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GIS-BASED MAPPING OF UNDERGROUND FIBER OPTIC NETWORKS USING DIFFERENTIAL GPS: EVIDENCE FROM THE UNIVERSITY OF ILORIN CAMPUS

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ABSTRACT

Purpose: *Accurate mapping and management of underground fibre optic infrastructure are critical for ensuring network reliability, minimising service disruptions, and supporting sustainable infrastructure planning. This study aims to develop a high-precision geospatial framework for mapping underground fibre optic cable networks within the University of Ilorin campus using Differential Global Positioning System (DGPS) integrated with Geographic Information System (GIS) technology.*

Design/methodology/approach: *High-accuracy spatial data of underground fibre optic cable routes connecting academic, administrative, and research buildings were collected using DGPS. Attribute data, including building functions, network capacity, cable characteristics, and connectivity details, were obtained through field observations and structured interviews with network personnel. Spatial and attribute datasets were integrated within a GIS environment to create a comprehensive digital geodatabase and detailed utility maps for visualisation, analysis, and asset management.*

Findings: *The study produced accurate and up-to-date digital maps of underground fibre optic cable networks across the campus. The DGPS–GIS integration significantly improved spatial accuracy and enhanced visualisation of utility infrastructure. The developed geospatial database supports efficient asset tracking, proactive maintenance planning, and informed decision-making for network expansion, thereby reducing the risk of accidental damage and service interruptions.* ***Research limitations/implications:*** *Data acquisition was constrained in some areas by difficult terrain and dependence on heterogeneous attribute data sources. Nevertheless, the methodology demonstrates strong potential for adaptation and scaling in similar institutional and urban environments.*

Practical implications: *The resulting digital utility database serves as a decision-support tool for infrastructure managers, improving maintenance efficiency and coordination during development activities.*

Originality/value:

This study provides a replicable DGPS–GIS-based framework for underground fibre optic utility mapping, contributing to smart campus development and advancing digital infrastructure management practices in Nigeria.

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Keywords: Geographic Information Systems (GIS), Differential Global Positioning System (DGPS), Fibre Optic Network Mapping, Underground Utility Management, Spatial Database Development

1.0 INTRODUCTION

Accurate identification, location, and mapping of underground utilities constitute a critical component of contemporary infrastructure management and urban development (Sharafat et al., 2021). Underground utility networks, including telecommunications, electrical distribution systems, water supply pipelines, sewer networks, stormwater drains, natural gas lines, cable television, and optical fibre systems, form the hidden backbone that supports modern urban and institutional operations (Agwor et al., 2025). In addition, major infrastructure assets such as oil and gas pipelines, mass transit systems, defence utilities, and underground tunnels further intensify competition for subsurface space, making reliable and up-to-date utility mapping indispensable for effective planning, maintenance, and risk mitigation (Odunaiya et al., 2018).

Traditionally, underground utility records were maintained using analogue maps and paper-based documentation, which are prone to deterioration, loss, and limited accessibility over time (Meehan et al., 2021; Kelly et al., 2022). These shortcomings often result in incomplete or inaccurate information, increasing the likelihood of accidental utility strikes during excavation activities. The advent of Geographic Information Systems (GIS) and Global Navigation Satellite Systems (GNSS) has transformed underground utility mapping by enabling precise spatial data acquisition, centralised data management, and advanced visualisation capabilities (Sunny, 2024). GIS-based utility databases integrate spatial and attribute information, facilitating efficient asset management, coordinated maintenance, and informed decision-making across infrastructure sectors (Meis et al., 2023).

In developing economies such as Nigeria, rapid growth in the telecommunications sector has been driven by the expansion of fibre optic infrastructure and broadband wireless services. The deployment of undersea fibre optic cables connecting Nigeria to global communication networks has significantly enhanced national connectivity and digital capacity (O’Connor et al., 2020). However, the reliability of these terrestrial and submarine fibre optic systems depends heavily on accurate mapping and continuous monitoring, as uncoordinated construction and excavation activities frequently result in accidental cable damage and service disruptions.

Within institutional environments, fibre optic networks are indispensable for supporting academic, administrative, and research activities. At the University of Ilorin, fibre optic cables form the backbone of campus-wide internet connectivity, enabling digital learning platforms, research collaboration, and administrative operations. The Network Operations Centre (NOC) is responsible for managing this extensive underground cable network. Effective maintenance and timely fault resolution require precise knowledge of cable routes, depths, and associated infrastructure, highlighting the necessity for a comprehensive digital utility mapping and management system (Odunaiya et al., 2018).

The consequences of inadequate or outdated underground utility information are far-reaching, ranging from service interruptions and safety hazards to increased maintenance costs and project delays (Al-Bayati & Panzer, 2020). These challenges underscore the growing need for integrated digital platforms capable of delivering accurate, real-time utility data to support proactive maintenance, emergency response, and infrastructure resilience (Sharafat et al., 2021).

Against this backdrop, this study focuses on the acquisition and management of spatial and attribute data for the underground fibre optic cable network within the University of Ilorin campus. By integrating Differential Global Positioning System (DGPS) technology with GIS software, the study aims to develop a detailed digital base map and geospatial database of fibre optic cable routes and associated infrastructure. The resulting system is intended to support efficient network maintenance, informed planning, and future expansion while minimising the risks of accidental cable damage and service disruption.

Specifically, the objectives of the study are to acquire high-precision spatial and attribute data of the campus fibre optic network using DGPS, develop a comprehensive GIS-based database for managing cable routes and infrastructure attributes, and produce detailed digital utility maps to enhance maintenance and planning operations. Beyond its immediate institutional application, this research is designed to serve as a scalable prototype for underground utility mapping in similar institutional and urban settings across Nigeria. By establishing a reliable digital framework for fibre optic infrastructure management, the study contributes to improved operational efficiency, enhanced infrastructure resilience, and data-driven decision-making in the management of critical communication assets.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study was conducted within the main campus of the University of Ilorin, located in Ilorin South Local Government Area of Kwara State, Nigeria. The university occupies an extensive land area of approximately 15,000 hectares (Oladimeji et al., 2025), making it one of the largest university campuses in the country. The campus comprises a heterogeneous landscape characterized by a mix of academic, administrative, residential, and research facilities, interconnected by road networks, open spaces, and areas of undeveloped land cover.

The campus is serviced by an extensive network of underground fibre optic cables that provide backbone connectivity for internet and data communication services across various buildings. These cables are centrally managed by the Department of Network Operations Centre (NOC), which oversees network maintenance, expansion, and fault resolution. Ongoing infrastructural development and frequent maintenance activities within the campus environment further emphasize the need for accurate and up-to-date mapping of underground communication utilities.

These physical and operational characteristics make the University of Ilorin campus a suitable and practical environment for the acquisition and management of spatial and attribute data for underground fibre optic infrastructure. The study area, therefore, provides an ideal setting for evaluating the application of Differential Global Positioning System (DGPS) and Geographic Information System (GIS) technologies in supporting effective campus planning and network management. Figure 1 presents the map of the study area.

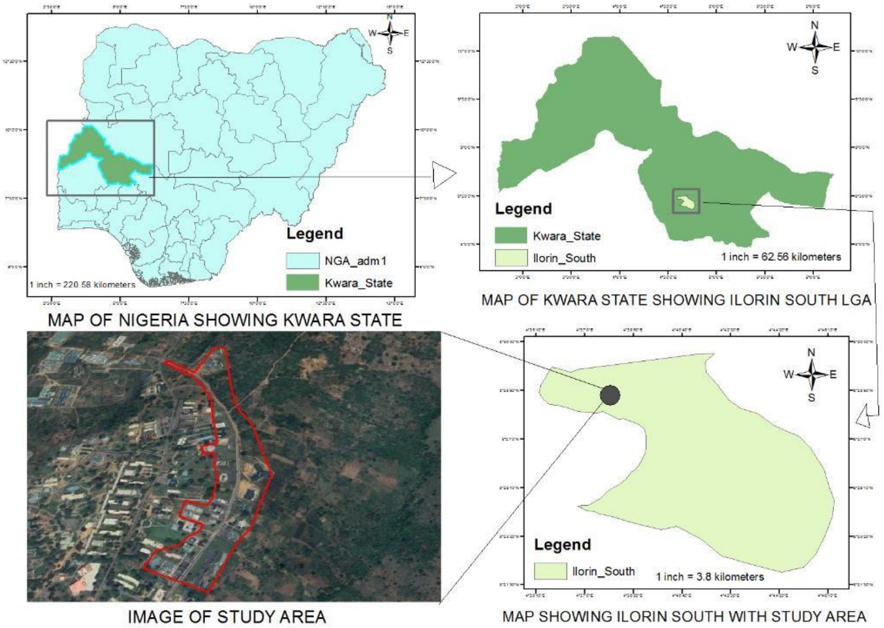

Figure 1: Map of the study area

2.2 Data Acquisition Equipment

Spatial data acquisition was carried out using a Differential Global Positioning System (DGPS) receiver, specifically the South Galaxy One GNSS device, which is capable of delivering highprecision positional measurements suitable for surveying and geospatial applications. Supporting accessories included a tripod stand for stable instrument setup, a 12-V external battery for continuous power supply, and a laptop computer for data storage and preliminary processing. Microsoft Excel and ArcGIS software were employed for field data organization, processing, and spatial analysis.

2.3 Field Data Collection

Spatial coordinates of underground fibre optic cable routes and associated surface features, including buildings, roads, and utility junction points, were collected using the DGPS in static observation mode. Before field data acquisition, a control verification exercise was conducted to confirm the integrity and positional accuracy of existing campus control points. The DGPS base station was established on a verified control point (UILSVG2021S002), while the rover unit was deployed to capture positional data along the fibre optic cable routes.

Data collection was conducted using the EGStar application on the DGPS controller. A new project was created, and the rover was connected to the base station via Bluetooth. Relevant parameters such as base antenna height, control point coordinates, and datum settings were configured before observations commenced. Collected points were labelled on-site using descriptive identifiers to facilitate subsequent processing. Survey observations followed the fibre optic routes from the Faculty of Agriculture to the Works Department, covering all accessible segments within the campus.

Attribute data were obtained through structured oral interviews with Network Operations Centre (NOC) personnel and facility users. Recorded information included building names, functional use, estimated user capacity, and network infrastructure characteristics such as transmission modes.

2.4 Data Processing and Management

The DGPS observations were downloaded and exported into Microsoft Excel as comma-separated values (CSV) files containing Easting, Northing, elevation, and point identification fields. These datasets were subsequently imported into the ArcGIS environment for spatial visualization and map development.

All spatial data were standardized to the WGS 1984 UTM Zone 31 coordinate reference system to ensure positional consistency and accuracy. Point datasets representing cable locations, buildings, roads, and ancillary features were converted into shapefiles. Using the ArcGIS editor tools, linear features were digitized by connecting sequential survey points along the fibre optic routes, resulting in continuous polyline representations of the underground cables. Attribute information obtained from field interviews were linked to corresponding spatial features, thereby enriching the database with descriptive and operational details.

2.5 Database Development

A geospatial database was developed to integrate spatial and attribute datasets, enabling efficient data storage, querying, visualization, and infrastructure management. The database contains geometric representations of fibre optic cable routes, buildings, and related infrastructure, alongside associated attributes such as building function, user capacity, and transmission mode. The database structure was designed to support ease of updating and scalability, allowing future network expansions or modifications without compromising data integrity.

2.6 Utility Map Production

Based on the processed spatial data and integrated geodatabase, detailed utility maps were produced illustrating the distribution of underground fibre optic cable routes, building locations, and associated network infrastructure across the University of Ilorin campus. These maps provide effective visual tools for network maintenance personnel, planners, and decision-makers, supporting routine maintenance, fault resolution, and strategic planning for future network expansion.

3.0 RESULTS AND DISCUSSION

3.1 Spatial Data Distribution and Assessment

The deployment of the South Galaxy One Differential Global Positioning System (DGPS) receiver enabled the acquisition of high-accuracy spatial data along the underground fibre optic cable routes within the University of Ilorin campus. A comprehensive set of positional coordinates was collected, capturing the spatial continuity and routing complexity of the fibre optic network extending from the Faculty of Agriculture to the Works Department. The DGPS observations achieved sub-meter positional accuracy, which is suitable for underground utility mapping and supports reliable maintenance planning, excavation control, and future network expansion (Sharafat et al., 2021; Sunny, 2024).

The acquired spatial data were imported into ArcGIS 10.7 for processing, visualization, and spatial analysis. Surveyed point features were digitized and sequentially connected to generate polyline representations of continuous fibre optic cable routes. This approach aligns with established GISbased utility mapping practices, where point-to-line conversion enhances network representation and spatial analysis efficiency (Meis et al., 2023). Attribute data obtained through structured interviews were integrated with the spatial features, linking cable segments and junction points to associated buildings and infrastructure characteristics such as building function, occupancy capacity, and network usage. The resulting geospatial database is dynamic and query-enabled, supporting effective asset management and informed decision-making for network operations (Odunaiya et al., 2018).

Figure 2 illustrates the spatial distribution of the field-collected DGPS data after importation into the ArcGIS software environment. Table 1 presents attribute information acquired for each building, including building name, estimated population of students and staff, functional purpose, and capacity. Table 2 summarizes fibre optic infrastructure attributes such as cable type, service provider, and routing information, while Table 3 details the characteristics of junction boxes, including their names, types, and associated routes. Figure 3 presents a pie chart illustrating the distribution of captured building facilities within the study area. Figures 4a and 4b show the spatial locations of mapped buildings alongside their identifiers, fibre optic cable routes, and service junctions. Table 4 provides a summary of all buildings captured during the survey.

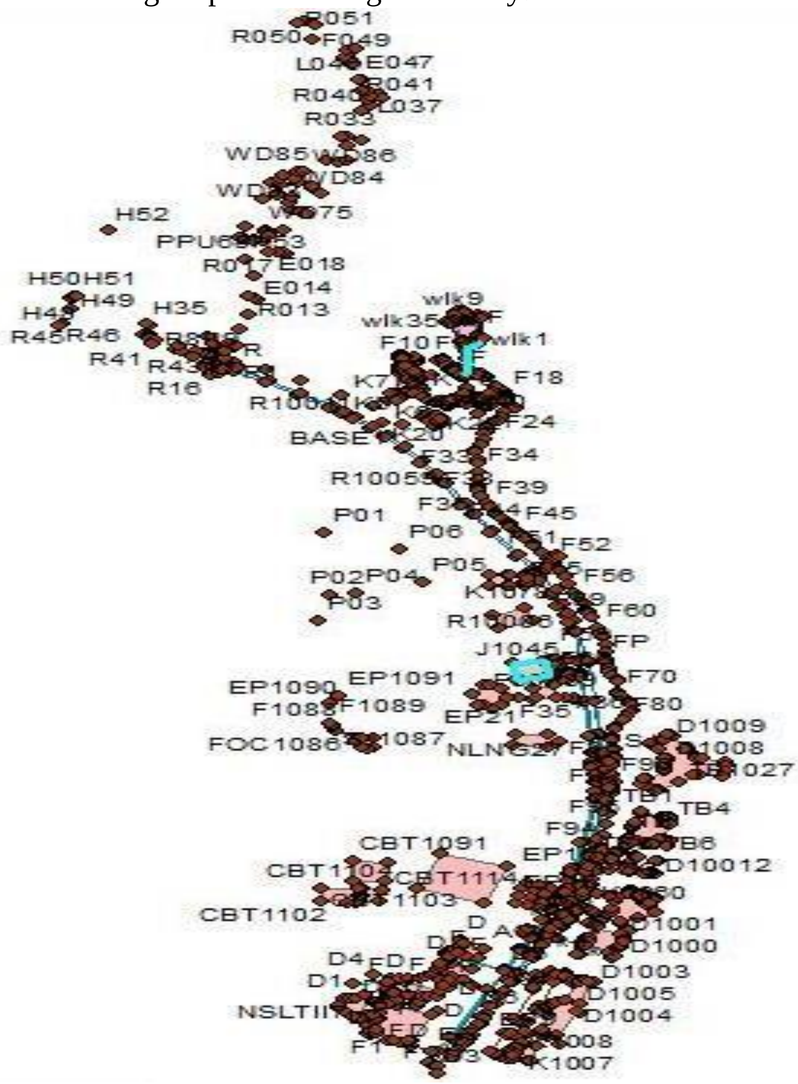

Figure 2: Field data after uploading to the ArcGIS Software Environment

Table 1 presents attribute information obtained through oral interviews for each mapped building, including building name, estimated population of students and academic staff, functional purpose, and occupancy capacity. Table 2 summarizes the characteristics of the fibre optic infrastructure, detailing cable type, service provider, and routing information. Table 3 provides information on the junction boxes, including their names, types, and associated routes. Figure 3 illustrates the distribution of the captured building facilities using a pie chart, while Figures 4a and 4b display the spatial distribution of buildings within the study area, together with their identifiers, fibre optic cable routes, and service junction locations. Table 4 presents a summary of all buildings captured during the survey.

Table 1. Attribute Table for All Buildings

S/N	PURPOSE	NAME	MODE OF TRANSMISSION	No. OF RADIO	No. OF OFFICES	No. OF CLASSROOMS	NUMBER OF LABS	CAPACITY
1	Academic	Management lecture hall	Radio	1	0	0	0	500
2	Agricultural research	Green house	N/A	0	0	0	4	500
3	Academic	Agriculture main lab	N/A	0	1	0	0	150
4	Academic	Agriculture lecture hall	Radio	1	0	0	0	500
5	Academic	Agriculture lecture theatre	Radio	1	2	0	0	500
6	Research	Engineering research centre	Radio	2	0	0	20	500
7	administrative	Advance centre	Radio	1	6	0	0	0
8	administrative	General study unit	Radio	1	12	0	0	0
9	Academic and administrative	Microbiology department	Radio	3	32	2	3	0
10	Academic	New science lecture theatre	Radio	1	2	0	0	500
11	Research	Animal house	N/A	0	1	0	16	0
12	Research	Block of research centre	Radio	4	30	0	20	0
13	Academic and administrative	Optometry vision science	Radio	2	8	8	2	0
14	Academic and administrative	Faculty of Science lecture theatre	N/A	0	2	0	0	400
15	TEF	N/A	N/A	N/A	N/A	N/A	N/A	

S/N	PURPOSE	NAME	MODE OF TRANSMISSION	No. OF RADIO	No. OF OFFICES	No. OF CLASSROOMS	NUMBER OF LABS	CAPACITY

		FUND building						
16	Academic and administrative	Chemical engineering building	N/A	0	0	0	0	0
17	Academic and administrative	Faculty of Life Sciences	Radio	5	12	3	4	0
18	Shed	CBT pavilion	Radio	1	0	0	0	0
19	Shed	CBT pavilion	Radio	1	0	0	0	0
20	Shed	CBT pavilion	Radio	1	0	0	0	0
21	Shed	CBT pavilion	Radio	1	0	0	0	0
22	Academic	CBT hall	Radio	1	0	0	0	0
23	Academic	CBT hall	Radio	1	0	0	0	0
24	Academic	CBT hall	Radio	1	0	0	0	0
25	Academic	CBT hall	Radio	1	0	0	0	0
26	Academic and administrative	Department of Surveying and Geoinformatics	Radio	4	14	0	2	0
27	Academic and administrative	Department of Quantity Surveying	Radio	4	14	0	2	0
28	Academic and administrative	Department of Estate Management	Radio	4	14	0	0	0
29	Shed	Walkway	N/A	0	0	0	0	0
30	Academic and administrati	Faculty of Environmental	Radio	2	0	0	0	0

S/ N	PURPOSE	NAME	MODE OF TRANSMISSION	No. OF RADIO	No. OF OFFICES	No. OF CLASS ROOMS	NUMBER OF LABS	CAPACITY
	ve	Science						
31	Academic	Faculty of Science	Radio	1	0	0	0	400
32	Wi-Fi control room	NOC building	Radio	0	5	0	0	0

Table 2. Fiber Cables and Their Attributes.

S/N	NAME	TYPE	PROVIDER	ROUTE
1	Fiber optic line	2 Core	NICC	Surveying and Geo-informatics
2	Fiber optic line	2 Core	NICC	Tetfund building
3	Fiber optic line	2 Core	NICC	CBT road- science lecture hall
4	Fiber optic line	2 Core	NICC	Faculty of life Sciences
5	Fiber optic line	2 Core	NICC	Microbiology department
6	Fiber optic line	2 Core	NICC	Microbiology-CBT road
7	Fiber optic line	2 Core	NICC	New science lecture theatre
8	Fiber optic line	48 Core	NICC	Advance centre
9	Fiber optic line	2 Core	NICC	NOC building
10	Fiber optic line	2 Core	NICC	Estate management
11	Fiber optic line	2 Core	NICC	Quantity surveying department
12	Fiber optic line	2 Core	NICC	Agriculture lecture hall
13	Fiber optic line	2 Core	NICC	Agriculture lecture theatre
14	Fiber optic line	2 Core	NICC	Agriculture service junction
15	Fiber optic line	2 Core	NICC	Optometry

16	Fiber optic line	12 Core	NICC	Faculty of Environmental Science

Table3. Junction boxes and their attributes

S/N	**NAME**	**TYPE**	**ROUTE**
1	Primary	Junction box	Faculty of Environmental Science
2	Secondary	Junction box	Chemical engineering building
3	Primary	Junction box	Faculty of life Sciences
4	Primary	Junction box	Faculty of Agricultural Science
5	Primary	Junction box	CBT road
6	Primary	Junction box	Faculty of Life Science Hall

Table 4. Summary table of Buildings

S/N	**BUILDINGS**	**No**
1	Buildings with Wi-Fi	25
2	Buildings without Wi-Fi	7
3	Number of academic buildings	10
4	Number of administrative buildings	2
5	Number of academic and administrative buildings	8
6	Number of research centre	4
7	Wi-Fi control building	1
8	Mode of transmission	RADIO
9	Number of service junctions	7
10	Total length of cable	2.12km
11	Number of primary junction box	6
12	Number of secondary junction boxes	1
	TOTAL	**32**

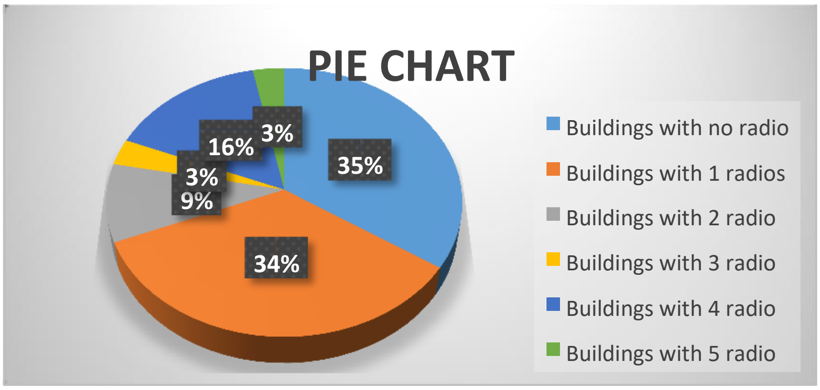

Figure 3: Pie chart of Buildings with the number of Radios

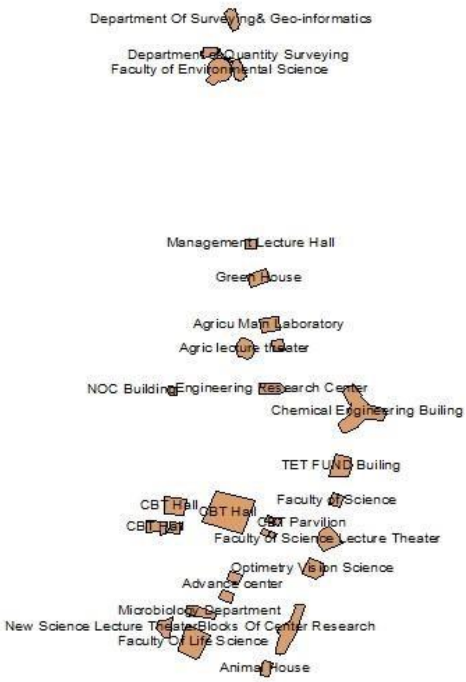

Figure 4a: Buildings with their names.

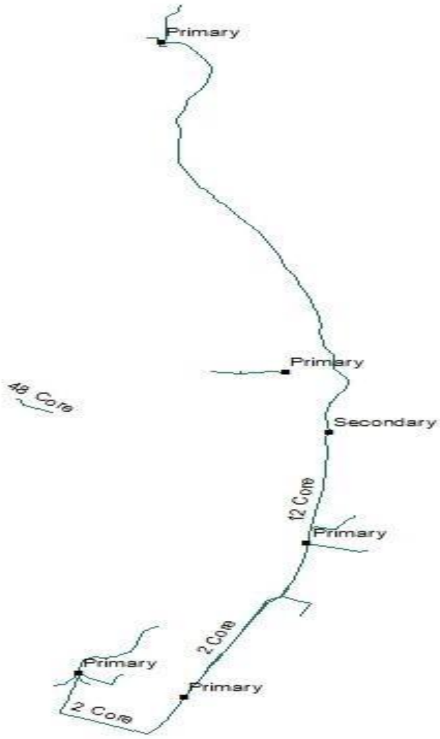

Figure 4b: Optical fibre cable route with its service junctions

3.2 Utility Map Production

The final output of this study is a detailed digital utility map that accurately represents the spatial layout of the underground fibre optic network within the University of Ilorin campus. The map clearly delineates fibre optic cable routes, building footprints, junction boxes, and other critical infrastructure components. The GIS environment enabled the integration of additional spatial layers, including road networks, pedestrian walkways, and drainage systems, thereby providing essential spatial context that enhances on-ground navigation and supports effective operational planning.

This utility map serves as a vital decision-support tool for the Department of the Network Operations Centre (NOC). It facilitates proactive network maintenance by enabling rapid identification of cable routes and associated infrastructure, thereby minimizing the risk of accidental damage during campus development activities, excavation works, or repair operations. Furthermore, the digital utility map provides a reliable foundation for future fibre optic network expansion and system upgrades. By leveraging GIS-based spatial analysis capabilities, network planners can evaluate alternative routing options, identify potential conflicts with existing infrastructure, and anticipate logistical constraints, thereby supporting efficient and sustainable network development. Figure 5 shows the route of the optical fibre cable running from bank area to faculty of environmental sciences.

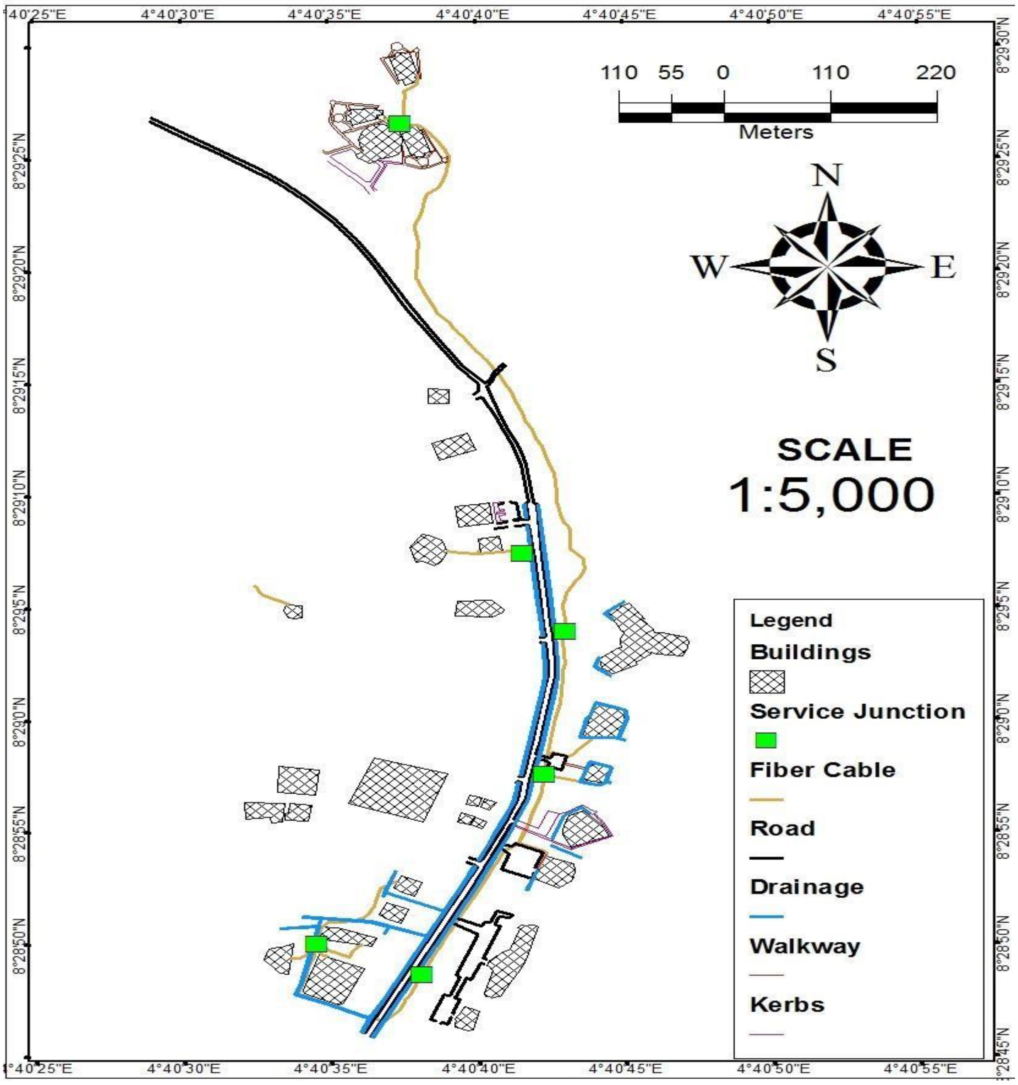

Figure 5: Map of optical fibre cable on Unilorin Campus

3.0 DISCUSSION

The mapped area within the University of Ilorin main campus covers approximately 5.343 hectares and is located in Ilorin South Local Government Area, Kwara State, Nigeria. Within this area, 32 buildings comprising academic, administrative, and research facilities were captured and analysed. This diversity of building functions reflects the complexity of institutional infrastructure networks and underscores the need for accurate underground utility mapping to support reliable service delivery and infrastructure planning (Sharafat et al., 2021).

Out of the 32 buildings surveyed, 25 are currently equipped with Wi-Fi connectivity, providing internet access to students, academic staff, and administrative personnel, while 7 buildings lack WiFi coverage. Functional classification revealed that 10 buildings are primarily academic, 4 are dedicated research facilities, 8 perform combined academic and administrative roles, and 2 serve strictly administrative purposes. Centralized network management is coordinated through the Network Operations Centre

(NOC), which functions as the control hub for all fibre-enabled Wi-Fi services across the campus. This centralized structure highlights the critical dependence of campuswide digital services on the integrity of the underlying fibre optic network (Odunaiya et al., 2018).

The fibre optic infrastructure mapped in this study spans a total length of approximately 2.12 km and comprises predominantly 2-core and 48-core fibre optic cables. These cables interconnect key campus buildings through a structured distribution network maintained by the Nigeria Communications Commission (NCC). The observed cable configuration aligns with standard institutional network designs, where higher-core cables serve as backbone links, while lower-core cables facilitate localized distribution (O'Connor et al., 2020).

Seven service junctions were identified along the fibre optic routes, including six primary junctions responsible for distributing connections to faculties and departments, and one secondary junction functioning as an intermediate breakpoint, typically spaced at approximately 250 m intervals. The spatial distribution of these junctions reflects deliberate planning for load distribution and fault isolation, which are essential for efficient network maintenance and rapid service restoration (Meis et al., 2023).

The integration of spatial and attribute data enabled accurate mapping and effective management of the campus fibre optic infrastructure. However, several challenges were encountered during data acquisition. Shaded and hard-to-access areas limited satellite signal reception, reducing coordinate accuracy in certain locations. In addition, some fibre optic cables had deteriorated or remained buried for extended periods, complicating their identification and surveying. Attribute data collection also relied heavily on personnel knowledge, which varied across facilities, introducing potential inconsistencies. These challenges are consistent with those reported in underground utility mapping studies in similar environments (Al-Bayati & Panzer, 2020).

Despite these limitations, the combined application of Differential Global Positioning System (DGPS) and Geographic Information System (GIS) technologies proved effective. The high spatial accuracy and centralized digital database significantly enhanced asset visibility for network managers, improved operational efficiency, and reduced response times during fault detection and maintenance activities (Sunny, 2024). The resulting dataset further supports strategic decisionmaking by revealing spatial relationships and infrastructure dependencies that were previously undocumented.

By establishing a prototype utility mapping framework tailored to an institutional environment in Nigeria, this study demonstrates the practicality and scalability of GIS-based fibre optic network management. The developed database and mapping system can be extended through integration with mobile GIS platforms for real-time field updates and expanded to include other underground utilities for holistic infrastructure management. Incorporating complementary technologies such as groundpenetrating radar (GPR) for subsurface validation could further enhance data completeness and positional accuracy (Sharafat et al., 2021).

Moreover, extending this approach beyond the university campus to urban fibre optic networks offers a viable blueprint for municipal utility management. Such expansion would contribute to improved infrastructure resilience, reduced service disruptions, and enhanced service quality in Nigerian cities, reinforcing the role of digital utility mapping as a cornerstone of smart infrastructure development.

4.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has demonstrated the effectiveness of integrating Differential Global Positioning System (DGPS) and Geographic Information System (GIS) technologies for the accurate mapping and management of underground fibre optic cable infrastructure within the University of Ilorin campus. High-precision spatial and attribute data were successfully acquired, processed, and organized into a comprehensive geospatial database, resulting in detailed digital utility maps that clearly delineate fibre optic cable routes, buildings, junction boxes, and associated network infrastructure. The developed framework meets the study objectives by providing an accurate, accessible, and digitally structured representation of campus-wide fibre optic assets.

The results indicate that the DGPS–GIS approach significantly improves underground utility visibility and supports proactive maintenance, efficient fault localization, and informed planning for network expansion and upgrades. Although data acquisition was constrained in shaded and difficultto-access areas and some attribute information relied on personnel knowledge, these limitations did not compromise the overall reliability of the database. Instead, the integrated geospatial platform enhanced operational efficiency and reduced the risk of accidental cable damage during excavation and infrastructure development activities.

5.2 Recommendations

The following are hereby recommended based on the research:

- Institutionalize the use of the developed geospatial database and digital utility maps as the primary reference for fibre optic network management and campus development planning at the University of Ilorin.
- Implement regular updates of the geospatial database to reflect network modifications and ensure sustained positional and attribute accuracy.
- Integrate mobile GIS technologies to enable real-time field data collection, improve coordination between field technicians and the Network Operations Centre, and enhance operational efficiency.
- Incorporate complementary subsurface investigation technologies, such as groundpenetrating radar (GPR), in future studies to improve the detection, validation, and completeness of buried utility data.
- Adopt the DGPS–GIS framework at the municipal and national levels by telecommunication providers and public agencies to enhance asset documentation, reduce service disruptions, strengthen infrastructure resilience, and support smart campus and smart city development initiatives nationwide in Nigeria.

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