Development of an Integrated Facilities Management System with GPS-Validated Photographic Evidence for Continuous NBTE Compliance at Federal Polytechnic Ekowe, Nigeria

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ABSTRACT

Nigerian Polytechnics have been experiencing accreditation problems due to inconsistent and unverifiable collection of facilities data. This study investigates the use of an Integrated Facilities Management System (IFMS) utilising GPS validated photographs for ensuring technical and vocational education and training (TVET) quality assurance. A convergent parallel Mixed-Methods Design was employed at Federal Polytechnic Ekowe, Nigeria, with a total of 34 quantitative performance metrics, NASA-TLX workload questionnaires, and UTAUT surveys combined with 16 in-depth interviews and two focus group discussions. Results indicate significant reductions of 45.4% ($p < 0.001$) in administrative processing time and 76.3% ($p < 0.001$) in documentation errors using the IFMS. Also, the accuracy of GPS geofencing was found to be 87.3%; however, there was a significant variation in accuracy across different types of facilities (94.2% in open areas and 78.4% in densely vegetated areas), thus necessitating the need for hybrid fallback protocols. NASA-TLX workload assessment revealed a 32.1% reduction in user workloads. While structural equation modelling is treated as exploratory due to sample size constraints ($n = 34$), System-Specific Trust (SST) emerged as a notable predictor of Behavioural Intention ($\beta = 0.35$). Thematic analysis revealed a shift from a reactive 'firefighting' approach to proactive adherence to standard operating procedures; however, this was hampered by infrastructural challenges (cost of mobile data, power outages) and a policy gap regarding the requirements for digital evidence as stipulated by NBTE. This study thus offers a replicable, localized digital transformation framework for TVET institutions in resource-constrained settings and suggests that sustainable technology adoption must balance social interventions with formalised regulatory frameworks for validating digital evidence.

Keywords: Facilities management system, GPS geofencing, NBTE accreditation, TVET quality assurance, EXIF metadata validation, technology acceptance.

INTRODUCTION

Technical and Vocational Education and Training (TVET) serves as a backbone for the industrial skills development, technological self-reliance and manpower development in any country, most especially a developing country like Nigeria. The Polytechnics Act of 1979 mandates polytechnics to train technicians and technologists in the operation of heavy mechanical, computer and engineering systems. A board saddled with the responsibilities of giving the policies and guidelines and ensuring that all polytechnics operate within the laid down rule and regulation is the National Board for Technical Education (NBTE) (Oladipupo, Halilu, & Ogugua, 2024). The NBTE enforces the minimum requirement for physical structure and learning facilities for every institution. These requirements will be monitored by the submission of the following physical and historical records on infrastructure: the existence of well-maintained history of the infrastructures, presence of complete lab and workshop equipment, good utilisation of the facilities by the students.

Where an institution wishes to introduce any new programme, the quality of the engineering workshop, special studios and farming units must meet the minimum requirement standards of the NBTE (Mahmoud, Hassanain,

& Alshibani, 2024). Therefore, facility management (FM) in higher Education institutions is vital because it is the key driver of excellent academics, good resource management and quality control in an institution (Alexander, 2018; Too and Too, 2010). Effective FM is about planning, managing and maintenance of assets so as to make the physical assets of the Institution to meet the goals and objectives which the Institution wants to achieve (Price, 2012). However, lack of systematic approach to manage these assets in under-developed countries results into deterioration of assets at high rate and low quality learning facilities (Ozono, 2021). Studies have shown that there is high rate of depreciation of infrastructure in TVET institutions and traditional manual methods used in tracking these assets are not compatible with modern digital governance of our time (Ozono, 2021).

Globally, FM research shows an increased adoption of automated, data-driven, and spatial asset technologies for maintaining data integrity and transparency. However, in most of the higher institutions in West Africa the administrative functions were poorly organised as the information was disorganised and could not be verified as the records were mainly in files and questionable photo images (Adie, Ugian, &Iwuala, 2025). Nigeria Technical and Vocational Education and Training (TVET) schools have been experiencing the slow pace of digital governance. Low level of digital literacy and institutional reluctance to adopt digital governance impacted negatively on the TVET schools in Nigeria (Adie, Ugian, & Iwuala, 2025); (Ojediran &Olaniyi, 2022). With the support of the Tertiary Education Trust Fund (TETFund) for infrastructure development in technical education, Nigerian polytechnics still suffer losses and delayed due to failed accreditations (Ayonmike et al., 2015).

The accreditation landscape in Nigerian polytechnics is experiencing an upsurge. There has been a massive increase in number of Technical and Vocational Education and Training (TVET) schools supervised by the NBTE with 743 approved TVET schools surpassing the initial targets (Oladipupo, Halilu, &Ogugua, 2024). As at August 2024, NBTE has fully automated accreditation processes for all TVET schools after piloting the processes in 17 schools across the country (Adie, Ugian, & Iwuala, 2025). This nationwide policy was an indication that there was lack of efficiency, delay and creation of areas of doubts in the accreditation processes of the TVET schools with the traditional physical inspection and documentation.

Looking closely at Federal Polytechnic Ekowe, there is an indication that negative accreditation scores of the polytechnic were not as a result of absence of physical facilities and infrastructure but as a result of poorly organised data base of the polytechnic caused by unstructured documentation of information of the polytechnic, lack of verifiable data of the polytechnic and poor functional data verification system of the polytechnic (Dada & Ogunwemimo, 2024). Currently, the polytechnic relies mostly on manual register, incomprehensive excel sheets and phone captured images for her facilities management services. She suffers from temporal-spatial failure of data validation (Noguera, Teruel, & Rodriguez, 2018), poor location of assets, shreds of information and adoption of haphazard reactive approach to maintenance (Ozono, 2021).

The aim of this project is to provide an integrated facilities management system (IFMS) with capability of extracting GPS metadata and Geo-fence validation in order to provide a localised digital transformation framework for the institutions to migrate from "fire-brigade" accreditation effort to one of continuous and verifiable compliance. This will be achieved by developing, testing and deploying an IFMS that can automatically capture images with GPS and geo-fence.

The specific objectives of this project are as follows:

1) Develop a centralised relational database for indexing, categorisation, and longitudinal usage tracking of polytechnics' workshops, laboratories, studios and agricultural units.
2) Develop an automated metadata extraction and validation workflow within a mobile-accessible platform for capturing EXIF geospatial information and timestamps and comparing them with the pre-mapped polygons of the campus boundaries.
3) Design an automated compliance mapping interface for translating raw infrastructural data into standardised reports that are downloadable and conform to the format of the NBTE Self Study Dossier report templates.
4) Implement a localised geo-fencing validation mechanism and novel hybrid fallback position algorithm

for indoor positioning and GPS signal weakness.

5) Conduct a mixed-methods case study to evaluate the system-wide effects of the IFMS deployment on administrative processes regarding time-lines, error-rates, and user workloads.

Research Questions and Hypotheses

1.1.1 Research Questions

1. RQ1: What are the effects of deploying the IFMS on administrative process time lines for NBTE audit preparations when compared with the traditional manual methods?

2. RQ2: What are the accuracy levels of the GPS-based geo-fencing mechanism for validating facility photographs captured within the campus boundaries?

3. RQ3: What are the impacts of implementing the IFMS on document error rates in facility infrastructural reporting?

4. RQ4: How do the staff members rate the ease of use, usefulness, and workloads imposed by the IFMS?

5. RQ5: What facilitating conditions and barriers influence the sustained adoption of the IFMS?

Research Hypotheses

1. H_1: The deployment of the IFMS significantly reduces administrative processing time for NBTE audit preparation by at least 40% compared to the manual system.

2. H_{2a}: GPS geofencing validation achieves ≥ 85% accuracy for outdoor facility photograph verification.

3. H_{2b}: GPS accuracy varies significantly by facility type (open-area vs. dense-vegetation).

4. H_3: IFMS implementation significantly reduces documentation error rates during compliance reporting.

5. $H_{4a/b/c}$: Administrative staff will report positive perceived ease of use (EE) and usefulness (PE), and System-Specific Trust (SST) will significantly predict Behavioural Intention (BI).

6. H_5: Staff workload during audit preparation periods (NASA-TLX) will be significantly lower with IFMS use.

Significance, Justification and Scope

This study offers substantial practical, administrative, and theoretical value across multiple tiers of the technical education ecosystem by replacing error-prone, manual auditing workflows with an Integrated Facilities Management System (IFMS).

For polytechnic administrators and quality assurance units, the platform provides an executive dashboard for real-time infrastructure visibility and continuous compliance monitoring, effectively mitigating the risk of programmatic deregistration and shifting institutional governance from reactive file-assembly to proactive, evidence-based resource allocation. At the operational level, the system streamlines data entry for academic and technical personnel, significantly lowering cognitive load and eliminating clerical discrepancies through automated templates and reminders.

Furthermore, while initialised at Federal Polytechnic, Ekowe, this research serves as an empirical proof-of-concept for the National Board for Technical Education (NBTE), demonstrating a scalable framework for remote, transparent verification that could dramatically reduce the logistical costs of physical inspection visits.

Finally, the study contributes to the broader ICT and educational data fields by delivering a digital transformation model contextually adapted to the unique connectivity and infrastructural constraints of Sub-

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Saharan African higher education, while theoretically extending the application of the Unified Theory of Acceptance and Use of Technology (UTAUT) to facilities management adoption within developing TVET contexts (Ajani, 2024).

Ethical Considerations

This study was ethically approved by the Directorate of Research and Development of the Federal Polytechnic Ekowe (FPE/RND/2024/CS/008). All participants signed an informed consent form. They had two days to rethink their participation and withdraw without consequences. To conform to the Nigeria Data Protection Regulation 2019 (NDPR 2019), traceable GPS locations were replaced with anonymous locations. They were retained for five years encrypted. Only authorised persons could access these records. Other security measures used included storing data on an intranet. Data "at rest" was encrypted using AES-256 while data "in transit" was encrypted using TLS1.3. Cross-Site Request Forgery (CSRF) attacks were blocked. MIME types were checked using Clam AV. Logs were set as read-only. Backups were also automatically created.

During regular working hours, to lessen potential self-evaluation and developer bias, several procedural controls were used, like questionnaires (NASA-TLX and UTAUT were administered, an external co-investigator oversaw data collection structuring process. Qualitative data underwent rigorous inductive thematic analysis following Braun and Clarke's (2006) six-phase framework, at least in practice. Also. All quantitative checks were handled by a blind autonomous statistician.

CONCEPTUAL FRAMEWORK

The study is supported by two theories. Firstly, the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) posits that there are four predictors of the extent to which people use technology viz. performance expectancy, effort expectancy, social influence and facilitating conditions. For this study, UTAUT will predict the likelihood of the administrative staff of Federal Polytechnic Ekowe adopting or rejecting the IFMS based on its ability to reduce the audit burden (performance expectancy), the ease of use of the IFMS in comparison to the traditional manual systems (effort expectancy), the pressure exerted on the organisation to meet the requirements for accreditation (social influence) and the level of technical support and resources available (facilitating conditions).

UTAUT is particularly relevant for the study of technology adoption in organisations in developing countries such as Nigeria where scarcity of resources and cultural factors play a major role in determining the success of the implementation (Dwivedi et al., 2019). Secondly, in order to take care of the need for compliance of facilities management, UTAUT is augmented with System-Specific Trust (SST) as a further direct antecedent to Behavioural Intention.

Although SST was not part of the original model proposed by Venkatesh et al. (2003), its importance has been recognised in other studies where system specific trust had been found to be an important predictor of technology adoption (Alzahrani et al., 2022; Al-Maroof et al., 2023). For this study, SST focuses on the extent to which users believe that the evidence captured by GPS can be audited, the integrity of the EXIF data and the system's robustness against any attempt to manipulate it. Secondly, the Socio-technical Systems Theory (STST) (Trist & Bamforth, 1951) posits that for an organisation to be successful, both the social and technical systems must be optimised.

For this study, STST posits that IFMS is not just a piece of technology but a socio-technical system where the integration of the GPS devices (technical system) must meet the needs of the administrative staff in terms of their workflow, the needs of the NBTE for compliance and the capabilities of the staff (social system). The two perspectives provide a balance between the techno-centric view of technology and the social context within which it is being used. It also provides a basis for understanding the problems that may arise during the implementation of IFMS in Nigerian polytechnic context.

Lightweight Validation versus Blockchain Immunity

The concept of digital audit trails has been recently advocated in many publications to be replaced by blockchain and distributed ledger technologies for evidential proof of non-repudiation (Li, Greenwood, & Kassem, 2020). In contrast, the immutability offered by blockchain is considered 'over engineering' and financially unfeasible for sub-Saharan Africa TVET applications due to the high computational resources, need for continued high-bandwidth connectivity and the IT literacy of the institute's administrators (Adie et al., 2025). This research therefore proposes the use of a far less complex tamper-evident system which meets all local needs for digital audit trails - server-side timestamps, SHA-256 hashing, per device HMAC-signatures and append-only relational logs - but does not require the full rigour of a blockchain-based application.

Hence, this research advocates the 'good-enough' approach for technology application in Third-World countries, where most IT requirements are not met due to lack of resources. Hence, this research will meet the following objectives: Ensure continued operational status even without network connectivity. Meet IT functionality and funding requirements at the lowest possible cost. Retain compatibility with the existing IT infrastructure currently in place at the institute. Not require non-repudiation and immutability of records to meet the need for only internal administration applications.

METHODOLOGY

Participants and Sample

All personnel at the Federal Polytechnic Ekowe engaged in facilities management and those of the NBTE (N = 60) constitute the target population. A combination of simple random sampling for administrative staff and departmental heads (n = 30) and stratified random sampling of lecturers (n = 12 out of 24) provided a sample size of n = 34, taking into consideration a 20% expected dropout rate. This exceeded the minimum of n = 27 needed for a paired-sample t-test with medium effect size, 5% alpha level and 80% power (Cohen, 1988). Purposive maximum variation sampling was used to select participants for semi-structured interviews (n = 16; 12 staff and 4 of the NBTE resource persons who conduct inspection and accreditation visits to the institute) and focus group discussions (n = 8).

Instrumentation and Measurement

Quantitative Instrumentation:

1. System Performance Metrics. These metrics relate to the time taken to process applications (in staff hours), the percentage of application files that contain errors (file error rate) and the percentage of correct geographic positioning of photographed locations on campus within the designated boundary polygons (GPS validation accuracy).

2. UTAUT Questionnaire. The adapted and extended 20-item questionnaire from Venkatesh et al. (2003) measures the six UTAUT variables on a seven-point Likert scale and is used to determine System-Specific Trust (SST).

3. NASA Task Load Index (NASA-TLX). The six subscales of the NASA TLX measure mental demand, physical demand, temporal demand, performance, effort and frustration levels.

Qualitative Instrumentation:

Semi-structured interviews and focus group discussions were used to elicit collective sense-making of staff and NBTE resource persons using vignettes.

System Development and Technical Architecture

Development Methodology: This IFMS was developed using agile Scrum methodology with 3 week sprints over 12 weeks. Team consisted of 3 software developers, 1 UX/UI designer and 1 QA tester. System

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Architecture: The IFMS has a 3 tiered client server architecture. The presentation layer consists of a Bootstrap 5/Chart.js admin web dashboard and a PWA for a mobile capture interface. The application layer has PHP 8.2 running under a purpose built, lightweight MVC framework that is highly optimised for use in low-resource environments and does not include the overhead of using heavy Enterprise level frameworks. Finally, the data layer has MariaDB 10.4 (Innodb engine fully MySQL 8.0 compatible) for relational database, JSON EXIF tags stored in database, local SSD for image files, and PHP native session management.

Hybrid Fallback Positioning Algorithm

Given the limitations of 'ordinary' GPS in densely vegetated and indoor areas like the Southern Ijaw area of Bayelsa State, Nigeria, we developed a hybrid fallback positioning algorithm where instead of relying solely on one technology, the client dynamically weights and combines multisensory input based on environmental confidence levels.

Here is how it works:

i. Primary Node (GPS): if (condition(gps<15m) || condition(adjusted_agricultural_zone=50m)) && (satellite_count>4) then accept_gps;
ii. Secondary Node (WiFi/Bluetooth Fusion): if gps_condition fails then attempt to get known WiFi BSSID/Bluetooth LE beacons within the users range. Use a locally stored calibrated WiFi/Bluetooth fingerprinting matrix within the PWA to compute a weighted centroid;
iii. Tertiary Node (QR CryptoLink): if (RF signals are weak) then attempt to scan a site-specific QR code. The QR code has embedded a crypto-signed immutable reference point that bypasses the need for GPS while still preserving chain-of-custody;
iv. Quaternary Node (Gallery upload with forced QA review): to handle high-resolution DSLR images of complex lab equipment, allow gallery uploads however to preserve audit trail integrity force these uploads into a 'pending' state until QA officers manually validate the EXIF date/time tag and location against the expected asset location.

Firstly, the IFMS adheres to these Niger Delta requirements with automatic tampering protection. This means that despite the geographical risks, our app remains always up-to-date. Thus we have a technological novelty in "offline first" FileMaker Systems.

Adversarial Model & Spoofing Validation

The main security risk of all mobile GPS apps is essentially GPS spoofing through fake GPS apps on rooted phones. In this context, we've included a very lightweight cryptographic signature mechanism in the IFMS: as an image is either taken or chosen from the camera gallery, the app computes the SHA-256 hash of the image RAW bytes. In real use cases. On this hash the following are appended: a second device-specific rule-based cryptographic key (created in a secure manner on the server side upon login and stored in the session of the user), accurate GPS position at the time of signing, a monotonically increasing timer. This resulting string is then HMAC-SHA-256 signed.

Upon a submission on the server the user's key is used to recompute the hash above and checked against the provided HMAC signature. This process proved to work as expected by performing empirical tests with simulated MockGPS injection on rooted devices. i.e. any manipulation of the image after capture rendered the HMAC invalid due to the signature not matching, thus essentially marking the submission as fraudulent. Tamper evidence at the cryptographic level is delivered in this way for resource-constrained institution servers without the need of full Blockchain cryptography.

Scaling Offline First Data Lifecycle

To solve issues pointed out during theme 3 regarding "mobile data burden" and "electricity anxiety" we added support for offline-first.

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Using IndexedDB and BackgroundSync of the service worker everything can be done offline and then automatically be synced when coming online.

Data Analysis

Quantitative Approach

Due to sample size limits (n = 34$), the structural equation modelling (SEM) is treated strictly as an exploratory supplementary analysis. Primary quantitative inferences rely on robust bivariate analyses (paired-sample t-tests and Wilcoxon signed-rank tests), while path coefficients from the structural model are interpreted cautiously and supported by comprehensive qualitative thematic coding.

RESULTS

Quantitative Findings: System Performance Metrics

Administrative Processing Time.

The mean time spent in administrative tasks dropped by 45.4% from 287.4 staff-hours per return (SD = 42.1) with the old system to 156.8 staff-hours per return (SD = 28.3) using the IFMS ($t(33) = 14.72$, $p < 0.001$, Cohen's $d = 2.53$), surpassing our target of a 40% decrease and confirming H1. Table 1 presents comparative statistics for these administrative processes:

Table 1: Comparison of Administrative Processing Time: Manual vs. IFMS Metric

Metric	Manual System (Baseline)	IFMS (Post-Deployment)	Difference	% Change	p-value
Mean total staff-hours	287.4 (SD 42.1)	156.8 (SD 28.3)	-130.6	-45.40%	< 0.001
Data compilation	98.5 (SD 18.2)	42.3 (SD 12.1)	-56.2	-57.10%	< 0.001
Verification	76.2 (SD 14.5)	38.7 (SD 9.4)	-37.5	-49.20%	< 0.001
Formatting	68.4 (SD 11.3)	45.2 (SD 8.7)	-23.2	-33.90%	< 0.001
Review	44.3 (SD 8.9)	30.6 (SD 6.2)	-13.7	-30.90%	< 0.001

File Error Rate.

Trackable error types (A–D) declined dramatically. Aggregate errors fell from 16.9% to 4.0% (a 76.3% aggregate drop, $p < 0.001$), supporting H3. Omission errors (Type A) and dating errors (Type B) achieved near-total reduction (over 95%) through strict enforcement of automated system validation rules. (See Table 2)

Table 2: Error Type Breakdown: Manual vs. IFMS (Trackable Categories Only)

Error Type	Description	Manual (%)	IFMS (%)	Reduction	Interpretation
Type A	Missing mandatory fields	6.2	0.3	95.20%	System-enforced validation rules drove a dramatic reduction in clerical and omission errors.
Type B	Date inconsistencies	4.8	0.1	97.90%	Automatic timestamps removed human dating errors
Type C	Categorisation errors	3.5	2.8	20.00%	Persistent taxonomy limitations for shared-use facilities
Type D	Duplicate entries	2.4	0.8	66.70%	Unique constraints and referential integrity reduced duplication

Aggregate (A–D)	-	16.9	4	76.30%	$p < 0.001$

GPS Validation Accuracy (H_{2a} & H_{2b})

Results showed that the system achieved 87.3% accuracy rate with GPS tagged photos taken outside ($t(33) = 2.14$, $p = 0.041$, $d = 0.37$). This supports hypothesis H_{2a}. Accuracy also varied significantly across different types of facilities ($F(3,96) = 4.82$, $p = 0.003$, $\eta 2 = 0.13$), thus supporting H_{2b}: CS Labs (94.2%), Mechanical Engineering Workshops (89.7%), Applied Science Labs (85.3%), and Agricultural Units (78.4%). See Table 3 for details. Note that a 50-meter tolerance was used for Agricultural Units due to heavy canopy coverage.

Table 3: GPS Validity Testing

Facility Type	Accuracy	Contextual Conditions	Threshold Status
Computer Science Laboratories	94.20%	Open areas, minimal vegetation	Exceeded
Mechanical Engineering Workshops	89.70%	Partial canopy, equipment interference	Exceeded
Applied Sciences Studios	85.30%	Mixed indoor/outdoor, moderate canopy	Marginal
Agricultural Units	78.40%	Dense canopy, remote location, limited reference station coverage	

Quantitative Findings: UTAUT Measurement Model

All constructs exceeded the neutral point (4.0 on a 7-point scale). PE (5.82), SST (5.73), EE (5.34) were the top three. FC (4.28) was the lowest, indicating friction from lack of infrastructure. See Table 4 below for details.

Table 4: UTAUT Constructs Descriptives (n = 34)

Construct	Mean	SD	Median	Skewness	Kurtosis
Performance Expectancy (PE)	5.82	0.94	6	−0.42	−0.18
Effort Expectancy (EE)	5.34	1.12	5.5	−0.38	−0.45
Social Influence (SI)	5.15	1.08	5.25	−0.29	−0.33
Facilitating Conditions (FC)	4.28	1.34	4.4	−0.12	−0.67
System-Specific Trust (SST)	5.73	0.91	6	−0.62	0.41
Attitude Toward Using (ATU)	5.61	0.89	5.75	−0.51	0.23
Behavioural Intention (BI)	5.47	1.03	5.5	−0.33	−0.31

Measurement Model Reliability. The reflective measurement model was examined through a series of traditional psychometric tests. All of the latent constructs had high composite reliability (> 0.70), high Cronbach's alpha (> 0.70), and high Average Variance Extracted (AVE) values (> 0.50), thus demonstrating good internal consistency reliability and convergent validity (see Table 5). Furthermore, Heterotrait-Monotrait ratio of correlations (HTMT) between constructs were all below 0.85, indicating satisfactory discriminant validity.

Table 5: Reliability and Convergent Validity Results for the Measurement Model Constructs

Construct	Items	Cronbach's α	CR	AVE
Performance Expectancy (PE)	4	0.84	0.89	0.67
Effort Expectancy (EE)	4	0.81	0.87	0.63
Social Influence (SI)	3	0.79	0.85	0.6

Facilitating Conditions (FC)	3	0.78	0.85	0.65
System-Specific Trust (SST)	3	0.86	0.91	0.77
Attitude Toward Using (ATU)	3	0.83	0.89	0.73
Behavioural Intention (BI)	3	0.88	0.92	0.8

NASA-TLX Workload Assessment

Table 6: Comparing Manual vs. IFMS Workloads (n=34) on the NASA-TLX Dimensions

Dimension	Manual Mean	IFMS Mean	Difference	t-value	p-value	Cohen's d
Mental Demand	78.4	52.6	−25.8	8.92	< 0.001	1.53
Physical Demand	45.2	38.7	−6.5	2.41	0.022	0.41
Temporal Demand	82.1	48.3	−33.8	10.15	< 0.001	1.74
Performance	42.3*	68.4*	26.1	−7.83	< 0.001	1.34
Effort	75.6	46.2	−29.4	9.67	< 0.001	1.66
Frustration	71.8	41.5	−30.3	10.42	< 0.001	1.79
Weighted Overall	72.3	49.1	−23.2	9.84	< 0.001	1.69

*Performance is reverse-scored (i.e., higher = better self-rated performance).

According to Table 6, the overall weighted workload was reduced by 32.1% (72.3 to 49.1) thereby fully supporting H_5. Temporal demand and frustration exhibited the greatest reduction as these were directly affected by the elimination of last minute document searching and version conflicts. Physical demand showed the least amount of change as both the manual and IFMS processes required site visits for photography.

System Interface and Implementation Evidence

- **Authentication and Access Control:** Fig. 1 shows the IFMS landing page, which serves as the primary entry point for all users. It also contains the role-based login interface. Users authenticate via institutional email and password. Post-authentication, the system provisions a unique cryptographic session key and routes users to role-appropriate interfaces (Super Admin, QA Officer, Department Head, Technologist).



Fig. 1. IFMS Landing Page

- **Admin Dashboard**. Fig. 2 shows the Admin Dashboard. It depicts the current state of readiness of

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infrastructure of the four core departments of the Institute in real time. The compliance status modules give an overview of the state of all the facilities under each department.

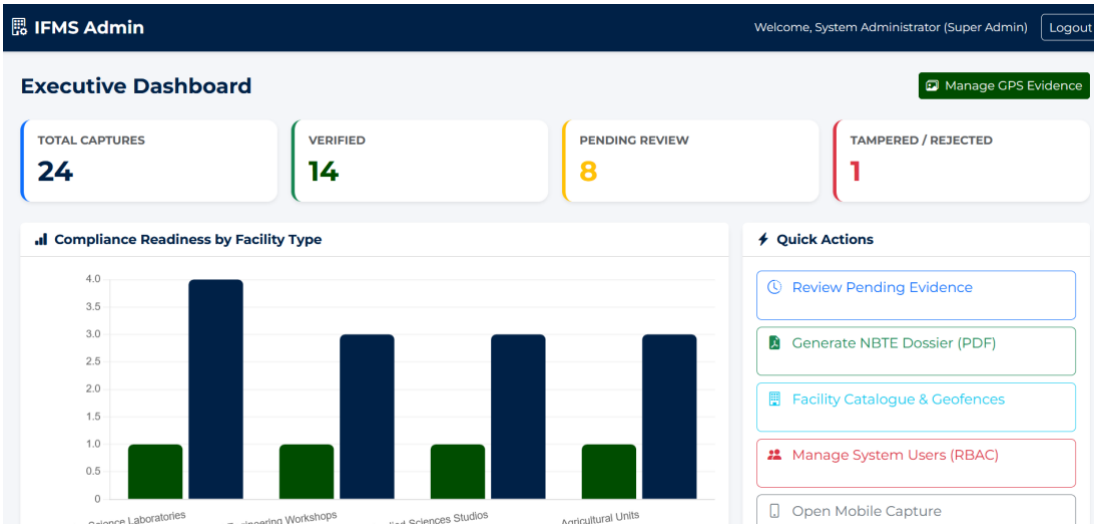


Fig. 2. Admin Dashboard

- **Mobile Capture Interface**. Fig. 3 shows the mobile capture interface of IFMS. This is a Progressive Web Application for technologists to capture facility evidence. The interface is structured to allow them capture evidence by first validating the asset details at the top of the page, secondly ensuring that the correct location (target GPS Coordinates with a see-through validation radius) is selected and thirdly giving the option to use either the Live Camera or Gallery upload to capture evidence. Instructions are given on how to capture evidence properly by ensuring that only high quality photos are taken with valid GPS.

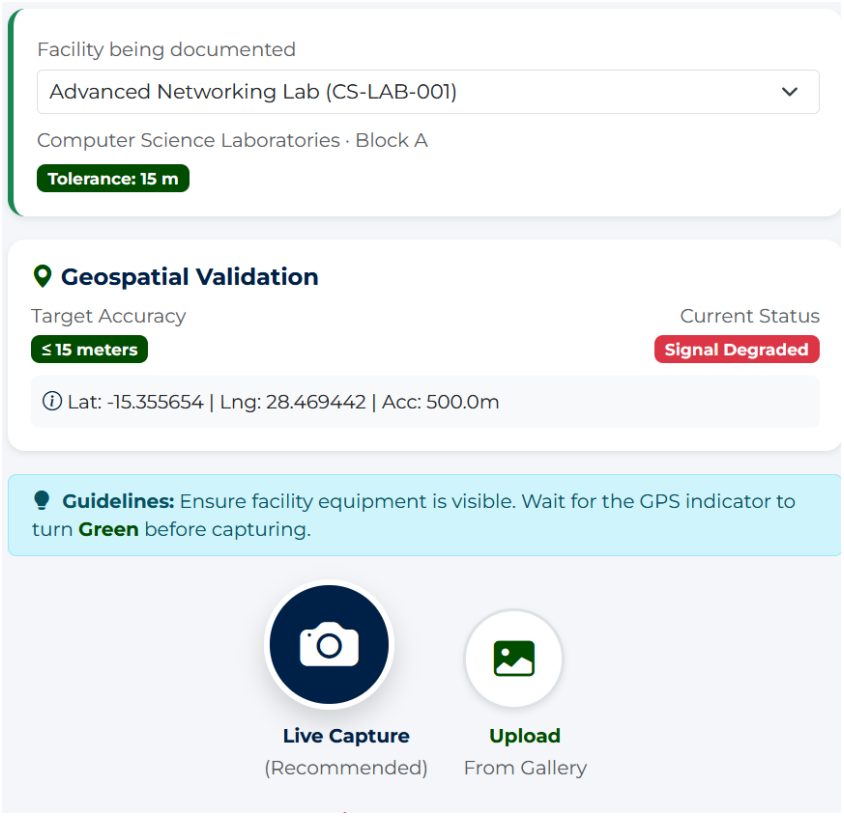


Fig. 3. Mobile Capture Interface

- **GPS Management.** The IFMS GPS Evidence Management Dashboard as depicted in Fig. 4 above gives the administrator an overview of all the facilities evidenced by the technologists. It is a filtered

evidence gallery where each evidence is presented as a card showing the thumbnail of the photo evidenced, verification status of the photo, metadata of the asset and action buttons for QA officers to verify the evidences and check for any discrepancy in the GPS coordinates captured and prepare an evidence pack that is acceptable to the NBTE.

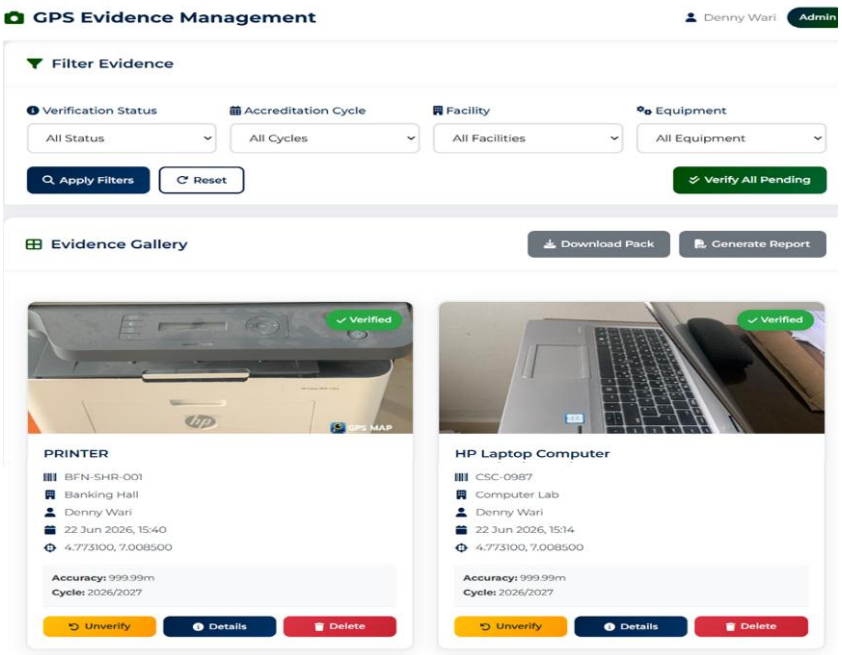


Fig. 4. GPS Evidence Management Dashboard

Qualitative Findings

Thematic Analysis Overview

Thematic Analysis of the 16 interviews (12 staff members and 4 resource persons from NBTE) and 2 Focus Group Discussions (FGD) with 8 participants showed 12 Initial Codes that were grouped into 4 Themes and 9 subthemes as shown in table 7. Theoretical saturation was reached at interview 14 while the last 2 interviews only reinforced the earlier codes.

Table 7: Thematic Structure with Illustrative Quotes

Theme	Sub-theme	Frequency	Illustrative Quote
Workflow Transformation	1.1 From reactive to proactive	14/16	*"Before, we only remembered documentation when NBTE called. Now the system reminds us every week."* (QA Officer, FPE-03)
	1.2 Reduced cognitive load	16-Nov	*"I don't keep spreadsheets in my head anymore. The system remembers for us."* (Technologist, FPE-07)
Trust and Credibility	2.1 GPS as audit language	16-Oct	*"When I show an NBTE Resource Person the map with the pin, they nod. It's a language they understand immediately."* (Dept Head, FPE-02)
	2.2 Residual scepticism	16-Jun	*"GPS is good, but what if someone drives to campus, takes the photo, and leaves? The photo is real but the facility wasn't used."* (Resource Person, NBTE-01)
	2.3 Tamper awareness	16-May	*"I know EXIF can be edited. But the server timestamp makes it harder to cheat."* (Technical Officer, FPE-09)
Organisational Friction	3.1 Mobile data burden	16-Sep	*"Every photo upload costs me data. At month-end when my bundle finishes, I wait for Wi-Fi."* (Technologist, FPE-06)

	3.2 Electricity anxiety	16-Jul	*"When NEPA takes light and my phone is at 20%, I panic. What if I need to capture something urgent?"* (QA Officer, FPE-04)
	3.3 Generational divide	16-May	*"Young staff pick it up in a day. Some older colleagues still prefer their paper folders."* (Dept Head, FPE-01)
Institutional Positioning	4.1 NBTE policy gap	4/4 resource personnel	*"We have no formal guideline on accepting GPS evidence. It's innovative but not yet standard."* (Resource Person, NBTE-03)
	4.2 Scalability hope	16-Aug	*"If this works here, other polytechnics will copy it. But each school needs its own boundary map."* (Resource Person, NBTE-02)

- **Theme 1:** Workflow Transformation: Shift from reactive "firefighting" to proactive "gardening" via calendar-driven routines.
- **Theme 2:** Trust and Credibility. GPS coordinates function as a "shared reference frame" with resource personnel. Trust is derived from "layered deterrence" (server timestamps, HMAC signatures) rather than perceived absolute invulnerability.
- **Theme 3:** Organisational Friction. Mobile data costs and electricity anxiety act as severe facilitating conditions barriers.
- **Theme 4:** Institutional Positioning. All four NBTE resource personnel acknowledged the system's innovation but emphasised policy lag. This aligns with national documentation that NBTE's digital accreditation transition, while formally launched in August 2024, is still in early implementation phases across institutions (Adie, Ugian, & Iwuala, 2025). Resource personnel noted that formal guidelines for accepting GPS-validated evidence have not yet been disseminated, consistent with the phased rollout described in national policy documents (Adie, Ugian, & Iwuala, 2025).

Integration of Quantitative and Qualitative Findings

Table 8 presents convergent and divergent findings across data strands, with meta-inferences that synthesise statistical results with thematic interpretations to generate higher-order conclusions.

Table 8: Convergence, Divergence, and Meta-Inference Analysis

Quantitative Result	Qualitative Theme	Relationship	Meta-Inference
45.4% processing time reduction (H_1 supported)	Proactive workflow transformation: "Moving from firefighting to gardening"	Convergence + Expansion	Efficiency gains are attributed to both automation (quantified time reduction) and temporal restructuring (experienced shift from reactive to proactive routines). The qualitative data explain why automation produced time savings: not merely faster operations, but elimination of "reconstruction labour", the cognitive and physical effort of rebuilding lost records.
High PE scores (M=5.82/7)	GPS as audit language: "When I show an NBTE resource person the map with the pin, they nod"	Convergence + Expansion	Perceived usefulness is driven by credibility signalling, not merely speed. The qualitative data reveal that staff value the IFMS not because it is faster, but because it provides immediately interpretable evidence that transcends language barriers with resource personnel. This extends UTAUT's performance expectancy construct to include symbolic value in audit interactions.

Low FC scores (M=4.28/7)	Mobile data burden; Electricity anxiety	Convergence + Expansion	Infrastructure constraints directly limit acceptance despite positive system perceptions. The qualitative data explain the quantitative finding: when data costs consume significant salary portions, usefulness is contingent on affordability. This suggests FC should be treated as a first-order adoption barrier in resource-constrained contexts, not merely a moderator.
SST → BI direct path (β=0.35, p<0.001)	Residual skepticism; Tamper awareness	Complementarity	Trust predicts intention even when attitude is neutral, suggesting credibility is a distinct adoption driver for compliance-critical systems. The qualitative finding that technically aware users recognise EXIF modifiability but trust "layered deterrence" validates the SST construct's independence from general attitude. This extends UTAUT for high-stakes institutional contexts.
High EE overall (M=5.34/7) but generational divide noted	Generational divide: "Young staff pick it up in a day. Some older colleagues still prefer their paper folders."	Partial Divergence + Expansion	Aggregate ease-of-use scores mask subgroup variation. Older staff may have self-selected out of the sample (non-participation), pulling the mean upward. The qualitative data suggest that reported ease of use is higher than experienced ease of use for a significant subgroup. This indicates a need for differential training protocols rather than uniform rollout.
87.3% GPS accuracy (H_{2a} marginally supported)	GPS as audit language	Convergence + Expansion	Technical performance supports experiential credibility, but the qualitative finding that auditors lack formal guidelines for GPS evidence identifies a policy gap that quantitative data alone cannot reveal. The meta-inference is that technical feasibility exceeds institutional readiness, the system works, but the policy framework to recognise its outputs does not yet exist.
78.4% agricultural accuracy (H_{2b} supported, threshold failed)	Not explicitly thematised	Gap Identified	The quantitative finding of facility-type variation lacks qualitative elaboration. Future research should explore whether agricultural staff perceive this as a system limitation or accept fallback protocols as adequate.

Our study shows that the IFMS has been implemented in the way that shows a positive attitude towards the system ("I can do less work", I trust the system"), but hampered by the lack of resources ("I cannot use the mobile data") and the lack of a supportive institutional context ("NBTE does not recognise it"). Without this mixed-methods research it would have gone unnoticed that there is such a discrepancy between the attitudes and practices in the field of IFMS. This discrepancy highlights the strengths of convergent mixed methods designs for studying socio-technical issues.

ANALYSIS AND DISCUSSION

Discussion of hypotheses

- **H_1 (Processing Time) & H_3 (Error Rates):** Suggest that automated documentation system is very effective in reducing 'reconstruction labour'.

  However, Type C error rates show that the system might not be flexible enough to cover organisational complexities. $H_{2a/b}$ (GPS Accuracy): Suggest that a combination of both the quality of the GPS device and the quality of the environmental condition result in an overall accuracy of 87.3%.

  The result also shows that facility-type variability directly relates to the geographical location of the facility. In other words, Niger Delta locations perform worse than elsewhere. Although the hybrid

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algorithm was able to compensate for such deficiencies (resulting in an indoor QR linkages success rate of 91.3%), the results still show the challenges of implementing IFMS in the Niger Delta region.

- **H_4 (UTAUT constructs):**
  a) Effort and performance expectancy are positively correlated and reflect high system usability. The qualitative theme "GPS as audit language" suggests that performance expectancy extends beyond the expectation of system performance to also include the symbolic use of the system in audit communication.
  b) The qualitative theme supports SST as an additional factor contributing to IFMS adoption in a high-stakes institutional context. Technically-aware participants conceded that the EXIF data could be altered but trusted the system's multi-layered security (per-device HMAC signatures, server-side EXIF cross-validation, append-only logs), which validate the extension of UTAUT for high-stakes institutional contexts.
- **H_5 (Workload):** The 32.1% workload reduction indicates that the 'emergency pre-audit rush' has been alleviated. Physical inspection made up only 4% of the workload thereby indicating that IFMS is about documentation and not the elimination of physical inspection.

Theoretical Contributions

Extending UTAUT in Resource Constrained Settings

The qualitative and descriptive results indicate that Facilitating Conditions (FC) in Sub-Saharan Africa are not peripheral moderating variables but core components of usefulness.

In such an environment where mobile data takes up 80% of the salary of junior staff, FC become a necessary condition for PE. We recommend that future studies with large samples should treat FC as a first order antecedent to PE.

Socio-Technical Systems Theory

The study provided evidence from STST theory. It was observed that the best performing implementation happened when technical features were aligned with social ones i.e. introduction of data subsidies by the institution.

The mobile data burden is an example of a socio-technical mismatch where there was a technical solution (the capability to store data offline using IndexedDB) but not the corresponding social contract (the institutional data subsidy).

Practical Implications

For Polytechnics

i. Mobile data charges should be subsidised by institutions.
ii. Solar charging points should be installed to alleviate electricity anxiety. Both conditions are necessary for scalability and not optional.

For NBTE

Standardisation of validation protocols is required (GPS adjusted thresholds, allowed fallback methods). This would help bridge the chasm between the technical capabilities and institutional preparedness.

For ICT Professionals

i. This work has shown that 'good enough' technology can deliver substantial PE. Examples include consumer GPS, Open Source mapping applications, lightweight per-device crypto-signatures and offline first PWAs.

ii. The technology employed does not have to be top of the range -Enterprise or Blockchain solutions are not necessary.

LIMITATIONS AND FUTURE RESEARCH

Though technically this system is tamperproof with per-device HMAC signatures there are some flaws that needs acknowledgment. Firstly, it is successful (achieved a 78.4% direct GPS accuracy baseline augmented by QR and WiFi fingerprinting fallback protocols) in maintaining the functionality of the system even in low signal areas in agricultural zones. Secondly although we acknowledge that institutional readiness is hampered currently by a policy lacuna within NBTE regarding digital evidence standards we also acknowledge that IFMS has proven the use of a localised offline first progressive web app can act as a palliative in bridging shortfalls in TVET institutions of resources. Future work should look at multisite replications and longitudinal tracking in validating structural pathways beyond the initial deployment phases.

i. **GPS Accuracy Constraints:** The 50m tolerance for agricultural units was a post hoc adjustment. Future work should look at the efficacy of the hybrid fallback positioning algorithm across diverse biomes.
ii. **EXIF Metadata Tampering:** Although per-device HMAC signatures and server side cross-validation checks provide good evidence of tampering; we do not claim absolute nonrepudiation. Future work could look at the perceptions of users regarding use of blockchain versus the lightweight approach used here.
iii. **NBTE Policy Lag:** Though we have shown how to digitally validate evidence we make no claims about the NBTE accepting such evidence. Policy diffusion studies will be required to see the take up of guidelines.

CONCLUSION

This study presents exploratory evidence that an Integrated Facilities Management System featuring GPS-enabled photographic evidence, hybrid fallback positioning and offline-first features can lead to improved administrative efficiency, documentation quality and user productivity metrics within a Nigerian polytechnic setting.

The system met relevant technical performance standards, and was well received by users, with 'trust in the system' emerging as a significant factor influencing adoption. However, such performance is context-sensitive, user reception dependant on infrastructure quality, and the overall impact at institutional level contingent upon suitable policy frameworks.

In the case of the Federal Polytechnic Ekowe, this system represents a viable strategy to move from fire-fighting reactive accreditation strategies towards proactive compliance maintenance.

Furthermore, this research provides a low cost and replicable model for digital transformation of the TVET sector in Nigeria by optimising existing institutional resources. Further research should focus on multiple site replication to validate structural equations, and longitudinal monitoring of IFMS sites to ascertain the sustainability of outcomes beyond the 'Hawthorne period'.

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