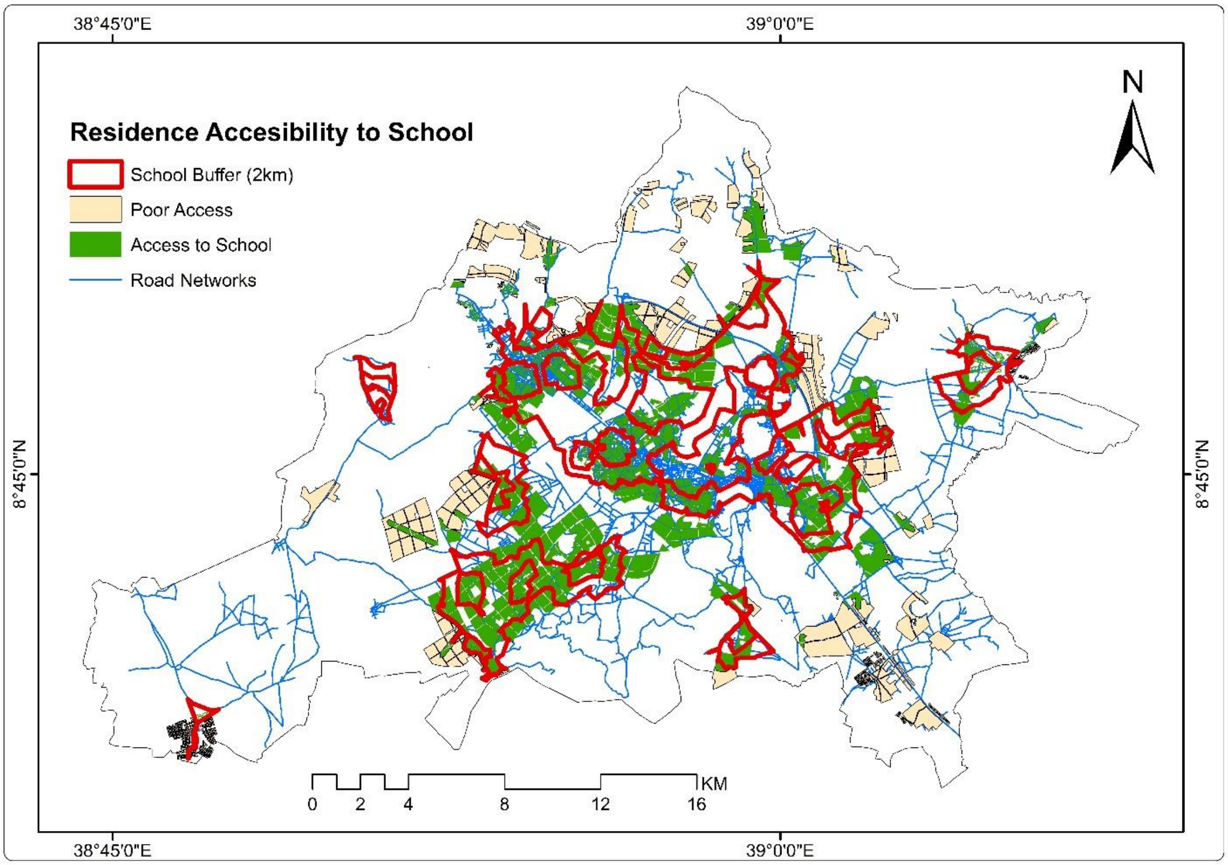

Figure 4-23: Residence accessibility to school

In terms of time impedance (Figure 4-22), travel time to schools was calculated based on road network conditions, incorporating realistic movement constraints. The time zones were classified into 10, 20, 30 minutes, 1 hour, and >1 hour. This analysis mirrors the distance-based findings, with inner-city areas typically accessible within 10 to 20 minutes. In contrast, peripheral areas experience longer travel durations sometimes exceeding 30 minutes to 1 hour indicating substantial barriers to timely school access.

This gap in accessibility highlights the need for strategic educational infrastructure planning. Scientific literature emphasizes that convenient access to schools ideally within 1 to 2 km or under 20 minutes is crucial for promoting school attendance, especially in low-income urban neighborhoods.

4.4. Discussion

The assessment of the spatial distribution of urban infrastructure in Bishoftu City corroborates existing research highlighting the prevalence of uneven urban development in many mid-sized cities across developing countries. As found in studies by Rodrigue et al. (2017), urban infrastructure tends to be concentrated in central business districts and affluent neighborhoods, which often results in peripheral urban and peri-urban areas facing infrastructure deficits. This spatial imbalance impacts not only access to basic services but also contributes to social and economic disparities (UN-Habitat, 2020). Bishoftu's situation, revealed through geo-spatial technologies, underscores the persistent challenge of managing rapid urban growth while striving for inclusive development, a concern echoed in urban studies globally (Seto et al., 2014).

Spatial and network analysis used in your study to evaluate infrastructure accessibility aligns with methodologies used in similar contexts worldwide. For example, a study by Geurs and van Wee (2004) discusses how network-based accessibility measures provide a nuanced understanding of how well populations can reach services and amenities. In Bishoftu, the longer travel distances and poor connectivity in outlying areas echo findings by Bhat and Guo (2007), who showed that transportation infrastructure disparities directly affect equitable access to urban services. Moreover, accessibility issues are linked to urban sprawl, a phenomenon described by Ewing (1997) as a driver of inefficiency and inequality in urban infrastructure provision.

The identification of infrastructure gaps and inequalities also reflects broader discourses on urban resilience and sustainability. Scholars like Parnell and Oldfield (2014) emphasize the necessity of targeted interventions to bridge these gaps, especially in the Global South, where rapid urbanization often outpaces infrastructure development. The smart city approach advocated in your study aligns with contemporary urban governance frameworks that utilize spatial data to enhance decision-making (Hollands, 2008). According to Komninos (2013), the integration of geo-spatial technologies within smart city frameworks can enable dynamic monitoring and adaptive planning, facilitating more equitable urban service distribution.

Furthermore, this research resonates with literature stressing the importance of participatory GIS and community engagement in addressing urban infrastructure inequalities (Elwood, 2006). Geo-spatial analyses provide the technical foundation, but sustainable improvements depend on incorporating local knowledge and stakeholder input, as highlighted by Sieber (2006). This approach ensures that smart city initiatives do not merely impose top-down solutions but reflect the lived realities of all urban residents.

In addition, the use of geo-spatial technologies for infrastructure assessment supports findings from international organizations advocating for spatially explicit urban planning. The World Bank (2019) has underscored the value of GIS-based infrastructure mapping in improving urban service delivery and monitoring. Likewise, the African Development Bank (2018) promotes spatial analytics to address infrastructure deficits in rapidly urbanizing African cities, making your study particularly relevant in regional development contexts.

The findings of this study align closely with international frameworks that advocate for inclusive, sustainable, and smart urban development. In particular, the United Nations' Sustainable Development Goal 11 (SDG 11) emphasizes the need to "make cities and human settlements inclusive, safe, resilient and sustainable," highlighting equitable access to basic services and infrastructure as a core target (UN, 2015). Your research's identification of infrastructure disparities and accessibility gaps in Bishoftu supports the SDG 11 agenda by providing spatially explicit evidence necessary for targeted interventions. Moreover, the New Urban Agenda (NUA), endorsed at Habitat III in 2016, calls for leveraging geo-spatial technologies and data-driven approaches to enhance urban planning, governance, and service delivery—principles directly reflected in your application of spatial and network analyses to diagnose infrastructure inequalities (UN-Habitat, 2017). Integrating your findings with these global frameworks underscores the critical role of geo-spatially informed strategies in advancing equitable and smart city development in line with internationally recognized urban sustainability and inclusivity goals.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1.Conclusion

The study's spatial analysis using geo-spatial technologies revealed that urban infrastructure in Bishoftu City is heavily concentrated within the central urban core, while the peripheral and suburban areas experience significant shortages in infrastructure facilities. This pattern of uneven spatial distribution reflects common trends observed in rapidly growing cities, where infrastructure development tends to prioritize central business districts and older neighborhoods, often at the expense of outlying communities. Such centralization creates pockets of infrastructural abundance juxtaposed with areas of relative deprivation, which can perpetuate social and economic inequalities.

The network and spatial accessibility analysis demonstrated substantial differences in how residents of Bishoftu can reach essential services such as healthcare, education, public transportation, and utilities. While the central areas enjoy relatively high accessibility with shorter travel times and well-connected networks, residents in peripheral neighborhoods face longer distances, inadequate road networks, and limited public transit options, resulting in reduced access to critical services. This limited accessibility can exacerbate vulnerabilities, hinder socio-economic development, and restrict opportunities for residents in less connected parts of the city. The findings highlight the importance of integrating transport and infrastructure planning with spatial accessibility considerations to improve connectivity and ensure that infrastructure services are equitably distributed.

By identifying clear gaps and inequalities in infrastructure availability and accessibility, this study underscores the critical role of geo-spatial technologies in diagnosing urban service delivery challenges and informing smart city development strategies. The spatially explicit findings serve as a foundation for evidence-based urban planning interventions aimed at bridging the infrastructural divide within Bishoftu. Incorporating these insights into policy formulation can help prioritize infrastructure investments in underserved areas, improve service delivery efficiency, and promote equitable access to urban amenities.

5.2.Recommendations

- Prioritize infrastructure investments in peripheral and underserved areas to reduce spatial inequalities in Bishoftu City.
- Expand and upgrade road networks and public transport to improve accessibility to key services across all city neighborhoods.
- Integrate geo-spatial technologies into urban planning for data-driven, real-time decision-making and smart city development.
- Strengthen institutional frameworks to promote data sharing, collaboration, and transparent urban governance.

5.3.Implications for future research

For future research, it is essential to integrate socio-economic and demographic data with geo-spatial analyses to deepen the understanding of urban inequalities in Bishoftu. Longitudinal studies tracking changes in infrastructure and accessibility over time would help evaluate the impact of planning interventions. Additionally, exploring emerging technologies like IoT and machine learning could enhance real-time infrastructure monitoring within smart city frameworks. Comparative studies with other similar cities, as well as participatory GIS research involving local communities, would further support inclusive and context-specific urban planning. Finally, investigating the environmental resilience of infrastructure is critical given the increasing climate challenges faced by rapidly growing cities.

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