



An Enhanced Technology - Organization–Environment Framework for Academic Information System Adoption in Nigerian Universities

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Abstract

This study investigated the factors influencing the adoption of Academic Information Systems (AIS) in higher education institutions in Nigeria using an enhanced Technology–Organization–Environment (TOE) framework. Eight predictors were examined, namely: system quality, compatibility, top management support, IT human resources, regulatory pressure, peer institutional influence, user training, and digital literacy. Data were collected from 151 respondents through a structured questionnaire administered via Google Forms, using a five-point Likert scale ranging from “strongly disagree” to “strongly agree.” Partial Least Squares Structural Equation Modeling (PLS-SEM) in R was employed for data analysis. The results revealed that top management support ($\beta = 0.314$, $p < 0.001$), regulatory pressure ($\beta = 0.465$, $p < 0.001$), and digital literacy ($\beta = 0.213$, $p = 0.003$) were significant predictors of AIS adoption. Other factors, including system quality, compatibility, IT human resources, peer institutional influence, and user training, showed positive but statistically insignificant effects. The findings highlight that organizational support, regulatory requirements, and user capabilities are the primary drivers of AIS adoption, while technological factors showed limited influence. These results emphasize the importance of leadership engagement, compliance with external regulations, and enhancing users’ digital literacy to improve the successful adoption of AIS in higher education. This study extends prior TOE research by incorporating user-centric factors, addressing gaps in empirical studies on AIS adoption in Nigerian universities.

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1.0 Introduction

Academic Information Systems (AIS) has become increasingly important for higher education institutions’ adoption as they streamline academic and administrative processes such as enrollment, course

registration, grading, scheduling, and communication (Sunarjo et al., 2024; Acharya, 2024). When effectively implemented, AIS enhance transparency, reduce administrative workload, and support data-driven decision-making (Saputri & Mulyani, 2022;

Thelma et al., 2024). Rising expectations from governments, accreditation bodies, and students have further made AIS adoption critical for improving institutional efficiency and competitiveness.

However, AIS adoption in developing countries faces challenges including inadequate infrastructure, limited IT support, resistance to change, high implementation costs, and weak policy direction (Madaki et al., 2024). These issues are compounded by varying levels of digital readiness among users.

To examine these factors, this study adopts the TOE framework, which considers technological factors (complexity, compatibility, relative advantage), organizational factors (management support, readiness, resources), and environmental pressures (regulation, competition, external support). The TOE framework is appropriate because AIS adoption depends not only on system features but also on institutional capacity and external influences.

Despite its wide application, prior studies have largely overlooked user-level factors such as digital literacy and training within the framework of AIS adoption in developing countries, particularly in Nigerian universities. To address this gap, the study enhances the TOE model by integrating digital literacy and user training. Digital literacy enables staff and students to effectively use AIS (Wei, 2023), while user training builds confidence, reduces resistance, and promotes system utilization. These enhancements align with recent research emphasizing the need for user-centric considerations in academic technology adoption (Stamate et al., 2024; Adade & DeVries, 2024).

Ergado et al. (2021) applied the TOE framework in a qualitative study and found that technological, organizational, and environmental barriers such as poor infrastructure, weak institutional support, and inadequate policies, significantly hinder ICT adoption in Ethiopian universities. Nguyen et al. (2022) extended the TOE framework to investigate drivers of online retailing (ORE) adoption among Vietnamese

firms using survey data and SEM analysis. Their findings showed that technological factors (relative advantage, compatibility, observability), organizational factors (top management support, entrepreneurial and technological orientation), and environmental factors (trends, government support, legal framework) significantly influence adoption. Firm age affected adoption, while firm size and competitive pressure did not. ORE adoption was found to positively improve business performance.

Adade and deVries (2024) further expanded the TOE framework by adding a stakeholder's dimension using the PRISMA method. They identified critical factors such as security and privacy (technological), top management support (organizational), political influence (environmental), and technological experience (stakeholders). Their study emphasized the importance of human-centric factors, including digital literacy and user training, and highlighted the need for stronger evidence from developing countries.

By incorporating these human-centered factors, the enhanced TOE model provides a more comprehensive and context-aware understanding of AIS adoption in higher education. This approach contributes to both theoretical advancement and practical insights, enabling universities to design more effective implementation strategies.

2.0 Materials and Methods

2.1 Research Design

This study adopts a quantitative, cross-sectional survey design to investigate factors influencing the adoption of Academic Information Systems in higher education institutions. The design allows the collection of numerical data at a single point in time, enabling examination of relationships between technological, organizational, environmental, and user-centric factors.

The study extends the traditional TOE framework by incorporating digital literacy and user training as additional human-centric dimensions. This extension addresses gaps in prior research and emphasizes user-level factors in AIS adoption in developing countries.

Data were collected using a structured questionnaire administered to students, lecturers, IT personnel, and administrative staff at Kaduna State University, Nigeria, who actively use the AIS. The questionnaire items were adapted from previous validated studies, with all items and their sources provided in Appendix A. Expert review was conducted to ensure clarity, relevance, and contextual appropriateness. The

proposed model was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) in R. PLS-SEM was selected due to its suitability for exploratory research, its ability to handle complex models, and applicability to small-to-medium sample sizes (Russo & Stol, 2021). Model hyperparameters, including the latent variable weighting scheme (Mode A for reflective constructs). Statistical significance of paths was assessed using the default PLS-SEM procedures in R. Figure 1 illustrates the research process, from theoretical framework development to data collection, analysis, and interpretation of results.

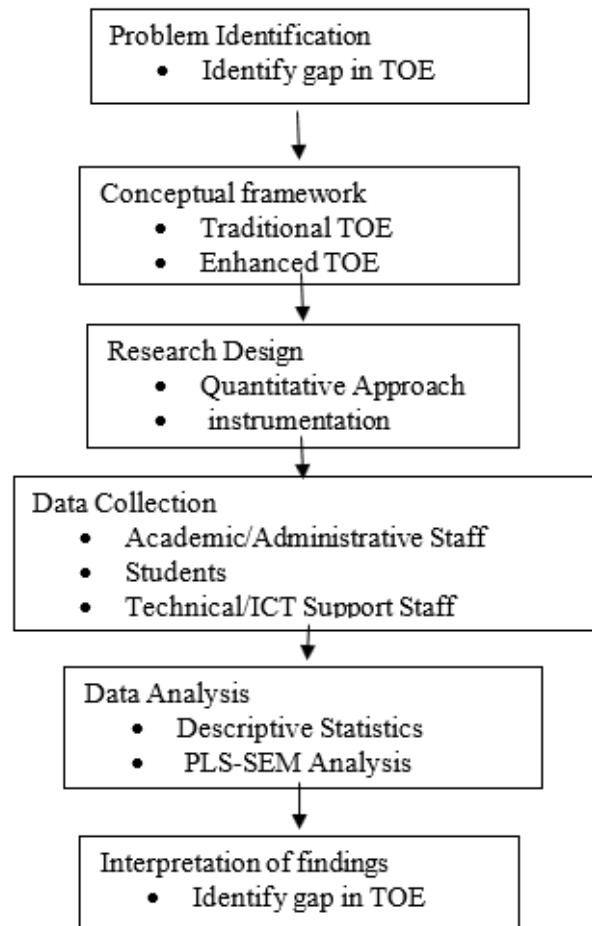


Fig 1: Research process for the study

2.2 Research Framework

The TOE framework explains technology adoption by examining technological, organizational, and environmental factors. This study extends the framework by adding two user-centric organizational factors: User Training and Digital Literacy. These enhancements recognize

that users' skills, confidence, and training experiences influence how effectively new technologies are adopted and utilized. Figure 2 presents the enhanced TOE conceptual framework, showing all constructs and their relationships.

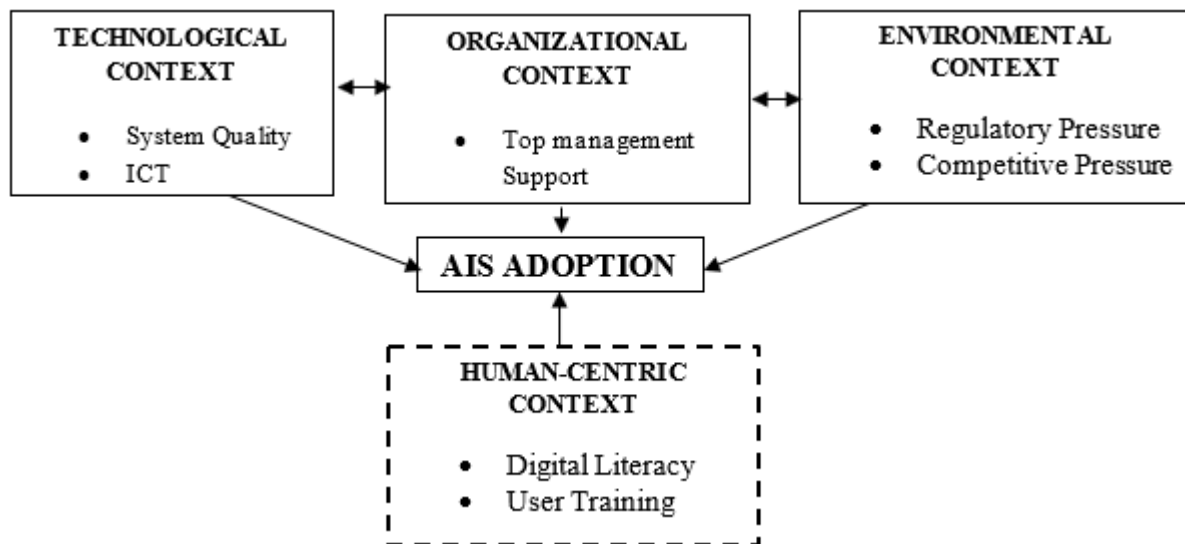


Fig 2: An Enhanced TOE Conceptual Framework (Adapted from Adade & DeVries, 2024)

2.3 Population and Sampling

The target population for this study consists of students, lecturers, IT personnel, and administrative staff at Kaduna State University, Nigeria, who are knowledgeable about and currently use the institution's Academic Information System. These groups were selected due to their direct experience with the system and their ability to provide meaningful insights into factors influencing its adoption. A purposive sampling technique was employed to ensure the inclusion of respondents who actively engage with the AIS. This approach is appropriate because it enables the collection of data from informed users who can accurately describe system usage patterns and adoption-related experiences.

2.4 Sample and Procedure

To identify the relevant respondents, a list of active users (students, lecturers, IT and administrative staff) was obtained. A structured, self-administered questionnaire was designed and distributed via Google Forms, allowing participants to respond at their convenience. The purpose of the study was explained, and informed consent obtained from all participants. The survey link was sent via respondents' email and academic WhatsApp platforms. A total of 151 respondents participated. This is considered sufficient based on prior research (Leoni et al.,

2022), which used 120 respondents for a similar study and indicated that this sample size is appropriate for PLS-SEM analysis.

2.5 Instrumentation

The questionnaire (Appendix A) consists of multiple sections measuring variables from the extended TOE framework:

Technological Context: System quality, Compatibility.

Organizational Context: Top management support, IT human resources, *Digital Literacy*, *User Training*

Environmental Context: Regulatory pressure, Peer institutional influence

AIS Adoption (dependent variable).

All items were measured using a five-point Likert scale ranging from 1 (Strongly Agree) to 5 (Strongly Disagree). The instrument was validated through expert review (Appendix A) to ensure clarity and relevance.

Reliability and Validity:

- Internal consistency was assessed using Cronbach's alpha ($\alpha > 0.7$ for all constructs).
- Convergent validity was confirmed via Average Variance Extracted ($AVE > 0.5$).
- Discriminant validity was evaluated using the Fornell-Larcker criterion and HTMT ratios (< 0.85).

2.6 Data Analysis

Data were analyzed using PLS-SEM in R, chosen for its ability to model complex relationships, handle reflective and formative constructs, and its suitability for prediction-oriented research with small-to-medium sample sizes. The analysis included:

1. Measurement Model Assessment: Evaluated reliability and validity, including Cronbach's alpha, AVE, and HTMT ratios.
2. Structural Model Evaluation: Estimated path coefficients (β), R^2 , effect sizes (f^2), and predictive relevance (Q^2).
3. Hypothesis Testing: Statistical significance of relationships within the PLS-SEM framework was assessed using ordinary least squares regression in R. Path coefficients were considered significant at $p < 0.05$, with t-values obtained directly from the regression output.
4. Model hyperparameters: latent variable weighting scheme and convergence criteria were set according to standard PLS-SEM guidelines in R.

2.7 Ethical Considerations

Participation was voluntary, and informed consent obtained before administering the questionnaire. Respondents were assured of anonymity and confidentiality, and data used solely for academic purposes.

3. Results

3.1 Descriptive statistics

A total of 155 responses was obtained over a period of three months from a purposively selected group of participants in Kaduna state university who met the inclusion criteria for the study. The data was first subjected to an initial screening process using the SPLS, in R programming language. During this stage, questionnaires with missing values, incomplete responses, or inconsistencies were automatically removed. As a result, 4 questionnaires were identified as invalid due to incomplete entries.

Following the cleaning process, 151 valid responses remained and used for analysis.

3.1.1 Demographic characteristics of respondents

This section presents the demographic characteristics of the respondents, including gender, age group, educational attainment, respondent category, work/study experience, and level of involvement with the academic information system, shown in Table 1 and respondents' category in Figure 3. These characteristics offer important background information that supports a clearer understanding of the study's results.

The gender distribution shows that most respondents were male (71.5%), while females represented 28.5%. The sample was largely composed of young and middle-aged adults, with the highest proportion aged 35–44 years (34.4%), followed by those aged 18–24 years (31.1%) and 25–34 years (29.8%). Only 4.6% were between 45–54 years.

In terms of educational attainment, Bachelor's degree holders formed the largest group (51.7%), while postgraduate respondents (Master's, PhD, PGD) made up 37.7%. Diploma/Certificate holders accounted for 9.9%, and only one respondent (0.7%) identified as an undergraduate. Overall, the sample was predominantly well-educated and actively engaged in academic or administrative activities within the institution.

3.1.2 Mean and Standard Deviation of the Study Variables

All nine (9) variables in this study were measured using a five-point Likert scale ranging from (1) Strongly Disagree to (5) Strongly Agree. Based on the interpretation guideline by Ahmed et al. (2024), mean scores ≤ 1.99 indicate a *low* level, 2.00–3.99 represent a *moderate* level, while mean values ≥ 4.00 indicate a *high* level. Table 2 presents the mean values and standard deviations for all the study constructs

Table 1: Profile of the Respondents (151)

Variable	Category	Frequency	Percent (%)
Gender	Female	43	28.5
	Male	108	71.5
Age	18-24	47	31.1
	25-34	45	29.8
	35-44	52	34.4
	45-54	7	4.6
	Diploma/Certificate	15	9.9
Education	Bachelor's Degree	78	51.7
	Undergraduate	1	0.7
	Post graduate	57	37.7
	Others	1	0.7
	11-15 years	12	7.9
Work/Study Experience	16-20 years	7	4.6
	5-10 years	47	31.1
	Less than 5 years	80	53
	NA	5	3.3
	Academic Staff	26	17.2
Respondents Category	Administrative Staff	5	3.3
	Non-Academic Staff	18	11.9
	Student	79	52.3
	Technical/ICT Support Staff	20	13.2
	High (frequent user/manager)	35	23.2
Level of involvement with AIS	Low (rarely use)	40	26.5
	Moderate (occasional user)	72	47.7
	NA	4	2.6

The results indicate that System Quality ($M = 3.633$, $SD = 0.822$), Compatibility ($M = 3.552$, $SD = 0.661$), Top Management Support ($M = 3.703$, $SD = 0.729$), IT Human Resources ($M = 3.633$, $SD = 0.785$), Regulatory Pressure ($M = 3.707$, $SD = 0.691$), Peer Institutional Influence ($M = 3.503$, $SD = 0.720$), User Training ($M = 3.270$, $SD = 0.839$), and AIS Adoption ($M = 3.844$, $SD = 0.720$) all fall within the *moderate* range. This suggests that respondents generally perceived these factors as moderately influential within their institutions. However, Digital Literacy recorded a mean of 4.141 ($SD = 0.732$), which reflects a *high* level of agreement among respondents. This implies that users consider themselves highly digitally literate, making it a strong enabler for AIS adoption.

3.2 Measurement model assessment

The first step in PLS analysis is, to assess the measurement model, this is required to determine how good the measurement items were when loaded on theoretical defined constructs. The measurement model was assessed for reliability and validity, following Chew et al. (2025). Key steps indicator loadings, internal consistency, convergent validity, and discriminant validity were examined.

3.2.1 Indicator loadings

Indicator loadings were examined to ensure that items load sufficiently on their respective constructs. Loadings greater than 0.70 are generally considered acceptable, although loadings between 0.60 and 0.70 are acceptable if composite reliability and AVE are satisfactory.

Table 2: Mean and Standard Deviation

Variable	Mean	Standard Deviation
SQ	3.633	0.822
CY	3.552	0.661
TMS	3.703	0.729
ITR	3.633	0.785
RP	3.707	0.691
PII	3.503	0.72
UT	3.27	0.839
Digital_Literacy	4.141	0.732
AIS_Adoption	3.844	0.72

3.2.2 Internal consistency reliability

Cronbach's Alpha and Composite Reliability (CR) values above 0.70 indicate satisfactory reliability. All constructs exceeded these thresholds, except Peer Institutional Influence ($\alpha = 0.543$), which had acceptable CR (0.816).

3.2.3 Convergent validity

All constructs achieved an AVE > 0.50 as indicated in Table 3, confirming that indicators share a high proportion of variance within their constructs. Since the measurement model demonstrated adequate reliability and validity.

Therefore, the constructs can be used to evaluate the structural model.

3.2.4 Discriminant validity

Discriminant validity was further assessed using the Heterotrait–Monotrait Ratio (HTMT), which is regarded as a more robust criterion compared to traditional methods such as the Fornell–Larcker criterion. According to Guenther et al. (2023), discriminant validity is established when HTMT values fall below the recommended thresholds of 0.85 (strict criterion) or 0.90 (liberal criterion).

Table 3: The Results of Measurement Model

Construct	Items	Cronbach_Alpha	Composite_Reliability	AVE
SQ	2	0.809	0.913	0.84
CY	3	0.715	0.841	0.639
TMS	3	0.8	0.883	0.715
ITR	3	0.84	0.904	0.758
RP	3	0.778	0.871	0.693
PII	2	0.543	0.816	0.689
UT	3	0.85	0.91	0.77
DL	3	0.822	0.895	0.739
AIS_Adoption	3	0.807	0.887	0.724

In this study, the HTMT.90 criterion was adopted. Table 4 presents the HTMT values for all construct pairs. The results show that all HTMT ratios are below the critical value of 0.90, indicating that each construct is conceptually distinct.

3.3 Structural model assessment

3.3.1 Path coefficients and hypothesis testing

The path coefficients (β) for each hypothesized relationship were estimated using ordinary least

squares regression (via the `lm()` function in R). Each coefficient's significance was assessed by examining the t-values and corresponding p-values. Hypotheses were considered supported when $p < 0.05$. Critical t-values for significance levels of 0.01, 0.05, and 0.10 were referenced to determine statistical significance (Ramachandran & Tsokos, 2020). Table 5 tabulated the path coefficients obtained from the analysis to assess the statistical significance in the structural model.

Table 4: Discriminant Validity (HTMT₉₀)

Construct	SQ	CY	TMS	ITR	RP	PII	UT	DL
SQ	1							
CY	0.44171	1						
TMS	0.386239	0.494009	1					
ITR	0.383894	0.506976	0.475695	1				
RP	0.354038	0.428092	0.421454	0.560884	1			
PII	0.363606	0.405747	0.430231	0.395973	0.501852	1		
UT	0.364895	0.538169	0.388347	0.600059	0.428436	0.421664	1	
DL	0.429851	0.394266	0.271382	0.392582	0.373694	0.217795	0.309654	1
AIS_Adoption	0.340181	0.363367	0.547609	0.482262	0.66004	0.437046	0.406975	0.443703

Table 5: Results of Structural Model Analysis (Direct Hypothesis)

Hypo-thesis	Path	Predictor	Beta	Std_Error	T_Value	P_Value	Significance	Decision
SQ	H1: System quality -> AIS Adoption	System_Quality	-0.024349912	0.059760832	-0.407456039	0.684304444	FALSE	Not Supported
CY	H2: Compatibility -> AIS Adoption	Compatibility	-0.132288723	0.082275824	-1.607868714	0.110149462	FALSE	Not Supported
TMS	H3: Top management support -> AIS Adoption	Top_Management_Support	0.313660771	0.069447399	4.516522939	0.000042	TRUE	Supported
ITR	H4: IT human resources -> AIS Adoption	IT_Human_Resources	-4.36E-05	0.07413409	-5.88E-04	0.999531496	FALSE	Not Supported
RP	H5: Regulatory pressure -> AIS Adoption	Regulatory_Pressure	0.464791886	0.077728506	5.97968374	0.000000009	TRUE	Supported
PII	H6: Peer institutional influence -> AIS Adoption	Peer_Institutional_Influence	0.056262558	0.069929881	0.804556751	0.422459406	FALSE	Not Supported
UT	H7: User training -> AIS Adoption	User_Training	0.066819532	0.065074707	1.026812648	0.306305145	FALSE	Not Supported
DL	H8: Digital Literacy -> AIS Adoption	Digital Literacy	0.213136971	0.06979678	3.05367915	0.002709773	TRUE	Supported

The results of the structural model analysis indicate that top management support ($\beta = 0.314$, $p < 0.001$), regulatory pressure ($\beta = 0.465$, $p < 0.001$), and digital literacy ($\beta = 0.213$, $p = 0.003$) significantly and positively influence AIS adoption. This indicates that active involvement and encouragement from management, adherence to external regulatory requirements, and higher levels of users' digital skills are key drivers that facilitate the adoption of AIS.

Factors such as peer institutional influence ($\beta = 0.056$, $p = 0.422$) and user training ($\beta = 0.067$, $p = 0.306$), though not statistically significant, has a positive effect on AIS adoption, suggesting that learning from other institutions and providing training to users may still support

adoption. While Factors such as, system quality ($\beta = -0.024$, $p = 0.684$), compatibility ($\beta = -0.132$, $p = 0.110$), and IT human resources ($\beta = -0.00004$, $p = 0.9995$) have limited impact on AIS adoption in the current study.

3.3.2 Coefficient of determination (R^2)

The coefficient of determination (R^2) assesses the explanatory power of the structural model by indicating the proportion of variance in the endogenous construct accounted for by its predictors. In this study, AIS Adoption serves as the endogenous variable. As shown in Table 6, the construct recorded an R^2 value of 0.5663, with an adjusted R^2 of 0.5419, indicating a moderate-to-substantial ability of the eight predictors to explain variance in AIS adoption.

Hair and Alamer (2022) emphasized that acceptable R^2 values should be evaluated within the contextual expectations of the research domain, noting that values ≥ 0.26 typically demonstrate substantial explanatory strength in

behavioral and organizational studies. Overall, the R^2 results confirm that the structural model possesses satisfactory explanatory power and meaningfully predicts the endogenous construct.

Table 6: Coefficient of determination (R^2)

Construct	R^2	Adjusted R^2	Sample Size
AIS Adoption	0.5663	0.5419	151

3.3.3 Effect sizes (f^2)

Effect sizes were computed to assess the substantive impact of each exogenous variable on AIS adoption. f^2 values of 0.02, 0.15 and 0.35 indicate small, medium, and large effects

respectively as shown in Table 7. Among all predictors, regulatory pressure has the strongest effect (medium), followed by top management support and digital literacy effects. All other predictors contribute negligibly to the model.

Table 7: Effect sizes (f^2)

Predictor	f^2	Effect_Size
System_Quality	0.001203047	Negligible
Compatibility	0.018733636	Negligible
Top_Management_Support	0.147818692	Small
IT_Human_Resources	2.51E-09	Negligible
Regulatory_Pressure	0.259105925	Medium
Peer_Institutional_Influence	0.004690664	Negligible
User_Training	0.007640175	Negligible
Digital_Literacy	0.075764122	Small

4.0 Discussion

The structural model examined the original TOE factors together with two newly introduced factors Digital Literacy and User Training. The findings show a mixed pattern of technological, organizational, and environmental factors shaping AIS adoption, giving a clearer picture of how these systems are actually used within higher education institutions.

Technological Factors

System Quality and Compatibility did not significantly influence AIS adoption. While these factors are traditionally considered central in technology adoption studies, their limited impact in this study suggests that AIS usage may already be institutionalized. When systems become mandatory or embedded in routine operations, technical performance and workflow alignment may no longer serve as primary determinants of adoption. Instead, compliance

structures and managerial directives may shape user behavior more strongly than perceived system characteristics.

This reflects a broader shift from technology-driven adoption to institutionally-driven adoption, particularly in regulated higher education environments.

Organizational Factors

Top Management Support emerged as a key driver of AIS adoption. Leadership commitment, visible endorsement, and strategic prioritization appear to create an institutional climate where AIS usage is perceived as necessary and aligned with organizational goals. This reinforces the organizational dimension of the TOE framework and supports prior research highlighting the role of leadership in technology acceptance.

In contrast, IT Human Resources did not significantly influence adoption. This suggests that the presence of IT personnel alone is insufficient to drive system use. The finding may indicate limited proactive engagement between IT units and end-users or a focus on maintenance rather than user empowerment. It highlights the need for IT departments to function not only as technical support units but also as facilitators of user capability development.

User Training had a positive yet non-significant effect. While training theoretically empowers users and enhances system acceptance, the non-significance suggests that existing training initiatives may be occasional, insufficiently targeted, or lacking depth. The positive direction confirms that training has potential value, but structured, continuous, and context-specific training programs are required to produce measurable improvements in AIS usage.

Environmental Factors

Regulatory Pressure emerged as the strongest determinant of AIS adoption. This demonstrates that compliance requirements, accreditation expectations, and reporting standards are powerful drivers of AIS adoption in higher education institutions, these findings are in line with previous study (Hartono et al., 2025), emphasizing the key role of the environmental context within the TOE framework, suggesting that external demands can be more influential than technology or user readiness.

Peer Institutional Influence showed a positive but non-significant effect, indicating that institutions did not adopt AIS primarily because other institutions were doing so. Although imitation dynamics are common in technology diffusion, their weak influence here suggests that the study context is shaped more by internal policies and regulatory requirements than by institutional competition.

Human-Centric Extension of TOE

Digital Literacy significantly influenced AIS adoption, validating the extension of the TOE

framework. Users with stronger digital capabilities are more confident in navigating system interfaces and integrating digital tools into their work processes. This finding demonstrates that human–digital readiness is increasingly central to technology adoption in contemporary institutional environments. The inclusion of Digital Literacy strengthens the explanatory power of the model and highlights the importance of user-level capability in institutional technology implementation.

Collectively, the findings indicate that AIS adoption is shaped more by leadership commitment, regulatory compliance, and user digital readiness than by system characteristics. This suggests that AIS usage has moved beyond voluntary technological acceptance and is now embedded within institutional governance and operational structures.

5.0 Conclusion

The study shows that AIS adoption in higher education is driven more by organizational and environmental factors than by technological features. Key determinants of adoption include strong leadership support, regulatory pressure, and users' digital literacy, highlighting the importance of institutional commitment and user capability. Although factors such as system quality, compatibility, IT human resources, peer influence, and user training were not significant, their positive directions suggest that improvements in system alignment and training could still enhance adoption. Overall, AIS uptake depends largely on internal support structures, external mandates, and the digital competence of users rather than the technical characteristics of the system itself.

Theoretical Contributions

This study contributes to the technology adoption literature in three main ways. First, it empirically validates the TOE framework within the context of higher education AIS adoption. Second, it extends the framework by integrating Digital Literacy as a human-centric capability

factor, thereby strengthening the model's explanatory relevance in digitally evolving institutional settings. Third, it provides context-specific evidence from a developing country environment, enriching the limited empirical literature on AIS adoption in African higher education institutions.

Practical Implications

From a managerial perspective, the findings suggest that university administrators should prioritize visible leadership support, ensure compliance alignment, and invest in structured digital capability development initiatives. Strengthening users' digital literacy may yield greater adoption outcomes than focusing solely on system upgrades or technical enhancements. Policymakers and institutional leaders should therefore view AIS adoption not merely as a technological investment but as an organizational transformation process.

5.1 Limitations and Future Research

Despite its contributions, this study has several limitations that provide directions for future research.

First, future studies could expand the scope of the research population beyond Kaduna State University to include multiple higher education institutions in Nigeria or other countries. This would help examine whether the enhanced TOE framework generalizes across different organizational contexts, technological infrastructures, and user demographics.

Second, while this study employs PLS-SEM, future research could apply covariance-based SEM or other advanced modeling techniques to provide complementary insights, including global goodness-of-fit measures, and to validate the robustness of the proposed model.

Third, subsequent studies could incorporate additional human-centric, contextual, or psychological factors that may influence AIS adoption, such as user motivation, organizational culture, perceived ease of use, or

trust in technology. This would provide a more holistic understanding of adoption determinants.

Finally, future research could adopt longitudinal designs to track AIS adoption over time, allowing researchers to explore causal relationships and the long-term impact of digital literacy and user training interventions on system usage and performance.

Competing of interest

The authors declare that they have no competing interests, regarding the research, authorship or publication of this manuscript.

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Author's Contribution

F.S., served as the student, conducted the data collection, preprocessing, analysis, and interpretation of the results. A.A. served as the major supervisor, providing overall guidance, A.M. acted as the second supervisor, offering additional supervision, reviewing the methodology, critical revisions and making editorial corrections. All authors read and approved the final manuscript.

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Appendices

Appendix A: Questionnaires/Measurement Constructs and Items

Construct	Item Statement	Source
System Quality	The AIS provides accurate and up-to-date information.	Alquhaif & Al-Mamary, 2024
	The AIS is easy to navigate and use.	Alquhaif & Al-Mamary, 2024
	The AIS is available when I need it.	Alquhaif & Al-Mamary, 2024
	The AIS is compatible with the way I prefer to work or study.	Alquhaif & Al-Mamary, 2024
Compatibility	The AIS fits well with other systems I use.	Alquhaif & Al-Mamary, 2024
	Using the AIS aligns with my job/study requirements.	Alquhaif & Al-Mamary, 2024
Digital Literacy	I am confident in using digital tools for academic tasks.	Kabakus et al., 2023
	I can easily learn to use new educational technologies.	Kabakus et al., 2023
	I can solve basic technical problems while using the AIS.	Kabakus et al., 2023
Top Management Support	University leadership supports the use of AIS.	Alquhaif & Al-Mamary, 2024
	Management allocates resources for AIS implementation and maintenance.	Alquhaif & Al-Mamary, 2024
	The university leadership encourages staff/students to use AIS.	Alquhaif & Al-Mamary, 2024
IT Human Resources	The university has skilled IT personnel to support AIS.	Alquhaif & Al-Mamary, 2024
	IT staff respond promptly when issues arise with the AIS.	Alquhaif & Al-Mamary, 2024

	Technical staff provide useful guidance on using the AIS.	Alquhaif & Al-Mamary, 2024
	I have received sufficient training to use the AIS effectively.	Al-Hattami et al.2022
User Training	The training provided improved my confidence in using AIS.	Al-Hattami et al.2022
	Training materials are available and easy to understand.	Al-Hattami et al.2022
	Government/educational policies encourage the use of AIS.	Alquhaif & Al-Mamary, 2024
Regulatory Pressure	Regulatory bodies require universities to adopt AIS.	Alquhaif & Al-Mamary, 2024
	AIS helps the university comply with national education standards.	Alquhaif & Al-Mamary, 2024
	Peer institutions influence our decision to adopt AIS.	Alquhaif & Al-Mamary, 2024
Peer Institutional Influence	The university monitors how other institutions use AIS.	Alquhaif & Al-Mamary, 2024
	Other universities' success with AIS influences our use.	Alquhaif & Al-Mamary, 2024
	I frequently use the AIS for my academic/administrative activities.	Alquhaif & Al-Mamary, 2024
AIS Adoption	AIS has improved my academic or work efficiency.	Alquhaif & Al-Mamary, 2024
	I intend to continue using AIS regularly in the future.	Alquhaif & Al-Mamary, 2024

Appendix B: R Script for Data Analysis

```
# ----- LOAD PACKAGES -----
library(readr)
library(dplyr)
library(stringr)
library(psych)
library(tibble)
```

```

library(purrr)
library(tidyr)

# ----- LOAD DATA -----
data <- read_csv("IMPROVING ACADEMIC SYSTEM ADOPTION IN UNIVERSITIES USING AN
  ENHANCED TOE FRAMEWORK2.csv")

# ----- DATA CLEANING -----
data_clean <- data %>%
  filter(!if_all(everything(), is.na))

# ----- DEMOGRAPHIC SUMMARY FUNCTION -----
get_demo <- function(df, pattern, label){
  col <- names(df)[grepl(pattern, names(df))]
  if(length(col)==0) return(NULL)

  df %>%
    count(Category = !!sym(col[1])) %>%
    mutate(
      Percent = round(n/sum(n)*100,1),
      Variable = label
    ) %>%
    rename(Frequency = n)
}

demog_summary <- bind_rows(
  get_demo(data_clean, "Gender", "Gender"),
  get_demo(data_clean, "Age", "Age Group"),
  get_demo(data_clean, "Educational", "Educational Level"),
  get_demo(data_clean, "Respondents Category", "Respondent Category"),
  get_demo(data_clean, "Years of Work", "Work Experience"),
  get_demo(data_clean, "Level of Involvement", "Involvement Level")
)

# ----- LIKERT CONVERSION -----
likert_map <- c(
  "strongly disagree"=1,
  "disagree"=2,
  "neutral"=3,
  "agree"=4,
  "strongly agree"=5
)

data_numeric <- data_clean %>%
  mutate(across(where(is.character),
    ~as.numeric(likert_map[tolower(trimws(.))])))

# ----- CONSTRUCT DEFINITIONS -----
constructs <- list(
  System_Quality = c("AIS provides accurate information?",
    "AIS is easy to navigate?",
    "AIS is available when needed?"),

  Compatibility = c("AIS fits your work/study style?",
    "AIS integrates with other systems?",
    "AIS aligns with job/study requirements?"),

```

```

Top_Management_Support = c("Leadership supports AIS use?",
                             "Management provides AIS resources?",
                             "Leadership encourages AIS usage?"),

IT_Human_Resources = c("University has skilled IT staff?",
                        "IT staff respond promptly?",
                        "Technical guidance is helpful?"),

Regulatory_Pressure = c("Policies encourage AIS use?",
                         "Regulators require AIS adoption?",
                         "AIS supports compliance?"),

Peer_Institutional_Influence = c("Peer institutions influence AIS use?",
                                  "University monitors other AIS users?",
                                  "Other universities' AIS success matters?"),

User_Training = c("You received sufficient AIS training?",
                  "Training improved confidence?",
                  "Training materials are clear?"),

Digital_Literacy = c("Confident with digital tools?",
                    "Can learn new technologies easily?",
                    "Can solve basic technical issues?"),

AIS_Adoption = c("You frequently use AIS?",
                 "AIS improved efficiency?",
                 "You intend to keep using AIS?")

```

```
)
```

```
# ----- CONSTRUCT SCORES -----
```

```

construct_scores <- function(df, constructs){
  map_dfc(names(constructs), ~{
    vars <- constructs[[".x"]]
    vars <- vars[vars %in% names(df)]
    if(length(vars)==0) return(NULL)
    tibble(!.x := rowMeans(df[vars], na.rm=TRUE))
  })
}

```

```
scores <- construct_scores(data_numeric, constructs)[1:151, ]
```

```
# ----- DESCRIPTIVE STATISTICS -----
```

```

descriptives <- scores %>%
  summarise(across(everything(),
    list(Mean = ~mean(.), SD = ~sd(.)))) %>%
  pivot_longer(everything(),
    names_to=c("Variable", ".value"),
    names_sep="_") %>%
  mutate(N=151)

```

```
# ----- RELIABILITY (CRONBACH ALPHA) -----
```

```

reliability_results <- map_dfr(names(constructs), ~{
  vars <- constructs[[".x"]]
  vars <- vars[vars %in% names(data_numeric)]
  if(length(vars) < 2) return(NULL)

```

```
alpha_val <- psych::alpha(data_numeric[vars])$total$raw_alpha
```

```

tibble(
  Construct = .x,
  Items = length(vars),
  Cronbach_Alpha = round(alpha_val,3)
)
})

# ----- HTMT DISCRIMINANT VALIDITY -----
htmt_matrix <- cor(scores, use="complete.obs")
# ----- HYPOTHESIS TESTING -----
model <- lm(AIS_Adoption ~ System_Quality + Compatibility +
  Top_Management_Support + IT_Human_Resources +
  Regulatory_Pressure + Peer_Institutional_Influence +
  User_Training + Digital_Literacy,
  data = scores)

model_summary <- summary(model)

hypothesis_results <- as.data.frame(model_summary$coefficients) %>%
  rownames_to_column("Predictor") %>%
  filter(Predictor != "(Intercept)") %>%
  mutate(Significant = `Pr(>|t|)` < 0.05)

# ----- MODEL FIT -----
r_squared <- model_summary$r.squared
adj_r_squared <- model_summary$adj.r.squared

cat("Analysis completed successfully.\n")

```