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An Integrated GNSS, Datum Transformation, and IOT Framework for Digital Geodetic Control Point Infrastructure in Urban Environments

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ABSTRACT
Accurate and accessible geodetic control point information is essential for modern surveying, mapping, and geospatial data infrastructure development. However, conventional analogue-based documentation systems are often fragmented, poorly maintained, and inefficient, particularly in rapidly urbanizing environments. This study presents the development and implementation of a semi-automatic Internet of Things (IoT)-enabled virtual repository for the storage, management, and retrieval of geodetic control point data, integrating high-precision Global Navigation Satellite System (GNSS) observations with systematic datum transformation. Static GNSS observations were conducted at selected control points in Benin City, Nigeria, and processed using continuously operating reference station (CORS) corrections to obtain precise three-dimensional coordinates in both the local Minna datum and the global WGS84/ITRF reference frame. Datum transformation was applied to evaluate positional consistency between the two coordinate systems, and the derived datasets were integrated into a centralized IoT-based web platform for real-time data access, visualization, and archival management. The results achieved centimetre-level horizontal accuracy and decimetre-level vertical precision, confirming the robustness of the adopted GNSS methodology. Comparative analysis revealed systematic horizontal shifts of less than 0.5 m and vertical discrepancies approaching 1.0 m, emphasizing the importance of accurate transformation models. The developed platform demonstrated efficient data storage, rapid retrieval, and reliable accessibility, providing a scalable solution for modernizing geodetic infrastructure, supporting smart city initiatives, and strengthening spatial data governance in developing urban environments.

Keywords: GNSS, Iot, Geodetic Control Points, Datum Transformation, Spatial Data Infrastructure, Smart City

INTRODUCTION
The sustainable establishment, maintenance, and accessibility of geodetic control points are fundamental to accurate surveying, mapping, navigation, land administration, and geospatial data integration. Control points provide the spatial reference framework required for precise positioning, engineering design, infrastructure development, and geospatial information system (GIS) applications (Bielecka *et al*., 2014; Lu *et al*., 2014). In developing countries, including Nigeria, control point information is still predominantly managed using analogue archival systems, which are characterized by poor accessibility, vulnerability to physical deterioration, and inefficient data retrieval processes (Fajemirokun and Nwilo, 1990; Nwilo *et al.*, 2016).

Traditional geodetic data management practices rely heavily on manual documentation, paper-based field records, and static map archives, which are increasingly incompatible with the demands of modern geospatial workflows. These analogue systems suffer from significant limitations, including delayed access to critical spatial information, loss of historical records, duplication of efforts in control establishment, and weak integration with digital surveying technologies (Ehigiator-Irughe and Audu, 2016; Janečka, 2019). Consequently, survey operations often experience inefficiencies that adversely affect project delivery timelines, data reliability, and cost-effectiveness.

Recent advances in Global Navigation Satellite Systems (GNSS), Continuously Operating Reference Stations (CORS), cloud computing, and wireless communication technologies have enabled high-precision positioning, real-time data transmission, and large-scale geospatial data management. These developments have significantly transformed surveying operations, offering unprecedented opportunities for automated data acquisition, processing, storage, and dissemination (Yan and Shi, 2013; Sánchez *et al.*, 2023). In parallel, the emergence of the Internet of Things (IoT) paradigm has introduced new possibilities for interconnecting sensors, devices, and data repositories, thereby enabling real-time monitoring, intelligent data exchange, and adaptive system control (Chen *et al*., 2020).

The integration of IoT technologies into geodetic infrastructure offers a transformative pathway for modernizing control point management systems. By enabling seamless connectivity between GNSS sensors, cloud platforms, and web-based interfaces, IoT-driven frameworks facilitate automated data acquisition, real-time accessibility, secure digital archiving, and efficient querying of geodetic control information (Borah, 2024). Several recent studies have demonstrated the effectiveness of IoT-based geospatial solutions in enhancing operational efficiency, data reliability, and decision-support capabilities for smart city applications (Janečka, 2019; Sánchez *et al*., 2023). However, in Nigeria and much of sub-Saharan Africa, the adoption of IoT-based geodetic data management systems remains limited, with institutional practices still largely dependent on analogue record-keeping.

In Edo State, Nigeria, geodetic control point documentation is primarily managed through manual filing systems within government ministries and academic institutions. These systems are prone to physical degradation, misplacement, unauthorized access, and limited spatial visualization capability. The absence of a centralized, digital, and remotely accessible control point repository significantly constrains efficient surveying operations, data reuse, and long-term geospatial infrastructure sustainability. Moreover, the lack of real-time access to verified control point information often results in repeated establishment of new controls, increased operational costs, and reduced positional consistency across geospatial projects.

Despite growing interest in smart city initiatives and digital governance frameworks in Nigeria, there remains a critical research gap in the development and deployment of IoT-enabled geodetic control data infrastructures. Most existing studies focus on GNSS positioning accuracy, CORS network densification, or geodetic datum transformation, with limited attention given to intelligent data archiving, retrieval automation, and web-based geospatial information services. This gap underscores the urgent need for a robust, scalable, and secure digital framework that integrates GNSS, IoT, and cloud computing technologies for geodetic control management.

This study addresses this gap by designing and implementing a semi-automatic Internet of Things (IoT)-based virtual repository and retrieval system for geodetic control points in Benin City, Nigeria. The system integrates GNSS-CORS observations, cloud-based storage, frontend–backend architecture, and web-based visualization tools to enable real-time access, efficient querying, and long-term digital preservation of control point data. A network of twenty-five first-order GNSS control stations was employed as a pilot dataset to validate the system's performance, accuracy, and operational reliability.

The specific contributions of this study are to:

i. Develop a semi-automatic IoT-enabled framework for geodetic control point archiving and retrieval.
ii. Integrate GNSS-CORS observations with cloud computing and web-based visualization platforms.
iii. Implement of a real-time digital repository for spatial data access, querying, and monitoring.
iv. Quantitatively assess datum transformation effects between Minna Datum and ITRF2014.
v. Establish a scalable digital geodetic database model applicable to smart city surveying and spatial data infrastructure development.

By bridging the technological divide between traditional analogue surveying practices and modern digital geospatial infrastructures, this research provides a practical pathway for enhancing geodetic data governance, improving surveying efficiency, and supporting sustainable smart city development in Nigeria and similar developing environments. Accordingly, this study addresses these objectives through GNSS-based coordinate establishment, datum transformation analysis, and the implementation of a semi-automatic IoT-enabled control point repository, with results evaluated in terms of positional accuracy, spatial consistency, and operational performance.

MATERIALS AND METHODS

Study Area Description

This study was conducted in Benin City, the capital of Edo State, Nigeria. Benin City is a rapidly expanding urban centre with increasing demand for accurate geospatial data to support surveying, mapping, infrastructure development, and land administration. The selected geodetic control points are distributed across strategic locations within the city, including university campuses, school environments, and secured institutional premises. These locations were deliberately chosen to ensure the safety, stability, long-term preservation, and accessibility of the monuments.

The study area falls within Universal Transverse Mercator (UTM) Zone 31N and lies approximately between coordinates 790061.21 m E, 707071.99 m N and 794246.44 m E, 706067.15 m N. This spatial coverage ensures adequate representation of the urban landscape, including developed zones and erosion-prone regions. The geographical distribution of the control points enhances their suitability for a wide range of geospatial applications. The map of the study area and location is presented in Figure 1.

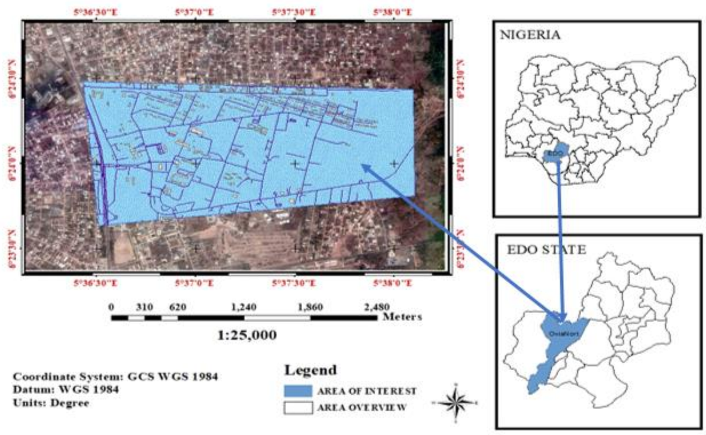

Figure 1: Map of the Study Area

System Concept and Design Framework

The proposed system was designed as a semi-automatic Internet of Things (IoT)-based virtual repository and retrieval platform for managing geodetic control point data. The system concept was guided by the principles of simplicity, scalability, data reliability, and ease of access, with special consideration for the infrastructural realities of developing environments.

The system comprises five major components: GNSS observation units, a Continuously Operating Reference Station (CORS) network, wireless communication infrastructure, cloud-based data processing and storage services, and a web-based frontend interface. Together, these components form an integrated workflow that supports real-time data acquisition, centralized storage, automated processing, and online retrieval of geodetic control information.

GNSS receivers deployed in the field are connected in real time to the CORS_Geosystems network, which provides differential correction data for high-precision positioning. Field observations are transmitted via mobile internet connectivity to a cloud-hosted processing server, where coordinate computation and quality control procedures are carried out. The processed coordinates and accompanying metadata are then archived within a secure digital repository, making them instantly accessible to authorized users through a web-based interface.

Development of the IoT-Based Virtual Repository

The virtual repository was implemented as a cloud-hosted geospatial database designed to support long-term storage, efficient retrieval, and secure management of control point data. Each control record integrates spatial coordinates, monument descriptions, site photographs, field notes, and integrity assessment reports within a unified digital framework.

A relational database structure was adopted to facilitate fast querying and scalable storage. User authentication and role-based access control mechanisms were implemented to protect sensitive geospatial information and restrict unauthorized access. These security features ensure data confidentiality while maintaining ease of access for authorized personnel.

The frontend interface was developed using a WordPress-based web platform, allowing users to view control locations interactively, retrieve coordinate data, assess monument condition, and download datasets for integration into GIS and surveying software environments. This digital framework significantly enhances operational efficiency and reduces dependence on analogue record-keeping systems. Figures 2, 3, and 4 show the components of the integrated systems.

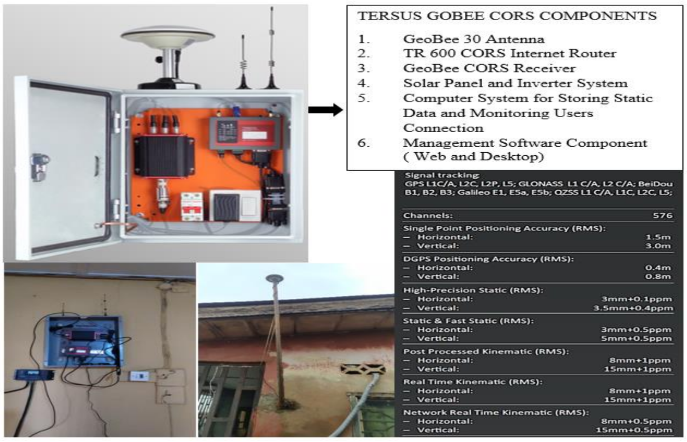

Figure 2: The CORS_Geosystems Parameters and Location (Ehigiator-Irughe and Oladosu 2023)

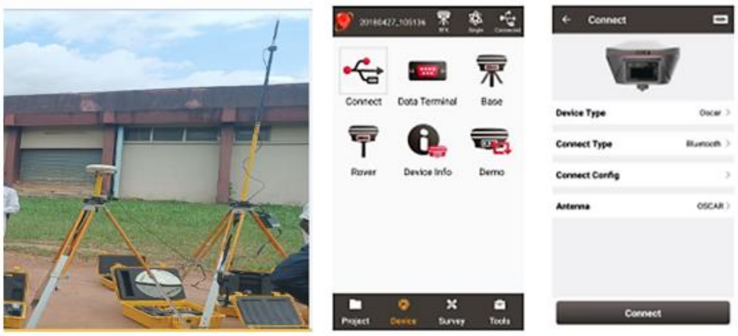

Figure 3: GNSS Receivers displayed at Uniben and NUWA android phone app connection interface

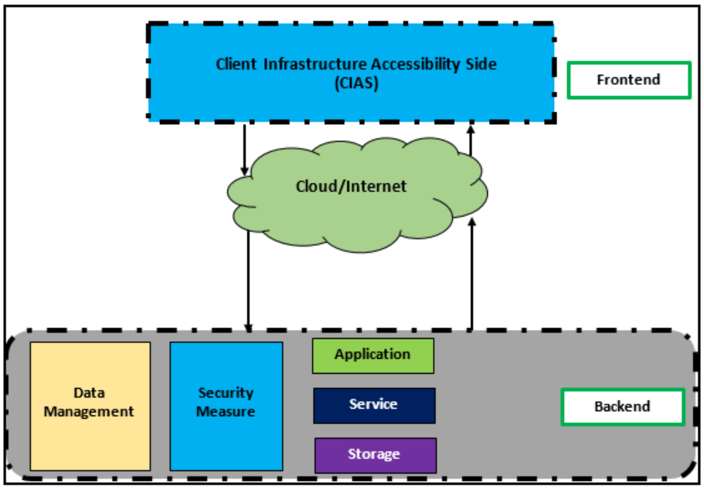

Figure 4: A Simple Frontend and Backend Architecture (Adapted from Borah, 2024)

System Workflow and Operational Implementation
The operational workflow of the system follows a logical sequence beginning with GNSS field observations and ending with real-time online data dissemination. Observations collected at control stations are transmitted to the cloud processing server, where coordinate computation and quality assurance are performed. The validated coordinates are then uploaded automatically into the virtual repository, becoming immediately available for retrieval through the web interface.

The semi-automatic nature of the system allows for rapid data updating while maintaining human oversight for quality assurance. This hybrid operational approach ensures reliability, flexibility, and adaptability, making the system suitable for academic research, professional surveying practice, and long-term geospatial data management.
Figure 5 is a chart showing the processes involved in the semi-automatic IoT. The website was design using word press platform while necessary information were added such as the pictures and the control points attributes.

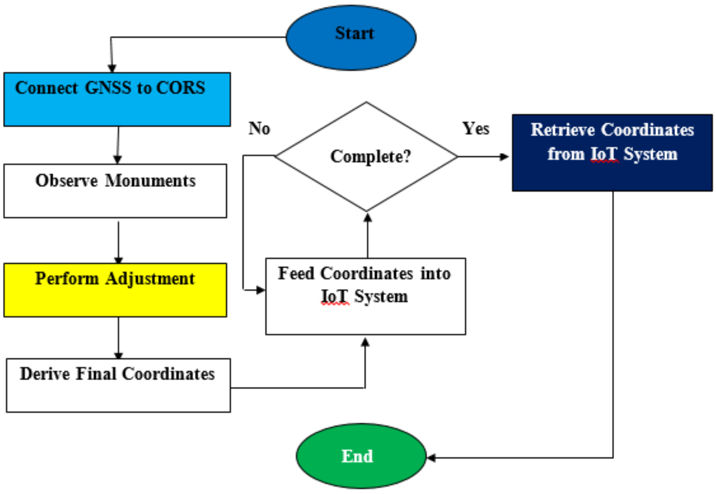

Figure 5: Flow diagram of the feeder and retrieval processes of the system

Presentation of Input Coordinates from Previous Observations

Table 1: Final Coordinates of Adjusted Control Points at First Campaign

Station Name	N(m)	Std.Dev_N(mm)	E(m)	Std.Dev_E(mm)	H(m)	Std.Dev_H(mm)
ADLC_01	706689.612	1.3	788183.288	1.7	123.527	2.9
ADLC_02	706779.020	1.3	788278.405	1.7	122.781	2.9
AGGS_01	697004.619	1.7	789891.112	2.1	82.986	3.5
AGGS_02	697057.118	1.7	789740.377	1.8	80.938	3.5
CORS_GEOS	700413.753	0.0	791974.756	0.0	108.163	0.0
GSTC_01	706121.559	1.5	791055.799	1.8	105.919	3.4
GSTC_02	706152.781	1.4	791215.221	1.9	107.457	3.4
QSS_02	701980.195	1.4	797859.323	1.5	101.997	2.9
QSS01	701999.662	1.3	797783.527	1.5	101.708	2.8

Table 2: Final Coordinates of Adjusted Control Points at Second Campaign

Station Name	N(m)	Std.Dev_N(mm)	E (m)	Std.Dev_E(mm)	H(m)	Std.Dev_H(mm)
AGGS01	697004.619	1.4	789891.112	1.7	82.986	3.5
BEM_606	697173.482	1.9	791205.656	2.2	82.373	4.9
CORS_GEO	700426.070	0.0	791979.716	0.0	108.163	0.0
ENV_101D	697055.312	2.2	791219.827	3.3	82.235	5.4
RAPH_02	708294.467	2.3	789884.722	2.8	121.067	4.5
SAP_001	694987.163	1.6	791460.573	1.9	77.572	4.1
SMGGS_01	698280.921	2.6	792122.412	2.9	96.799	6.7
SMGGS_02	698213.000	1.9	792049.327	2.3	95.639	4.8

Table 3: Final Coordinates of Adjusted Control Points around Uniben

STATION	E(m)	N(m)	h(m)
Base_0	791899.4258	700531.0251	108.2221
GPS100	789397.9902	708576.4309	127.3695
UNIBEN B 03 P	789095.6985	707620.7465	123.6165
PBE193	789310.2549	707506.4772	124.3210
UNIBEN SG 01	789270.5860	707601.5790	125.1501

STATION	E(m)	N(m)	h(m)
UNIBEN BP 04	789242.9627	707627.6946	125.3942
GEM 043	789280.9021	707630.5084	124.6709
RAPH GNSS 08	789471.9735	707672.4490	124.1947
RAPH GNSS 09	789613.5716	707698.0238	122.6097
RAPH GNSS _10	790224.2104	707795.0919	113.6297
RAPH GNSS 11	790434.3178	707854.0069	111.5225
RAPH GNSS 06	790634.4358	708614.1895	110.5127
RAPH GNSS 5	790229.6224	708704.0707	112.7036
RAPH GNSS 04	790115.5881	708710.1920	114.4501
UNIBEN 02	789875.7324	708645.7109	119.1559
UNIBEN 03	789844.3431	708526.0107	120.1763
RAPH UNIBEN 02	789804.4312	708399.3471	120.6859
RAPH UNIBEN 01	789774.1402	708303.8314	121.1585
UNIBEN 01	789633.0081	708612.0767	124.0336
UB GPS 101	789212.2153	708567.7054	128.0804
UB GPS 102	788961.2346	708529.1693	128.5405
GEM 31	788944.5586	708508.1774	128.2211
GEM 030	788781.7142	708467.9004	129.2154

RESULTS AND DISCUSSION

GNSS Coordinate Determination and Accuracy Assessment

The processed GNSS observations yielded precise three-dimensional coordinates for all surveyed control points in both the local Minna datum and the global WGS84/ITRF reference frame. The computed coordinate values are presented in Tables 6 and 7.

The horizontal positioning accuracy achieved across the network remained within the centimetre range, while vertical accuracy generally fell within the decimetre range. These results indicate high-quality satellite geometry, stable signal reception, and effective network correction from the continuously operating reference station (CORS) infrastructure. The consistency of the results confirms the reliability of the adopted GNSS observation and processing methodology.

Stations located in open environments exhibited superior positional accuracy compared to those situated in partially obstructed urban settings. Slight degradation in precision observed at some stations can be attributed to multipath interference, vegetation cover, building proximity, and local atmospheric effects. Nevertheless, the overall accuracy achieved satisfies the tolerance requirements for first-order geodetic control establishment, engineering surveys, and high-precision geospatial mapping applications.

These results demonstrate that the deployed GNSS framework provides a robust foundation for control network densification and spatial data referencing within urban and peri-urban environments.

Table 6: Previously Defined Coordinates in Local Datum

MINNA DATUM NTM						
Name	**Sc.fact1**	**Lat2**	**Lon2**	**Northing**	**Easting**	**Elevation**
Base_0	1.00065482	6°19'55.165"N	5°38'15.236"E	257879.400	356659.249	108.2221
GPS100	1.00063681	6°24'17.310"N	5°36'55.225"E	265926.400	354182.96	127.3695
UNIBEN B 03 P	1.00063465	6°23'46.270"N	5°36'45.237"E	264972.270	353878.074	123.6165
PBE193	1.00063618	6°23'42.517"N	5°36'52.195"E	264857.430	354092.170	124.3210
UNIBEN SG 01	1.00063590	6°23'45.617"N	5°36'50.921"E	264952.590	354052.784	125.1501
UNIBEN BP 04	1.00063570	6°23'46.471"N	5°36'50.027"E	264978.760	354025.255	125.3942
GEM 043	1.00063597	6°23'46.557"N	5°36'51.261"E	264981.490	354063.200	124.6709
RAPH GNSS 08	1.00063734	6°23'47.890"N	5°36'57.481"E	265022.840	354254.248	124.1947
RAPH GNSS 09	1.00063836	6°23'48.698"N	5°37'02.090"E	265047.970	354395.827	122.6097
RAPH GNSS _10	1.00064274	6°23'51.755"N	5°37'21.964"E	265143.190	355006.309	113.6297
RAPH GNSS 11	1.00064425	6°23'53.637"N	5°37'28.806"E	265201.460	355216.434	111.5225
RAPH GNSS 06	1.00064569	6°24'18.334"N	5°37'35.440"E	265960.510	355418.629	110.5127
RAPH GNSS 5	1.00064278	6°24'21.325"N	5°37'22.291"E	266051.530	355014.372	112.7036
RAPH GNSS 04	1.00064196	6°24'21.543"N	5°37'18.583"E	266057.970	354900.445	114.4501
UNIBEN 02	1.00064024	6°24'19.485"N	5°37'10.773"E	265994.240	354660.558	119.1559
UNIBEN 03	1.00064001	6°24'15.596"N	5°37'09.732"E	265874.690	354628.861	120.1763
RAPH UNIBEN 02	1.00063973	6°24'11.482"N	5°37'08.413"E	265748.24	354588.605	120.6859
RAPH UNIBEN 01	1.00063951	6°24'08.380"N	5°37'07.412"E	265652.87	354558.052	121.1585
UNIBEN 01	1.00063850	6°24'18.431"N	5°37'02.874"E	265961.34	354417.901	124.0336
UB GPS 101	1.00063548	6°24'17.057"N	5°36'49.182"E	265918.22	353997.282	128.0804
UB GPS 102	1.00063368	6°24'15.845"N	5°36'41.014"E	265880.45	353746.368	128.5405
GEM 31	1.00063357	6°24'15.165"N	5°36'40.468"E	265859.50	353729.635	128.2211
GEM 030	1.00063240	6°24'13.881"N	5°36'35.166"E	265819.74	353566.796	129.2154

MINNA DATUM NTM						
Name	**Sc.fact1**	**Lat2**	**Lon2**	**Northing**	**Easting**	**Elevation**
GEM 001	1.00063157	6°24'00.145"N	5°36'31.315"E	265397.57	353449.369	130.1173

Table 7: Newly Redefined Coordinates in ITRF/WGS 84

ITRF2014						
	UTM			**WGS84**		
Name	**Easting**	**Northing**	**Elevation**	**Lat1**	**Lon1**	**Ellipsoidal H**
Base_0	791899.4258	700531.0251	108.2221	6°19'53.533"N	5°38'17.712"E	109.687
GPS100	789397.9902	708576.4309	127.3695	6°24'15.703"N	5°36'57.705"E	128.928
UNIBEN B 03 P	789095.6985	707620.7465	123.6165	6°23'44.660"N	5°36'47.716"E	125.171
PBE193	789310.2549	707506.4772	124.3210	6°23'40.906"N	5°36'54.675"E	125.872
UNIBEN SG 01	789270.5860	707601.5790	125.1501	6°23'44.007"N	5°36'53.400"E	126.703
UNIBEN BP 04	789242.9627	707627.6946	125.3942	6°23'44.861"N	5°36'52.506"E	126.947
GEM 043	789280.9021	707630.5084	124.6709	6°23'44.947"N	5°36'53.741"E	126.223
RAPH GNSS 08	789471.9735	707672.4490	124.1947	6°23'46.280"N	5°36'59.961"E	125.745
RAPH GNSS 09	789613.5716	707698.0238	122.6097	6°23'47.088"N	5°37'04.570"E	124.159
RAPH GNSS _10	790224.2104	707795.0919	113.6297	6°23'50.145"N	5°37'24.443"E	115.172
RAPH GNSS 11	790434.3178	707854.0069	111.5225	6°23'52.027"N	5°37'31.285"E	113.063
RAPH GNSS 06	790634.4358	708614.1895	110.5127	6°24'16.726"N	5°37'37.919"E	112.057
RAPH GNSS 5	790229.6224	708704.0707	112.7036	6°24'19.718"N	5°37'24.770"E	114.253
RAPH GNSS 04	790115.5881	708710.192	114.4501	6°24'19.936"N	5°37'21.063"E	116.001
UNIBEN 02	789875.7324	708645.7109	119.1559	6°24'17.878"N	5°37'13.252"E	120.709
UNIBEN 03	789844.3431	708526.0107	120.1763	6°24'13.988"N	5°37'12.212"E	121.729
RAPH UNIBEN 2	789804.4312	708399.3471	120.6859	6°24'09.874"N	5°37'10.893"E	122.238
RAPH UNIBEN 1	789774.1402	708303.8314	121.1585	6°24'06.771"N	5°37'09.892"E	122.710
UNIBEN 01	789633.0081	708612.0767	124.0336	6°24'16.824"N	5°37'05.353"E	125.590
UB GPS 101	789212.2153	708567.7054	128.0804	6°24'15.450"N	5°36'51.662"E	129.641
UB GPS 102	788961.2346	708529.1693	128.5405	6°24'14.238"N	5°36'43.494"E	130.104
GEM 31	788944.5586	708508.1774	128.2211	6°24'13.557"N	5°36'42.948"E	129.785
GEM 030	788781.7142	708467.9004	129.2154	6°24'12.274"N	5°36'37.646"E	130.780
GEM 001	788665.4490	708045.0810	130.1173	6°23'58.537"N	5°36'33.795"E	131.680

Datum Transformation and Coordinate Shift Analysis
A comparative analysis between coordinates referenced to the Minna datum and those expressed in the WGS84/ITRF reference frame reveals systematic horizontal and vertical shifts across the study area. The horizontal displacement components (ΔE and ΔN) generally remain below 0.5 m, indicating moderate planar shifts between the two reference systems. In contrast, the vertical component (ΔH) exhibits larger discrepancies, reaching magnitudes of approximately 1.0 m in some locations. This pronounced vertical difference reflects limitations in the realization of the national vertical datum and the accuracy of existing geoid models in the region.

The spatial distribution of the transformation residuals is illustrated in Figure 6. The displacement vectors display coherent directional trends across the control network, suggesting that the observed coordinate differences are systematic rather than random. This behaviour confirms that the detected discrepancies originate primarily from reference frame inconsistencies rather than observational errors.
These findings highlight the necessity of applying accurate transformation parameters when integrating legacy geospatial datasets into modern global reference frameworks. Failure to account for these systematic shifts may introduce significant positional distortions into engineering design, cadastral mapping, navigation systems, and geospatial decision-support applications.

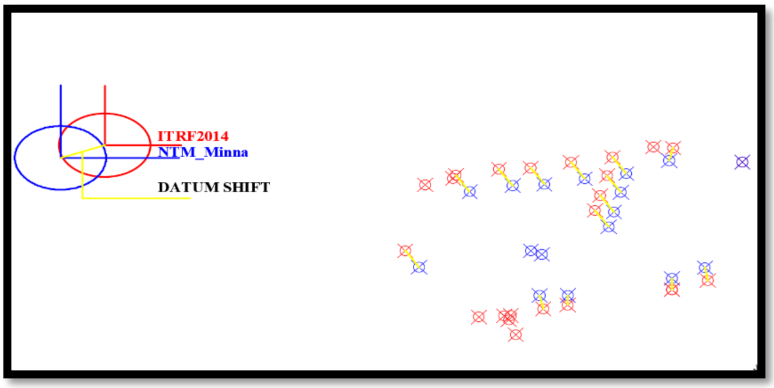

Figure 6: Datum shift plot result

Figure 6, is the shift observed in the local datum to that of the international datum system. ITRF2014 and WGS84 (G1762) are practically equivalent in their new definitions if their epochs (moments in time) are the same. WGS84 (G1762) is the standard epoch for both. The typical standard epoch for ITRF08 and ITRF2014 is 2005.0. And 2010.0. Respectively. To translate positions from one epoch to another, NGS created a program called Horizontal Time Dependent Positioning. In other words, this application supports the current ITRF and WGS84 realizations, as well as the movement of positions from one date to another and the translation of one reference frame to another. This emphasizes the fact that the ITRF and WGS84 systems are worldwide, and their realizations account for the reality that the planet is always in motion due to the movement of tectonic plates throughout the world.

Spatial Distribution and Geodetic Network Geometry

The spatial distribution of the established control points and the GNSS observation network geometry are illustrated in Figures 7, 8 and 9. The network demonstrates adequate spatial coverage across the study area, ensuring uniform geometric strength and reliable positional control.

The configuration of the control points provides balanced baseline distribution and optimal satellite observation geometry, which contributes significantly to the achieved positional accuracy. Network geometry analysis indicates that the established control framework supports both large-scale engineering surveys and urban mapping applications.

Furthermore, the spatial density of the network enhances redundancy, minimizes error propagation, and strengthens overall positional reliability. This configuration ensures the suitability of the network for continuous densification, cadastral boundary surveys, infrastructure development, and high-resolution spatial modelling.

Figure 7: Plot of controls in UTM-Minna

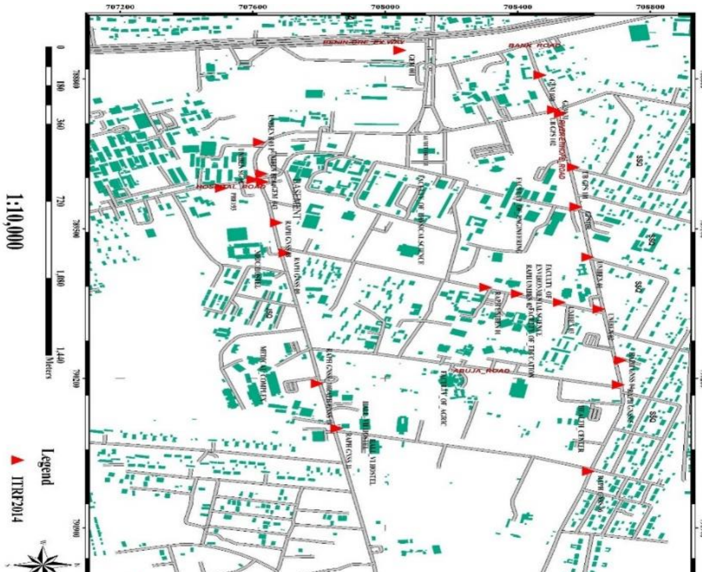

Figure 8: Plot of projected controls, ITRF2014

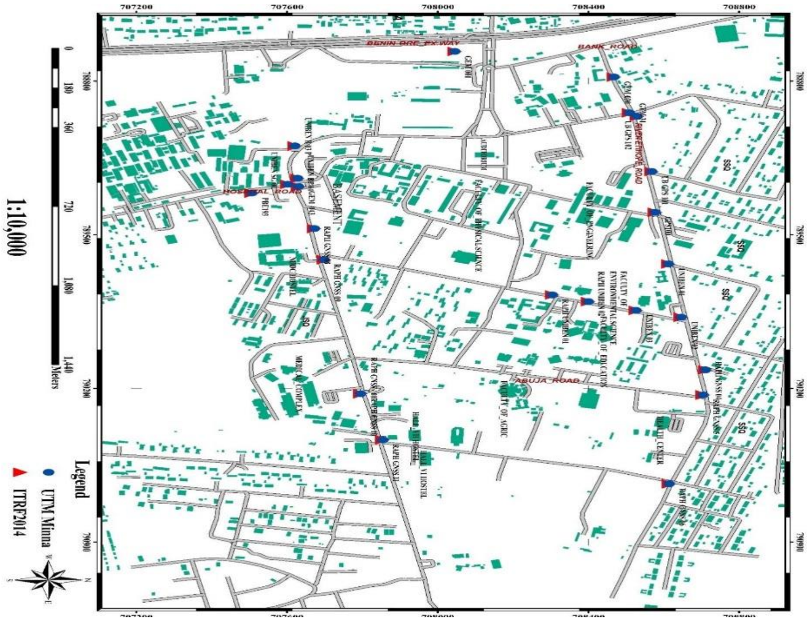

Figure 9: Plot of controls overlay in UTM-Minna and ITRF2014

Performance Evaluation of the IoT-Based Virtual Control Point Repository

The developed semi-automatic IoT-based control point repository demonstrated efficient functionality in the storage, retrieval, visualization, and management of geodetic data. The system architecture and web interface design are presented in Figures 10, 11 12 and 13.

The platform enables seamless real-time access to control point coordinates, monument descriptions, photographs, and positional metadata through a centralized web-based interface. System testing revealed rapid data query response times, stable data synchronization, and reliable accessibility under typical internet connectivity conditions.

The implementation of this digital framework significantly reduces dependence on analogue record-keeping systems, thereby minimizing data loss, duplication, and retrieval delays. The platform also supports collaborative data sharing among surveyors, GIS analysts, engineers, and urban planners, thus enhancing operational efficiency and project coordination.

The website to access the control is found at https://ehigiatorcontrols.com/ where the procedure to check the control parameter can be easily followed.

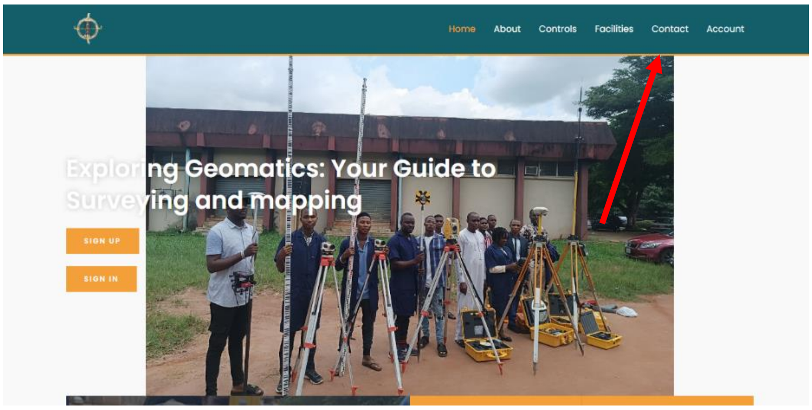

Figure 10: Interface for accessing controls

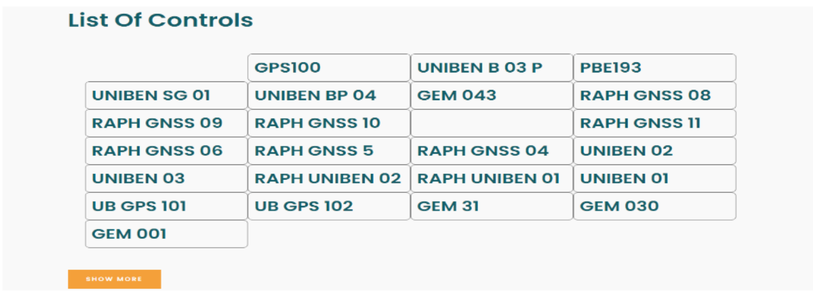

Figure 11: List of controls

In Figure 11, each control point can be accessed by simply clicking on it, which will display its properties and coordinates. At the lower left-hand corner, there is a “See More” option that provides access to additional control points, each hyperlinked for easy visualization along with their corresponding information. Tables 4 and 5 present details of selected control points, and similar information is available for all other controls, as summarized in the results section.

Table 4: Randomly Selected Control Points Result

CONTROL ID	NTM MINNA		ITRF2014		DATUM SHIFT
	E	**N**	**E**	**N**	**S(m)**
Raph_uniben_02	354588.605	265748.244	708399.3471	708399.3471	0.0192

Description: A typical First-order control beacon made of a concrete block with a thin iron rod in the middle. It is caged with 4 galvanized steel pipes 5cm from each corner.

Location: It is in front of the quantity surveying department with the Faculty of Education just across the road in the opposite direction.

Integrity check: Still in situ with a check score of 98%

Figure 12: Detailed Description of Raph_Uniben_02 Control

Table 5: Randomly Selected Control Points Result

CONTROL ID	NTM MINNA		ITRF2014		DATUM SHIFT
	E	**N**	**E**	**N**	**S(m)**
Raph_uniben_01	354558.0520	265652.8710	789774.1402	708303.8314	0.0228

Description: A typical second-order control beacon made of a concrete block with a thin iron rod in the middle. It is a bit brittle at the edges due to the weathering effect on the concrete structure.

Location: This control point can be found along the river Ethiope Road few meters away from the side of the old management science building

Integrity check: Still in situ with a check score of 95%

Figure 13: Detailed Description of Raph_uniben_01 Control

Integrated System Performance and Operational Implications

The integration of high-precision GNSS positioning with a semi-automatic IoT-enabled data management platform represents a significant advancement in geodetic infrastructure modernization. The synergy between accurate coordinate determination, systematic datum transformation, and centralized digital archiving establishes a scalable framework for intelligent geospatial data governance.

The proposed system offers substantial improvements in operational efficiency, cost-effectiveness, and data reliability. By enabling real-time access to verified control point information, the system reduces redundant field surveys, shortens project timelines, and enhances decision-making accuracy.

In the context of developing urban environments, such digital geodetic infrastructure provides a practical pathway for supporting smart city initiatives, spatial data infrastructure (SDI) development, and sustainable urban planning. The system also promotes interoperability with global reference frameworks, facilitating regional mapping programs and international geospatial collaboration.

CONCLUSION

This study demonstrates the successful development of a semi-automatic IoT-enabled virtual repository for geodetic control point management, integrating high-precision GNSS observations, reliable datum transformation, and an efficient web-based data management system. The results confirm that the adopted methodology achieves centimetre-level horizontal accuracy and acceptable vertical precision, making it suitable for urban geodetic applications and network densification. The observed positional differences between Minna datum and WGS84 further emphasize the importance of accurate transformation models in ensuring spatial data consistency across reference systems. By addressing the limitations of traditional analogue record-keeping, the developed platform significantly enhances data accessibility, integrity, and operational efficiency through real-time access, centralized storage, and intuitive spatial visualization. Overall, the framework provides a scalable and practical solution for modernizing geodetic data management, with strong relevance for urban planning, infrastructure development, and emerging smart city systems.

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