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Research Article

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Development of GIS-Based Intelligent Transport System for Abuja Metropolis, Federal Capital Territory, Abuja

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Abstract The efficient transportation system is crucial for a nation's socio-economic progress. However, the Abuja metropolis faces challenges such as poor management and inadequate facilities due to a significant portion of commuters residing in rural satellite towns with limited amenities and employment opportunities. This study aims to develop a GIS-based Intelligent Transport System (ITS) for Abuja, Federal Capital Territory, Nigeria, to improve transportation effectiveness. The study's objectives include acquiring and processing relevant road network and transportation facility data to build a transportation geodatabase, designing a robust ITS framework that incorporates route optimization, closest facility analysis, service area analysis, location allocation, and origin-destination cost matrix analysis, and demonstrating the system's effectiveness through modeled scenarios.

The methodology involves data acquisition, database design, and creation, and various analyses, such as route optimization, closest facility assessment, service area analysis, location allocation, and origin-destination cost matrix analysis. The study applied the ITS to optimize a waste collection route, reducing it from 40km to 38km. It also examined medical facility accessibility during road accidents, identifying the three closest medical facilities. The service area analysis of road-mounted CCTV cameras revealed coverage patterns. An OD Cost matrix analysis determined the shortest distances for food delivery routes. Implementing an ITS in the study area is recommended as it can enhance transportation by optimizing routes, improving efficiency, and providing critical information on emergency medical facility access, telecommunication service coverage, and courier delivery route optimization. An effective transportation system is essential for Abuja's development and overall quality of life.

Keywords: Abuja, GIS, ITS, Network Analysis, Transportation,

1.Introduction

GIS-based road information management system applications are currently used broadly by transportation analysts and decision makers in different areas of transportation planning and engineering, infrastructure planning, design and management, traffic safety analysis, transportation impact analysis, public transit planning and operations to intelligent transportation systems (ITS) such as Advanced Traveller Information Systems (ATIS) and Commercial Vehicle Operations (CVO) (Vonderohe, Travis, Smith and Tsai, 1993). Road transport information system is the system that collects, organises and stores data about the road network, and provides facilities for reports to be produced on these data, in a variety of formats (Robinson, Danielson, and Snaith, 1998). GIS techniques can be used in organizing and integrating Road Transport Information such as road inventory, traffic statistics, construction, maintenance data, etc. The road transport agency in the French department de la Loire has been using GIS since 1989 for many purposes: Traffic accident patterns are visualised and safety improvements are made where they are most needed.

Road transport is by far the most dominant mode of transport in Nigeria, carrying well over 90% of passenger and freight traffic and serving as a true backbone for Nigeria's economy (TRB, 2004). Nigeria has the largest road network in West Africa and the second largest south of the Sahara, with roughly 108,000 km of surfaced roads in 1990 (67,112 miles) of roads. Of this total, 30,000 kilometers (18,642 miles) were paved, 25,000 kilometers (15,535 miles) were gravel, and 53,000 kilometers (32,935 miles) were unimproved earth (Sunday R. Thlakma, 2014). Much of the road system is in disrepair and barely usable. The roads are poorly maintained and are often cited as a major cause for the country's high rate of traffic fatalities. This led to the establishment of Federal Road Maintenance Agency (FERMA) in 2002 during the administration of President Olusegun Obasanjo. In a quest to facilitate the transportation of goods and services, decision-makers in governments and international organizations are faced with difficult challenges such as insufficient or inadequate transport infrastructures, bottlenecks and missing links, as well as lack of funds to remove them. Solving these problems is not an easy task, it requires action on the part of the governments concerned, actions that are coordinated with other governments at international level (UNECE, 2008).

Transportation is one of the fastest growing in many fields in which GIS is applied (Rodrigue *et al*, 2006). Diverse areas of transportation, including high-way and rail-way infrastructure management, international shipping, airport management, fleet logistics, traffic management and intelligent transportation systems (ITS), transit bus and rail service planning, transportation modelling, supply chain modelling, and others, are applying GIS to their work (ESRI, 2003). The breadth of the field in the integration of GIS and transportation system provides large opportunities for the development of new and innovative applications in transportation system of different transportation organizations (Curtin *et al*, 2003). Since GIS has a seamless relation with space and location, given that their main objective as a tool is to store, retrieve, and facilitate the analysis of spatial data (Goodchild and Janelle, 2004), they have become one of the most powerful tools to support transportation studies and applications. The liaison between GIS and transportation is indeed quite natural, given that transportation itself is linked to space organization on the development of networks in space and time, just like geography itself (Haggett, P. and Chorley, R. J., 1969). GIS technology serves three distinct transportation needs: infrastructure management, fleet and logistics management, and transit management. It can also be used to integrate mapping analysis into decision support for network planning and analysis, vehicle tracking and routing, asset management, inventory tracking, route planning and analysis, and everything in between (TRB, 2004). The prospective growth of the volume of traffic intensity, its impact on the infrastructure and the economy, as well as the impact on human lives, requires proper management of the transport system. The creation of the integrated intelligent transport system requires the application of a comprehensive approach which should include the mechanism of state management, the relevant road infrastructure and an intelligent information system to manage the transport system (Olga Katerna, 2016).

According to Jonkers and Gorris (2015), Intelligent Transport System (ITS) and traffic management are instruments that enable operators of urban transport networks to manage traffic and transport to meet policy goals. The applications of ITS includes telematics and all types of communications in vehicles, between vehicles (e.g. vehicle-to-vehicle), and between vehicles and fixed locations (e.g. vehicle-to-infrastructure). Intelligent transportation systems (ITSs) have two key elements: intelligence and integration. The first is characterized by knowledge discovery made possible by better access to data and advanced data-analysis techniques, while the second is the understanding of how to use that data to manage the elements of the system more efficiently (Daiheng Ni, 2016). ITS and traffic management applications help cities to achieve policy goals with regard to accessibility, livability and safety, accelerated by technology and ICT developments. The possibilities of using ITS and traffic management in urban environments have increased substantially in the past decade. European cities are facing a number of challenges that are related to transportation and the economic costs of traffic congestion are estimated to be 80 billion Euros annually (European Commission, 2013). In Europe, the Urban areas account for 23% of all carbon dioxide (Co_2) emissions from transport and 38% of road fatalities, with vulnerable users such as pedestrians being particularly exposed (European Commission, 2013). Other transportation challenges are related to the robustness and reliability of the public transportation system and increasing parking demands. With high population densities and a high share of short-distance trips, there is a great potential for cities to contribute to reducing greenhouse gas emissions from transport by 60% by 2050 and halving the use of "conventionally fueled" cars in urban transport by 2030 (European Commission, 2011). Managing urban traffic requires finding a balance between throughput, livability, safety and sustainability. As cities are expected to grow in the coming decades (leading to increased traffic demand), the challenge of managing traffic will increase, as space to develop road networks is often limited or non-existing. Intelligent Transport Systems (ITS) and traffic management are instruments that enable operators of urban transport networks to manage traffic and transport to meet policy goals.

Nigeria's rural transport infrastructure has been identified as a crucial component for the economic development of the country by linking the rural communities to the urban areas (FGN, 2007). A good transportation network expands economic activities by improving accessibility and facilitates movement of goods including agricultural commodities in all the nooks and cronies of the country (Amba, 2013). Transportation is demanded to execute the objectives of every other sectors in the economy. Not only does transportation provide mobility for people and goods, it helps shape an area's economic health and quality of life. Mobility is fundamental to economic and social activities, including commuting, manufacturing or supplying energy. Movements of people, goods and services have always been fundamental components of human societies. An efficient transport system covering rail, waterways, air, and road, is a catalyst for economic growth and development (Oyesiku, 2013).

This study seeks to develop a GIS-based Intelligent Transportation System (ITS) for Abuja metropolis, Federal Capital Territory, Nigeria. Remote sensing and GIS techniques as well as other relevant technics will be deployed in achieving the aim and objectives of the study.

Effective transportation system is very essential to the social-economy advancement of any nation. However, this very important service is faced with challenges of poor management and inadequate facilities in the Abuja metropolis. This is because majority of the commuters in the Federal Capital Territory live in the rural areas called satellite towns, where there are very poor social amenities and lack of employment opportunities. Also, the population of the Federal Capital Territory especially the rural dwellers has grown geometrically over the years with no proportional development of the transport system. These rural dwellers move to the Abuja city centre in search of greener pastures and return back at the close of the day's business, thereby putting pressure on the transportation facilities especially at the peak periods due to high volume of vehicular traffic on the road at the same time. These problems of transportation in Abuja metropolis is made worse as a result of bad interconnecting road networks between the city centre and the satellite towns where the majority of the civil servants and artisans reside due to cheaper housing schemes.

Nwankwo, Fawohunre and Obasanjo (2016) carried out research on the impact of Abuja Urban Mass Transport Company on passenger movement within the Abuja metropolis and the results revealed that the bus transit services are ineffective due to inadequate buses, lack of dedicated lanes, and inadequate bus stops resulting in commuters waiting unnecessarily in an unfavourable weather condition thereby leading to poor services. Ali (2014) worked on the assessment of passenger satisfaction with intra-city public bus transport services in Abuja. The study shown that passengers are not satisfied with the public bus transport services due to four factors identified as lack of comfort in buses, difficulty in accessing public bus transport services, inadequate bus stop facilities and inadequacy of bus carrying capacity. The use of Geographic Information Systems (GIS) and Global Positioning System (GPS) in Traffic Management System in Abuja City Center was demonstrated by Ashara, Saleh, Hassan and Kaura (2020). The results of the study showed that traffic condition can be monitored and managed using GIS and GPS technology. In all these works and researches, the problems persisted because they were unable to provide an effective transportation management system. This is why the development of a GIS-based intelligent Transport System for Abuja metropolis is necessary to enhance the operations of the transport services.

2. Study Area

Abuja is the capital city of Nigeria, located approximately at the centre of the country in the Federal Capital Territory (FCT). Abuja was created as Nigeria's capital on the 3rd of February 1976, but it became functional and officially replaced the country's most populous city of Lagos as the capital on 12th December 1991 under the leadership of the Military Head of state, General Ibrahim Badamasi Babngida. It lies between latitude 8º57´51.34´´N and 9º07´44.56´N and longitude 7º23´57.64´E and 7º31´58.58´´E east of Greenwich Meridian. The Abuja city centre is situated within phase I and phase II of the Abuja developmental master plan, in Abuja

Municipal Area Council (AMAC) of the Federal Capital Territory. It covered twenty (20) district centers namely, Maitama, Asokoro, Wuse, Garki, Guzape, Katempe, Utako, Wuye, Jabi, Kado, Mabushi, Jahi, Kaura, Dakibiyu, Centre Business District, Gudu, Durumi, Gaduwa, Dutse, Duboyi of the Abuja master plan. For ease of co-ordination and development, the city was classified into phases I to V by the Town Planners and Architects who designed the Abuja Master Plan. Also, there are six administrative Local Government Areas in the Federal Capital Territory, commonly referred to as Area Councils. These include; Abaji Area Council, Abuja Municipal Area Council, Bwari Area Council, Gwagwalada Area Council, Kuje Area Council and Kwali Area Council.

3. Methodology

The research methodology employed a comprehensive approach to analyze transportation infrastructure and road networks, with a focus on optimizing routes and enhancing the overall efficiency of the transportation system. This multifaceted methodology encompassed various stages, each of which played a crucial role in understanding and improving the transportation network.

1. **Data Acquisition**: The initial step involved the systematic acquisition of pertinent data related to road networks and transportation infrastructure. This data collection process was extensive, encompassing a wide array of geospatial information such as road types, road conditions, traffic data, and the locations of various transportation facilities. The data was obtained from reliable sources, including government agencies, GIS databases, and satellite imagery.
2. **Database Design and Creation**: With the acquired data in hand, the research team proceeded to design and create a robust and organized geospatial database. This database was meticulously structured to efficiently store and manage the vast amount of transportation-related information. It included tables for road attributes, transportation facility details, geographic coordinates, and other relevant data points.
3. **Route Optimization**: Route optimization was a fundamental aspect of the methodology. Advanced algorithms and GIS software were employed to determine the most efficient routes for various transportation modes, be it for private vehicles, public transit, or cargo logistics. Factors like traffic congestion, road conditions, and distance were considered to minimize travel time and resource usage.
4. **Closest Facility Analysis**: Closest facility analysis was conducted to identify the nearest transportation facilities or services from specific locations. This included determining the closest hospitals, fire stations, police stations, or other critical amenities. The results were used to improve emergency response times and accessibility to essential services.
5. **Service Area Analysis**: Service area analysis was crucial for understanding the geographic coverage of transportation services. This involved creating service areas or catchment zones around transportation hubs, such as bus stops or train stations, to assess the reach and accessibility of these services. The analysis also helped in identifying underserved areas that required transportation improvements.
6. **Location Allocation Analysis**: Location allocation analysis was employed to optimize the placement of transportation facilities and services. By considering demand, capacity, and cost factors, the methodology aimed to determine the optimal locations for new transportation hubs, distribution centers, or service stations. This helped in enhancing the overall efficiency of the transportation network.
7. **OD Cost Matrix Analysis**: Origin-Destination (OD) cost matrix analysis played a significant role in understanding travel patterns and assessing the costs associated with traveling between different locations. This analysis was crucial for urban planning, traffic management, and resource allocation.

The research methodology went beyond simple data acquisition and delved into database design, route optimization, service area analysis, location allocation analysis, and OD cost matrix analysis. By applying a holistic approach to transportation infrastructure and road network analysis, the study aimed to improve transportation efficiency, accessibility, and planning for both urban and regional areas. These findings were valuable for urban planners, transportation authorities, and policymakers seeking to enhance the overall transportation network and services for the benefit of the community.

4. Results

4.1 Spatial Distribution of Facilities in Abuja Metropolis

The spatial distribution of facilities is crucial to the overall performance of an intelligent transport system. It affects accessibility, traffic management, integration of transportation modes, demand-responsive services, and emergency preparedness. By carefully planning and optimizing the distribution of facilities, an ITS can enhance efficiency, improve user experience, and contribute to a more sustainable and resilient transportation network. A spatial distribution analysis of the facilities in Abuja metropolis was carried out using nearest neighbour analysis to determine

The spatial pattern of transportation hubs in Abuja Metropolis shows an observed mean distance of 1105.62m, expected mean distance of 1244.01m, nearest neighbor ratio of 0.88 and z-score of -0.92, this means that the transportation pattern in the study area does not appear to be significantly different than random, (see figure 4.1).

For road network in Abuja Metropolis, the spatial distribution gave an observed mean distance of 56.04m, expected mean distance of 74.33m, nearest neighbor ratio of 0.75 and the z-score of -78.14, this indicates that there is a less than 1% likelihood that this clustered pattern could be the result of random chance, (see figure 4.2)

Lastly, for the railway network, the spatial pattern gave an observed mean distance of 35.34m, expected mean distance of 1240m, and nearest neighbor ratio of -18.49, this indicated that there is a less than 1% likelihood that this clustered pattern could be the result of random chance, see figure 4.3).

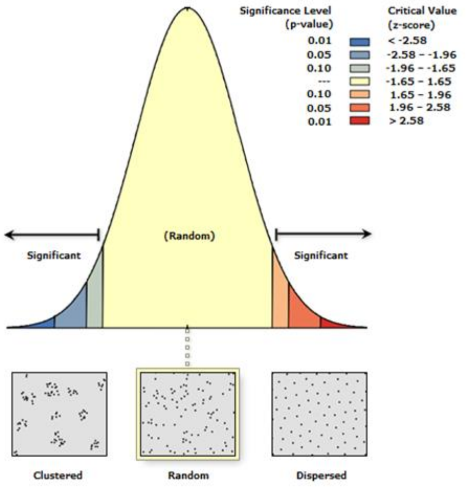

Figure 4.1: Transportation Hubs Average Nearest Neighbour Analysis

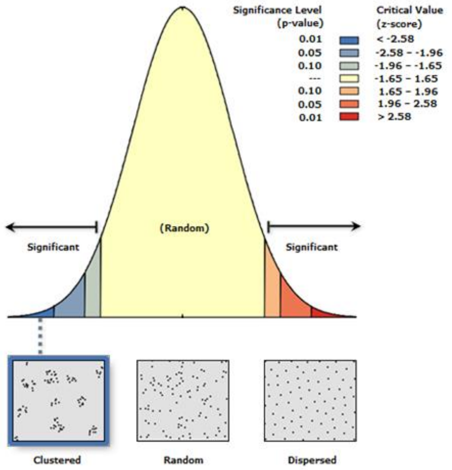

Figure 4.2: Road Network Average Nearest Neighbour Analysis

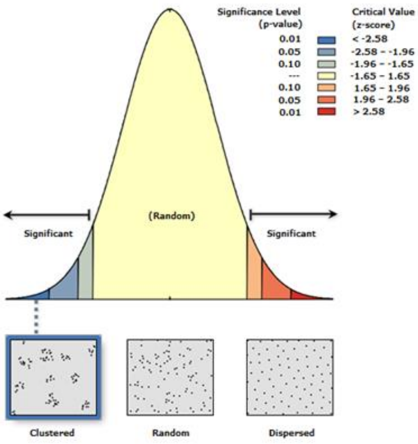

Figure 4.3: Railway Network Average Nearest Neighbour Analysis

Consequently, the significance of the results presented in figures 4.1-4.3, to an Intelligent Transport System indicates that the distribution of facilities in the study area does not show a significant spatial pattern. This means that the facilities are relatively evenly distributed or lack a clear spatial arrangement. A lack of significant spatial pattern in facility distribution could impact system efficiency and accessibility.

An intelligent transport system benefits from strategically located facilities to ensure convenient access and optimal coverage across the transportation network. However, if the observed distribution is not significantly different from random, it may indicate that there is room for improvement in facility placement to enhance system performance.

The clustered pattern observed for the road network indicates a significant departure from randomness, suggesting that there may be localized concentrations of road segments in certain areas. This could have implications for traffic flow, congestion, and the effectiveness of traffic management strategies.

The clustered pattern observed for the railway network also indicates a significant departure from randomness. This suggests that the railway segments are not evenly distributed but are concentrated in specific areas. This clustered pattern could have implications for connectivity, accessibility, and the efficiency of the railway system within the study area.

based on the statistics, the distribution of transportation hubs in the study area does not appear significantly different from random, while the road and railway networks show clustered patterns. These findings highlight the importance of carefully assessing and optimizing the spatial distribution of facilities, such as transportation hubs and infrastructure, in an intelligent transport system to enhance efficiency, accessibility, and overall system performance.

4.2 Network Analysis

Network analysis plays a crucial role in the functioning of an intelligent transportation system (ITS) as it enables the modeling and analysis of intricate interactions among various transportation modes, routes, and facilities. By employing network analysis, an ITS can optimize transportation operations, enhance safety and security measures, and improve overall system efficiency. In the context of this study, the findings can be summarized as follows:

4.2.1 Route Optimization

An intelligent transport system (ITS) can play a significant role in optimizing waste collection routes to minimize costs related to waste collection. By utilizing real-time data and advanced analytics, an ITS can design efficient waste collection routes while distinguishing between the collection of residential and industrial waste. Since Study area is majorly residential and commercial areas, an ITS can help establish fixed frequencies for emptying waste bins, ensuring waste collection is carried out efficiently.

Waste collection is a vital municipal service that involves significant expenditures. However, it is a challenging operational issue to solve. An ITS can aid in waste collection by providing garbage disposal trucks with real-time data on waste bin locations, thus eliminating the tedious task of keeping track of all waste bins without a map or GPS tracker. The study optimized the initial routes being used by Abuja Municipal Area Council by factoring in the distance and time traveled from the starting point to the end point, with the aid of an intelligent transport system. By optimizing routes, an ITS can reduce the time and costs associated with waste collection, resulting in a more efficient waste management system. The results are shown in figures 4.4 and 4.5.

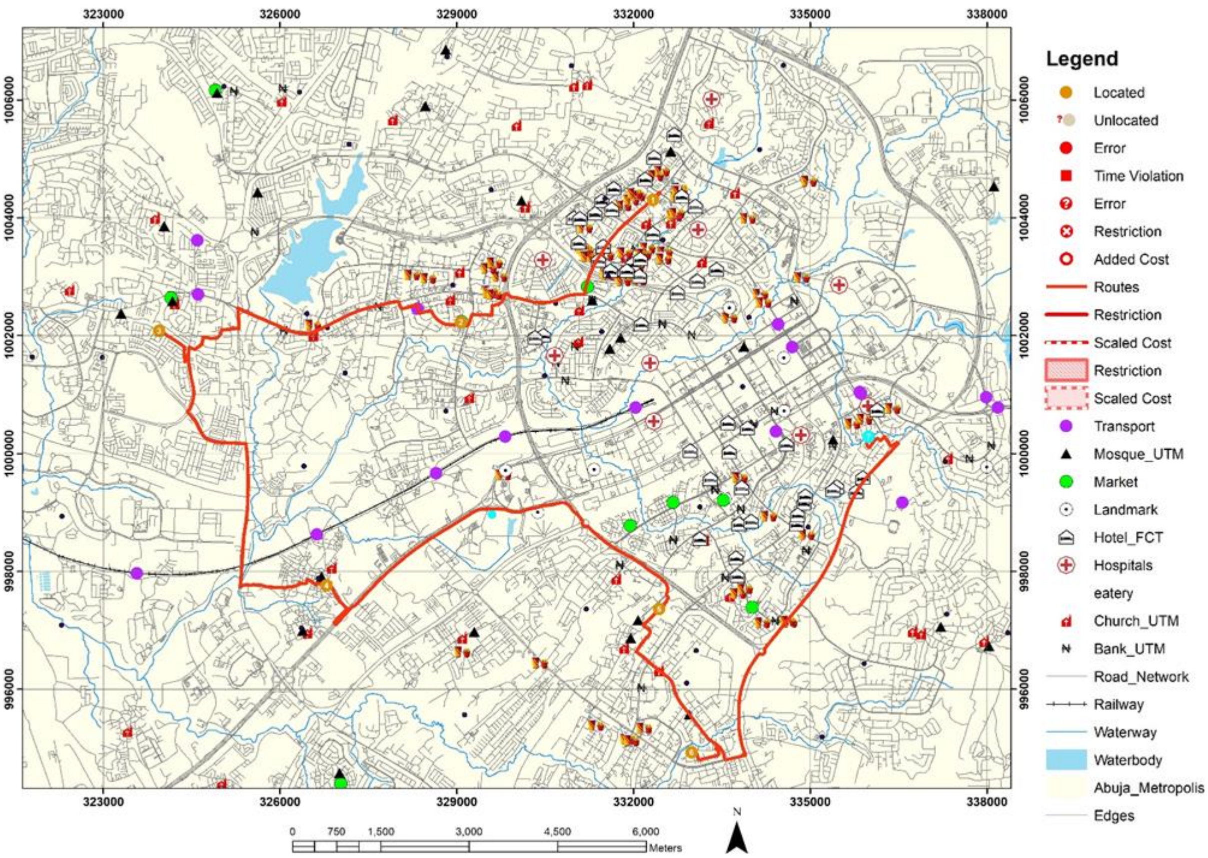

Figure 4.4: Initial Waste Transportation Route

From figure 4.4 the initial waste collection route covered Seven pick up points with a total travel distance of 40 km and a time travel of 5.3 hours. Covering Kashim Ibrahim Way, Aminu Kano Crescent, Herbert Macaulay Way, Dan Suleiman Street, J.J. Oluleye Street, Nnamdi Azikiwe Expressway, Obafemi Awolowo way, Umaru Musa Yar´Adua Expressway, David Jemibewon Crescent, Murtala Mohammed Expressway, Shehu Shagari way and terminating 200m off Lord Lugard Street. This is illustrated in figure 4.5 and 4.6.

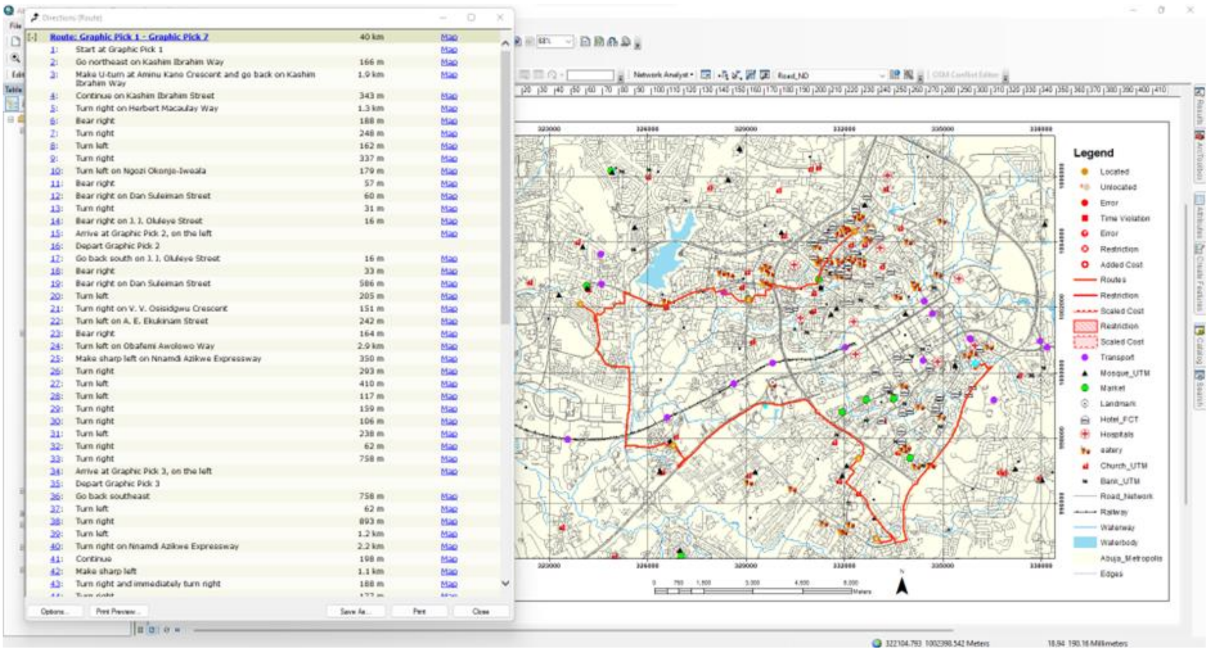

Figure 4.5: Initial Driving Distance

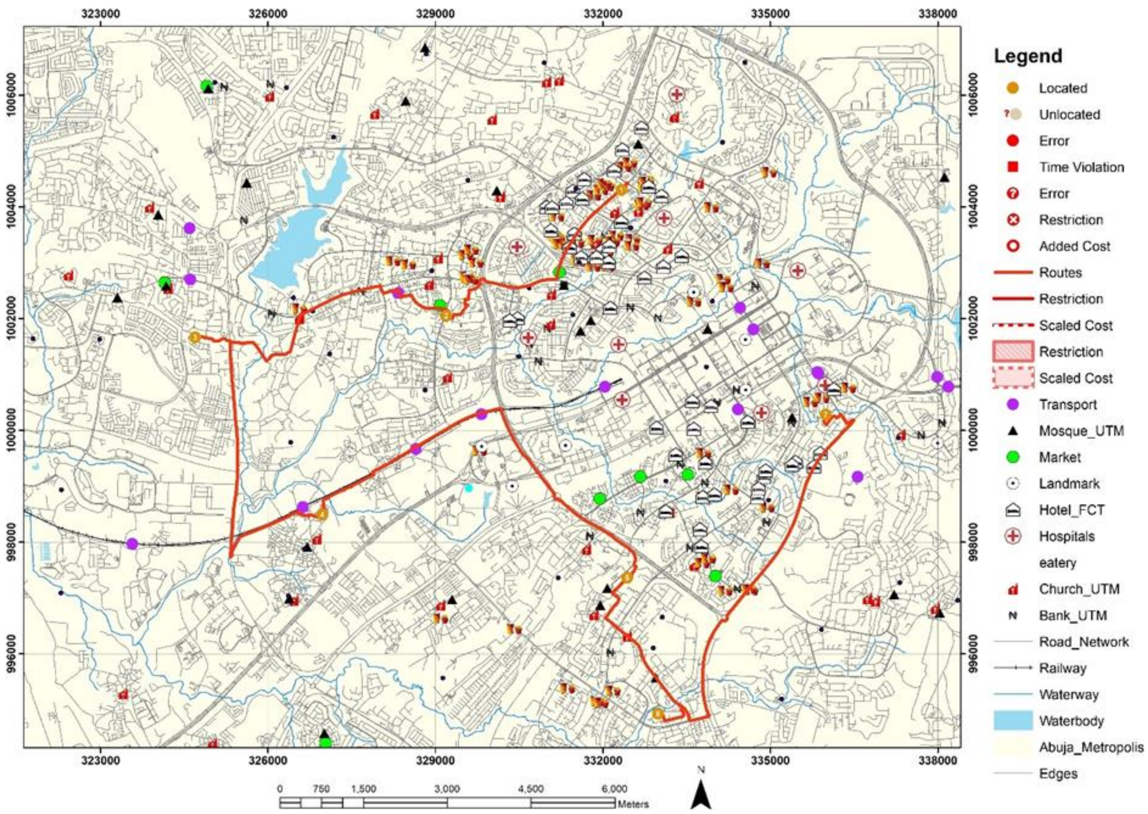

Figure 4.6: Optimized Waste Transportation Route

Based on the optimized waste collection route presented in figure 4.6, the waste collection vehicle was able to cover a total travel distance of 38km and complete the task in 4.7 hours. The collection route comprised of seven pick up points, covering Kashim Ibrahim Way, Aminu Kano Crescent, Herbert Macaulay Way, Dan Suleiman Street, J.J. Oluleye Street, Nnamdi Azikiwe Expressway, Obafemi Awolowo way, Umaru Musa Yar´Adua Expressway, David Jemibewon Crescent, Murtala Mohammed Expressway, Shehu Shagari way, however, it diverted to Jesse Jackson Street, continued on King Faisal Street, terminating 201m off Lord Lugard Street.

Overall, the waste collection vehicle was able to cover a significant distance and pick up waste from multiple locations, highlighting the effectiveness of the optimized collection route. This is illustrated in figure 4.7.

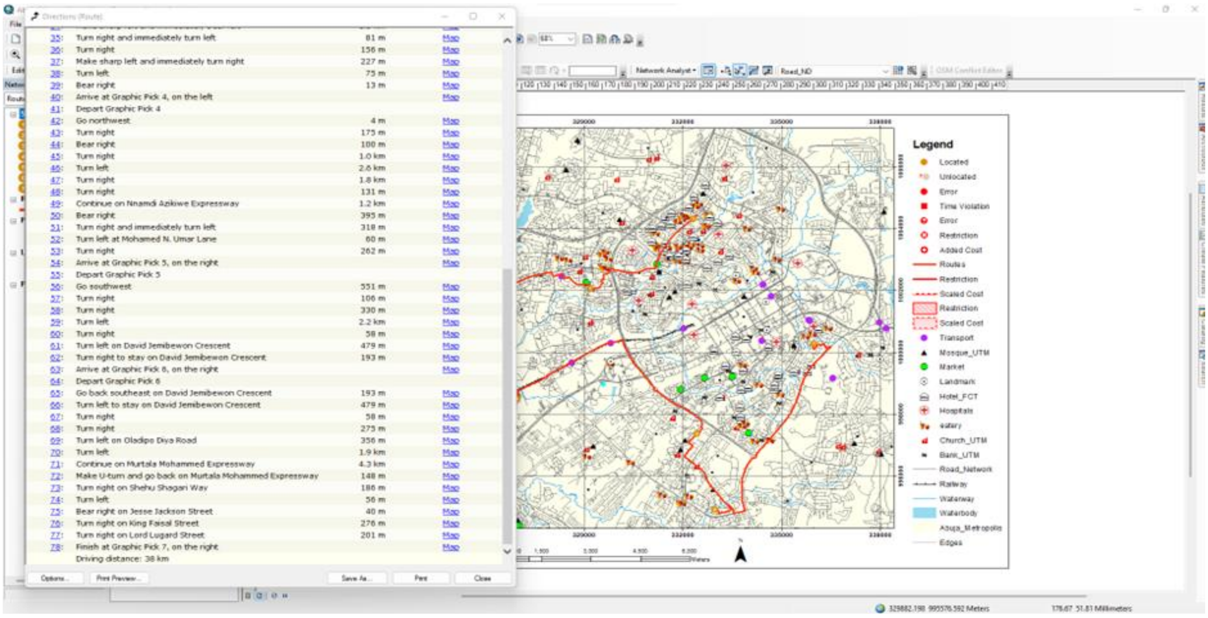

Figure 4.7: Optimized Driving Distance

A comparative analysis of the waste collection route in Abuja Metropolis was conducted, examining the impact of implementing an intelligent transport system (ITS) for route optimization. Initially, the waste collection route encompassed seven pick-up points, spanning a total travel distance of 40 km and requiring 5.3 hours of travel time. The route covered various areas, including Kashim Ibrahim Way, Aminu Kano Crescent, Herbert Macaulay Way, Dan Suleiman Street, J.J. Oluleye Street, Nnamdi Azikiwe Expressway, Obafemi Awolowo Way, Umaru Musa Yar´Adua Expressway, David Jemibewon Crescent, Murtala Mohammed Expressway, Shehu Shagari Way, and concluded 200m off Lord Lugard Street.

After the implementation of the optimized waste collection route using the ITS, significant improvements were observed. The waste collection vehicle covered a reduced travel distance of 38 km and completed the task in 4.7 hours. The revised collection route maintained the same seven pick-up points, covering Kashim Ibrahim Way, Aminu Kano Crescent, Herbert Macaulay Way, Dan Suleiman Street, J.J. Oluleye Street, Nnamdi Azikiwe Expressway, Obafemi Awolowo Way, Umaru Musa Yar´Adua Expressway, David Jemibewon Crescent, Murtala Mohammed Expressway, Shehu Shagari Way, but also incorporated a diversion to Jesse Jackson Street, continuing on King Faisal Street, and terminating 201m off Lord Lugard Street.

The optimized route resulted in a more efficient waste collection process, achieving significant reductions in travel distance and time while still covering all essential pick-up points. This demonstrates the effectiveness of implementing ITS route optimization for waste management in Abuja Metropolis. By utilizing the ITS system, cost savings can be realized, and waste management practices in urban areas can be enhanced, contributing to improved efficiency and sustainability.

4.2.2 Closest Facility Analysis

Closest facility analysis is a crucial component of an intelligent transport system (ITS) as it helps to optimize route planning and improve operational efficiency. By using geographic information systems (GIS) and other location-based technologies, closest facility analysis enables ITS to determine the most efficient route to reach a destination and identify the closest facility to provide a particular service.

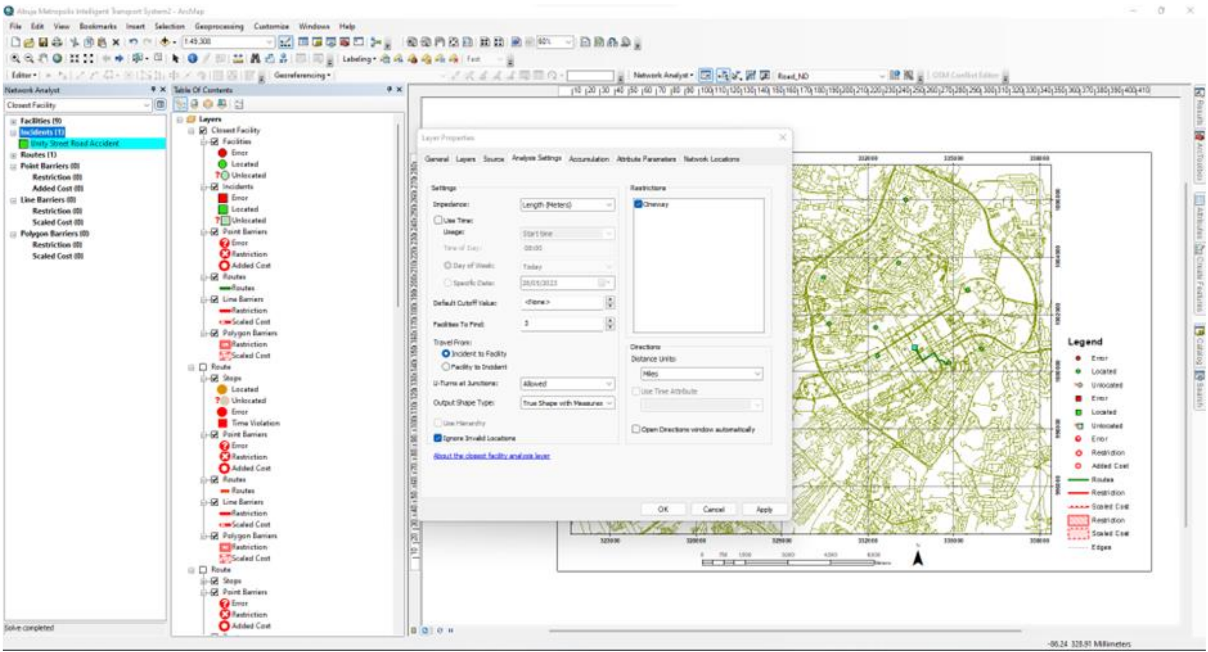

Figure 4.8: Closest Medical Facilities to a road accident Victim

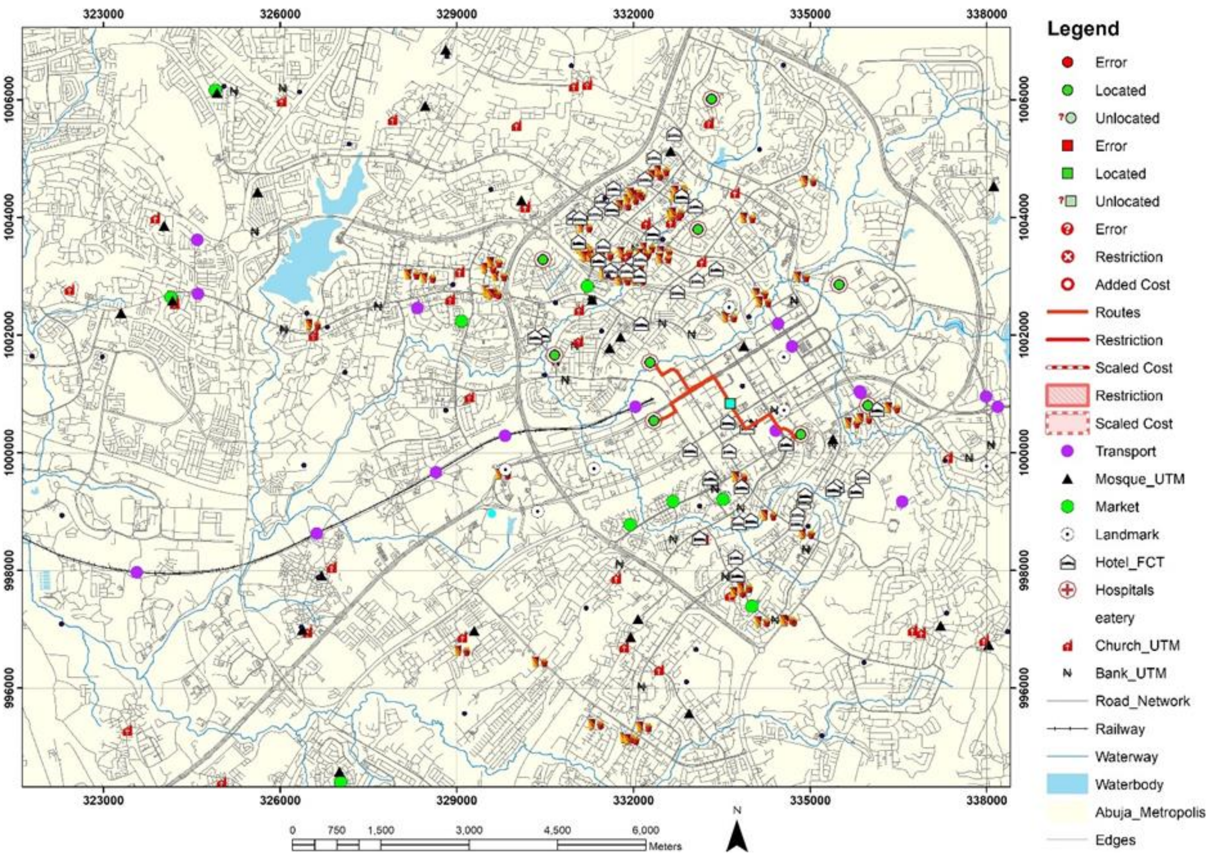

Figure 4.9: Closest Medical Facilities to a road accident Victim

Closest facility analysis is particularly important in emergency situations. In emergency response, quick response time is critical in saving lives and minimizing damages. An intelligent transport system that utilizes closest facility analysis can help emergency services respond quickly and efficiently to emergency situations by identifying the closest facilities such as hospitals, fire stations, and police stations to the emergency location.

In the context of Accident emergencies, this study investigated the utilization of an intelligent transport system's closest medical facility feature. The closest facility analysis plays a critical role in determining the most efficient route to the nearest medical facility that can provide the necessary medical attention. In particular, emergency medical services (EMS) can benefit from this analysis as it helps them identify the quickest route to the nearest hospital equipped with specialized departments. An intelligent transport system can provide EMS with up-to-date information on traffic conditions, road closures, and other factors that may affect their route. With this knowledge, they can make well-informed decisions and reach the patient in the shortest possible time, which can potentially save the person's life. The results of the analysis is showing in figure 4.8 and 4.9.

The result of the study presented three closest medical facilities to the road accident at unity street, these include Asokoro General Hospital at 6.7km, National Hospitalat 7.2km, and Maitama General Hospital at 7.7km. This information can be vital in selecting the most appropriate medical facility for a road accident emergency.

The result of this study highlights the significance of utilizing the closest facility analysis feature of an intelligent transport system in the context of Accident emergencies. By investigating the utilization of this feature, the study revealed that emergency medical services (EMS) can benefit significantly from it by identifying the most efficient route to the nearest medical facility with emergency departments.

One of the essential benefits of using this analysis is that it provides up-to-date information on traffic conditions, road closures, and other factors that may impact the EMS route. With this information, they can make well-informed decisions and reach the patient in the shortest possible time, which is critical in situations where every second counts.

Overall, the study's findings emphasize the importance of utilizing the closest facility analysis feature of an intelligent transport system in emergency situations, specifically in cases of road accidents. The information provided by this analysis can help EMS to make well-informed decisions and potentially save a person's life by reaching the patient in the shortest possible time.

4.2.3 Service Area Analysis

An Intelligent Transport System can employ advanced technologies such as traffic monitoring, incident detection, video analytics, geospatial mapping, predictive modeling, and integration with command centers to determine the coverage areas of CCTV for roads. By leveraging these capabilities, ITS helps optimize the allocation of resources and enhances the effectiveness of surveillance systems for improved safety and security.

Service area analysis is a valuable component in determining the coverage areas of CCTV for roads within Abuja Metropolis. Service area analysis involves evaluating the spatial extent or coverage of a particular service or facility. In the context of CCTV coverage, service area analysis can help identify the geographic regions or zones that can be effectively monitored by a CCTV camera.

This study employed the service area analysis to determine the service area coverage of the CCTVs mounted in Abuja Metropolis at the range of 5 - 10minutes drive within the study area. This is shown in figure 4.10.

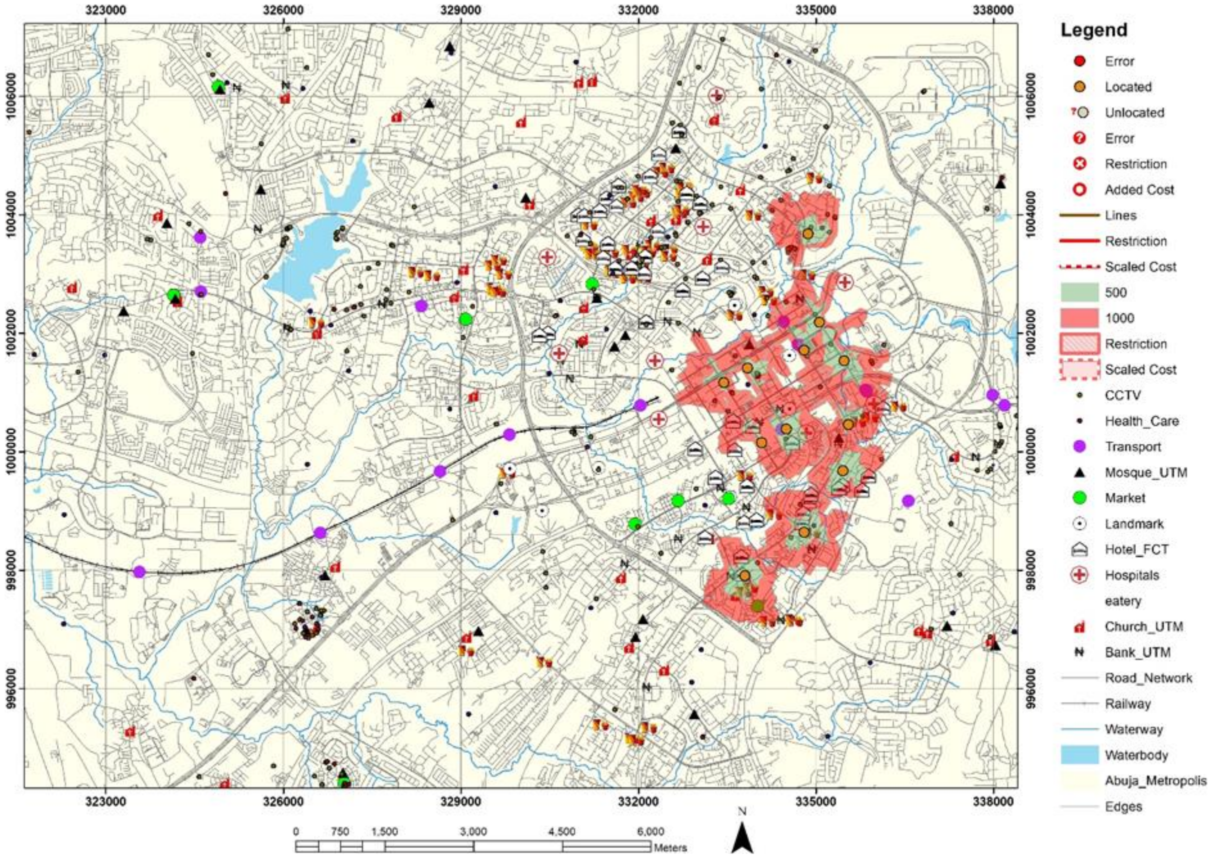

Figure 4.10: Road Mounted CCTV Service Areas

The intelligent transport system-based service area analysis conducted in Abuja Metropolis, which spans an area of 608.89 km2, yielded significant findings regarding the coverage of road-mounted CCTV cameras. The results of the study indicated that there were 12 CCTV cameras primarily clustered within the city center.

Within a 5-minute driving distance, the CCTV cameras provided coverage to a total service area of 2.18 km2. The minimum service area covered was 0.05 km2, while the maximum service area covered was 0.29 km2. This implies that the CCTV cameras were concentrated in specific areas, resulting in relatively limited coverage within a short driving time.

Expanding the analysis to a 10-minute driving distance, the CCTV cameras extended their coverage to a total service area of 12.94 km2. The minimum service area covered within this range was 0.73 km2, while the maximum service area covered was 1.44 km2. These findings indicate a broader coverage area compared to the 5-minute driving distance, allowing for increased surveillance reach.

The significance of these results lies in understanding the distribution and extent of CCTV coverage within Abuja Metropolis. The clustering of cameras in the city center suggests a focus on high-traffic or critical areas, possibly for enhanced security measures. However, the relatively limited coverage within a 5-minute driving distance implies that areas beyond the city center may have reduced surveillance presence.

The expansion of coverage within a 10-minute driving distance reveals a broader reach of the CCTV cameras, encompassing a larger portion of Abuja Metropolis. This expanded coverage can contribute to improved surveillance, incident detection, and response times within the extended service areas.

The study's results underscore the importance of strategically placing CCTV cameras to optimize coverage and enhance security measures across Abuja Metropolis. It highlights the need for considering factors such as population density, traffic patterns, and potential risk areas when planning the deployment of CCTV infrastructure. The findings can inform decision-makers in identifying areas where additional cameras may be required to ensure comprehensive surveillance and improve overall safety and security within the metropolis.

4.2.4 OD Cost Matrix

OD Cost Matrix analysis in an Intelligent Transport System (ITS), is used to determine the distance and time between all possible origin-destination pairs within a network. The tool calculates the cost, in terms of travel time or distance, for each possible route between two locations in a network.

To illustrate this application, the study makes use of the case of a food delivery service from Bites and Grills at Shop 4 Grace Court Estate, delivering food packs to six different locations (1) Embassy of Ireland at 11 Negro Crescent Maitama District, (2) Reiz Continental Hotel at 10th Street Cadastral Zone, (3) Standard Chartered Bank at Plot 374 Adetokunbo Ademola Crescent, (4) Residential address at Queen India Street Asokoro, (5) Zenith Bank at Plot 1205, Cadastral Zone, Wuse 2 District, and (6) Residential address at No 11 Zambezi Crescent Maitama District.

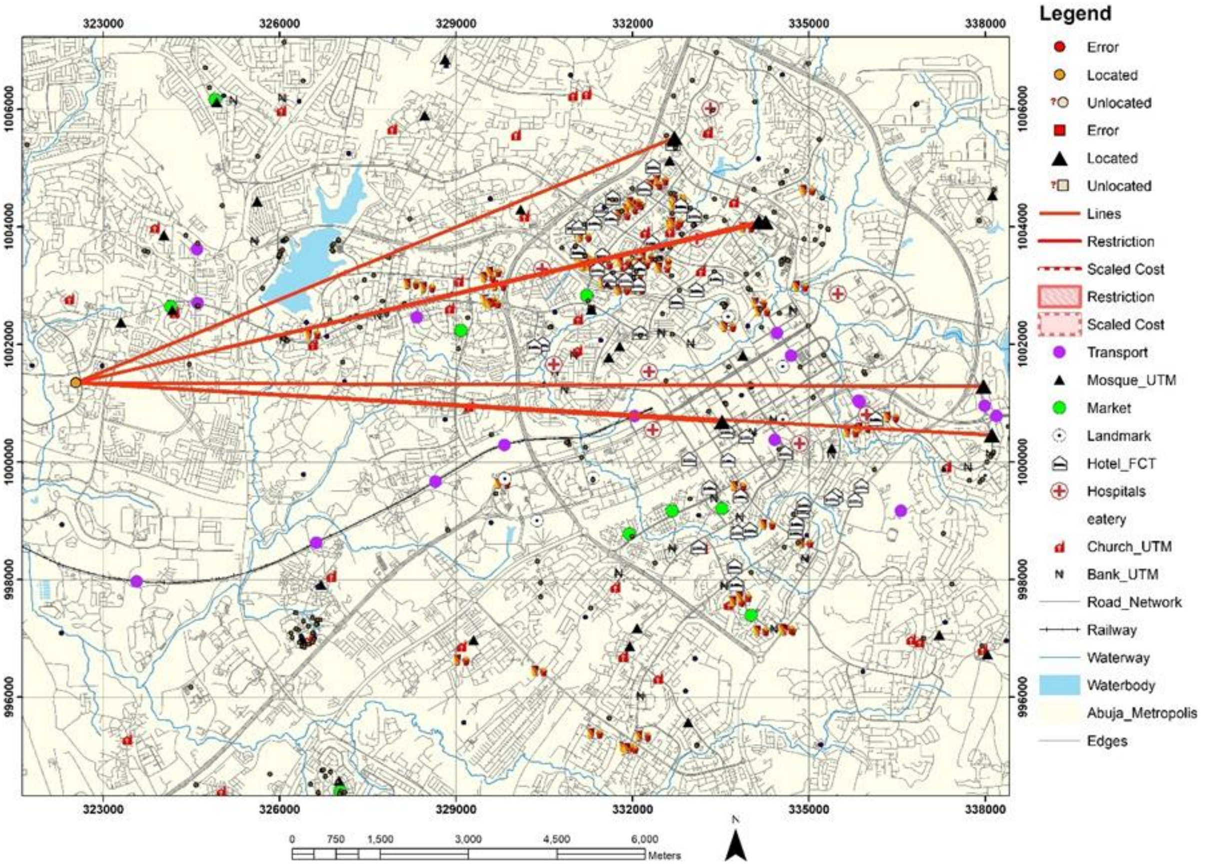

Figure 4.11: OD Cost Analysis

The OD Cost Matrix tool can be used to optimize the delivery routes. The tool would calculate the shortest or fastest route between each origin-destination pair, taking into account traffic conditions, road closures, and other factors that may affect the delivery time. This can help the courier service to plan and optimize their delivery routes, reducing travel time and increasing efficiency.

Moreover, the OD Cost Matrix can be used to estimate the delivery time and cost for different delivery options, such as express delivery or standard delivery. This can help the courier service to offer their customers different delivery options with varying delivery times and costs, improving their service quality and customer satisfaction. The result is shown in 4.11 and 4.12.

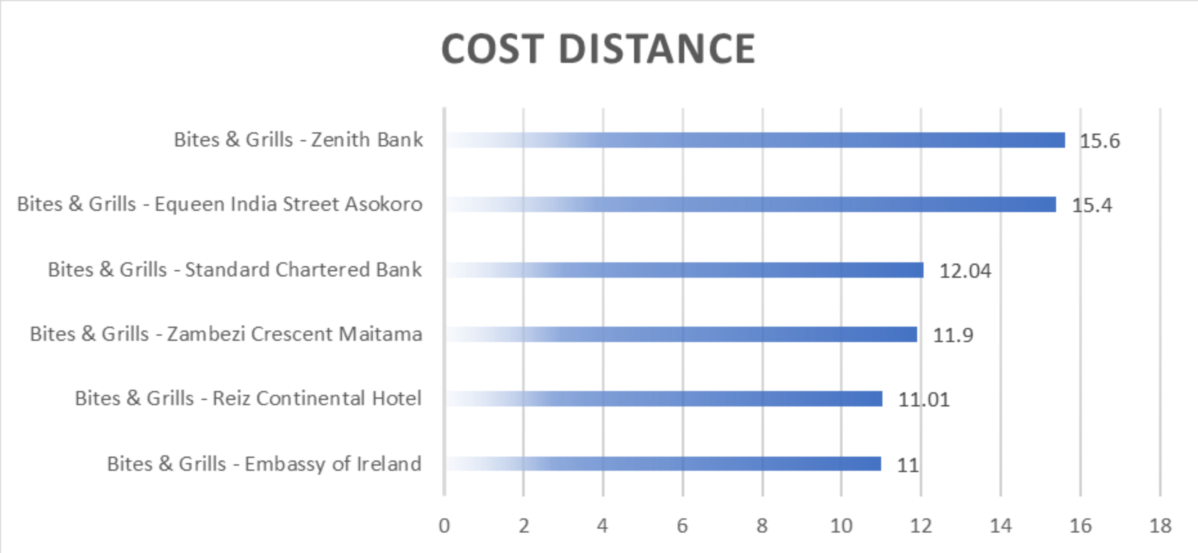

Figure 4.12: The shortest distance covered by the food delivery service to delivery destination

The OD Cost matrix analysis (Figure 4.11 and 4.12) for the food delivery service (Bites & Grills) reveals the shortest distances and total distance to be covered while delivering food packs to six different locations. The shortest distances to the destinations were 11 km to Embassy of Ireland, 11.01 km to Reiz Continental Hotel, 11.9 km to 12.04 km, 15.4 km to Standard Chartered Bank, 15.4 km to Queen India Street Asokoro, and 15.6 km to Zenith Bank.

The results indicate that the courier service will travel a total distance of 76.95 km to deliver the food packs to the six destinations. This information is significant as it can help the food service delivery to plan and optimize their delivery routes, reducing travel time and increasing efficiency. By considering the shortest distances to each destination, they can minimize the time and fuel required for each delivery, resulting in cost savings and improved service quality. Moreover, this analysis can be used to estimate the delivery time and cost for different delivery options, helping the courier service to offer their customers different delivery options with varying delivery times and costs, improving their service quality and customer satisfaction.

4.2.5 Location Allocation

Location allocation in an intelligent transport system (ITS) is a technique used to identify the optimal location of facilities (such as health care services) to serve a given set of demand points (such as localities) within a transportation network. The aim is to find the best allocation of resources to meet the demand while minimizing the total cost of the service.

In this study, location allocation analysis was used to determine the best locations for health care services in the study area. The ITS helped identify areas that are underserved or have limited access to health care, taking into account travel time, distance, and traffic conditions to ensure that health care facilities are located in areas that are accessible to those who need them the most.

From the study, 35 health care services were available to serve 66 demand points from the localities. This analysis was structured to determine which health care would handle the most demand within a range of 5 km and which locality within the study area would have to travel far distances to access health care services.

Overall, location allocation analysis in an intelligent transport system can help improve access to health care services, reduce travel time and costs for patients, and enhance the overall efficiency of the health care system. The results of this analysis are shown in figure 4.13 and 4.14.

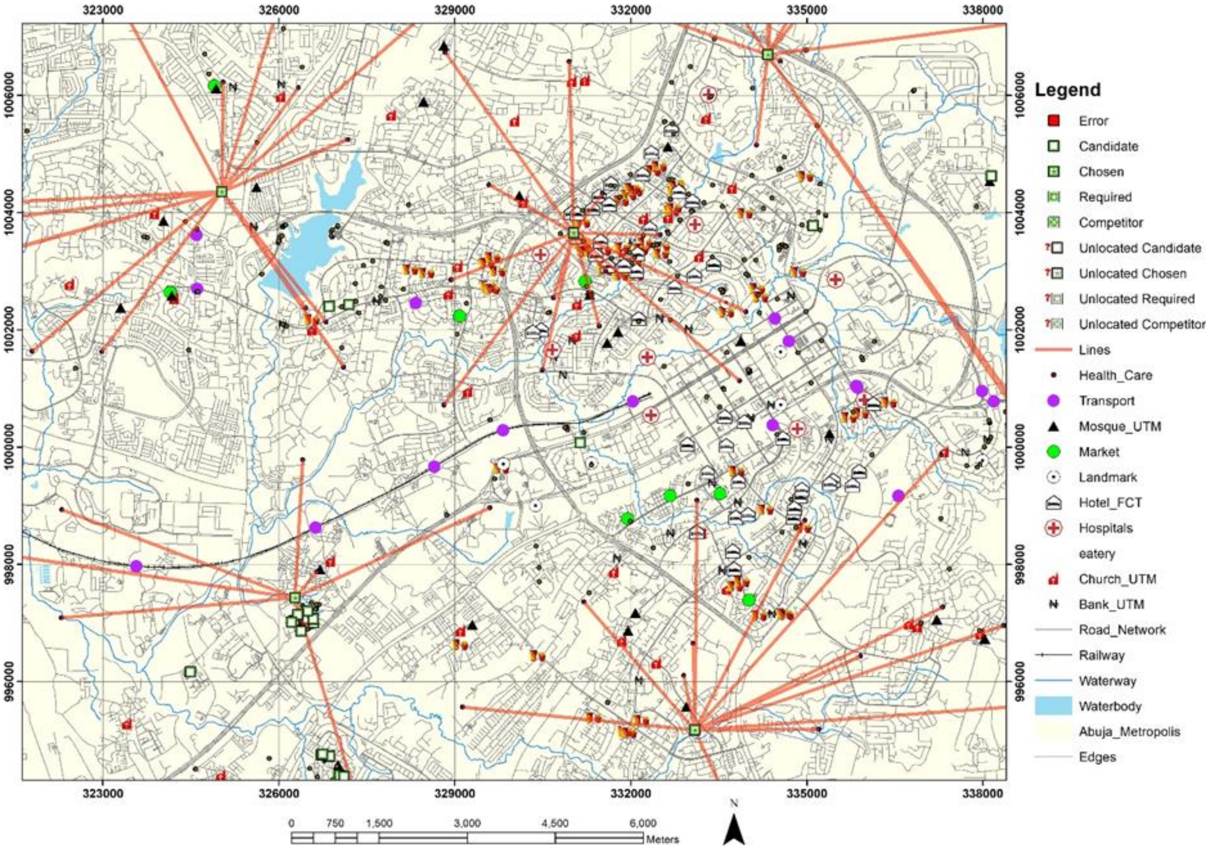

Figure 4.13: Location Allocation Analysis

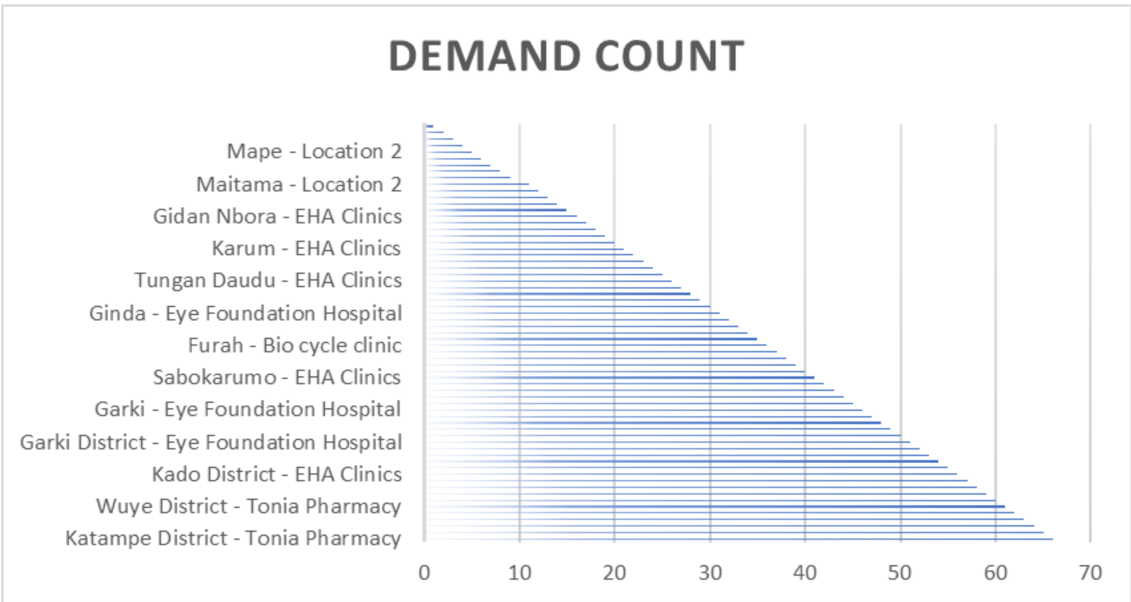

Figure 4.14: Health Care/Localities Demand Count

The results of the location allocation analysis (shown in Figure 4.11 and 4.12) provide valuable insights into the distribution of demand for health care services in the study area. Out of the 35 health care centers available to serve 66 demand points from the localities, Tonia Pharmacy has the highest demand as a health care service from Katampe District with a demand count of 66 within a 5km range. This was followed by Eye Foundation Hospital, Bio Cycle Clinic, and EHA Clinics with 65 demand count from Kaura District, 64 demand counts from Dakibiyu, 63 demand counts from Gwarinpa and 61 demand counts from Jahi District respectively.

Abuja, Central Business District, Wuse II District, Dutse, Mape, Mpape, Kurunduma, Dakiniu and Jiru all had the lowest demand within the study area, with demand counts ranging from 1 – 9, see appendix 1 for more details.

This information can be used to inform decision-making processes for health care resource allocation in the area. By identifying areas with high demand and those with limited access, health care providers can improve service delivery and ensure that their services are accessible to those who need them the most. This can improve the health outcomes of the population and ultimately contribute to the development of a healthier society.

With the help of an ITS, health care facilities can be optimally located to ensure accessibility for those who need them the most while minimizing the total cost of the service. This will lead to improved health care services, increased efficiency, and overall better health outcomes for the population.

5. Conclusion

The application of intelligent transport systems (ITS) in various scenarios has yielded significant insights and opportunities for enhancing transportation efficiency, waste management, emergency response, security, food delivery, and healthcare service allocation in Abuja Metropolis. The study's findings underscore the importance of optimizing the distribution and utilization of facilities within the intelligent transport system for improved performance and accessibility. Notably, the study has demonstrated the potential benefits of ITS in diverse urban and service delivery contexts.

Significances of the Results

1. **Spatial Distribution Analysis**: The findings emphasize the need for a more deliberate and balanced distribution of transportation hubs, road networks, and railway segments within Abuja Metropolis. Addressing the clustered patterns observed can lead to improved system efficiency, traffic management, and railway connectivity, ultimately enhancing urban mobility and accessibility.
2. **Waste Collection Route Optimization**: The successful implementation of ITS for route optimization in waste collection demonstrates the substantial benefits of ITS in improving urban services. The resulting reduction in travel distance and time not only leads to cost savings but also contributes to more sustainable and efficient waste management practices.
3. **Emergency Medical Facility Proximity**: Identifying the closest medical facilities to a road accident location provides critical information for emergency response. ITS can aid in making prompt and informed decisions to ensure the injured receive timely medical attention, potentially saving lives.
4. **CCTV Camera Placement**: The service area analysis of CCTV cameras highlights the importance of strategic placement for improved security and surveillance in Abuja Metropolis. Concentrated coverage in the city center and extended reach with longer driving distances enhance the effectiveness of security measures.
5. **Food Delivery Route Optimization**: The analysis of food delivery service using an ITS presents opportunities for efficient delivery route planning. It allows for cost-effective and timely food delivery, benefiting both service providers and customers.
6. **Healthcare Service Allocation**: The location allocation analysis offers valuable insights into the demand for healthcare services in different districts. By optimizing the location of healthcare facilities, ITS can ensure equitable access to healthcare services, improving healthcare outcomes and service quality.

In conclusion, the findings highlight the versatility and effectiveness of intelligent transport systems in addressing various urban challenges, from transportation and waste management to emergency response, security, service delivery, and healthcare. These results provide a foundation for informed decision-making and the potential for significant improvements in urban living and service delivery in Abuja Metropolis.

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