Mathematical Modelling of the Challenges in the Adoption of Technology by Healthcare Professionals in the Primary Healthcare Centres (PHCS) of North Eastern Nigeria

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The integration of technologies, such as Electronic Health Records (EHRs), telemedicine, mHealth, and health management information systems, into the value chain of healthcare delivery especially at the Primary Healthcare (PHC) level is essential for improving healthcare delivery in settings where resources are limited. However, its adoption in Primary Healthcare Centres (PHCs) in North-Eastern Nigeria remains low. The aim of this study is to identify, quantify, and model the key challenges hindering technology adoption among healthcare workers/professionals in PHCs across North-Eastern Nigeria focusing on three states viz: Adamawa, Borno and Yobe states. A cross-sectional survey was conducted among 284 healthcare professionals (Community Health Officers, Nurses, Midwives) across 45 PHCs in Adamawa, Borno, and Yobe states. Although 300 questionnaires were distributed, only 284 were returned completed. A structured questionnaire, designed based on the Unified Theory of Acceptance and Use of Technology (UTAUT), was used to collect and analyse data on Performance Expectancy(PE), Effort Expectancy(EE), Social Influence(SI), Facilitating Conditions(FC), and Behavioural Intention(BI). Data were analysed using SPSS v.26 and AMOS v.23 software. A confirmatory factor analysis (CFA) was performed to validate the measurement model, and the structural model was tested to examine the relationships between constructs. The measurement model demonstrated a good fit (CMIN/DF = 2.15, CFI = 0.94, TLI = 0.92, RMSEA = 0.06). The structural model revealed that Facilitating Conditions ($\beta = 0.42$, $p < 0.001$) was the most significant direct predictor of Behavioural Intention to use technology, followed by Performance Expectancy ($\beta = 0.28$, $p < 0.01$).

Keywords: Technology Adoption, Primary Healthcare, Mathematical Modelling, Structural Equation Modelling (SEM), UTAUT, North-Eastern Nigeria, Healthcare Professionals.

1. INTRODUCTION

North Eastern Nigeria, comprising Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe states, faces significant healthcare challenges worsened by prolonged conflict, poverty, and infrastructural deficits. These states, heavily impacted by the Boko Haram insurgency since 2009, have seen disruptions in healthcare delivery, with over 7.1 million people in need of humanitarian assistance as of 2024. Primary Healthcare Centres (PHCs) serve as the frontline for basic medical services, yet their capacity is limited by manual processes, leading to inefficiencies in patient management, disease surveillance, and resource allocation.

The transformative potential of health information technology (HIT) in enhancing the

efficiency, quality, and accessibility of healthcare is widely acknowledged globally (WHO, (2016). In developing countries, technologies like Electronic Medical Records (EMRs), mobile health (mHealth) applications, and telemedicine promise to bridge critical gaps in primary healthcare (PHC) delivery (Ojo, 2017). The PHC system in Nigeria, particularly in the North-Eastern region, which is bedevilled by numerous challenges, which include but is not limited to insecurity, poverty, and various types of communicable diseases (NBS & UNICEF, 2017). The effective adoption of HIT in this context could revolutionize disease surveillance, patient record management, and resource allocation.

Despite various initiatives and investments, the adoption of HIT by healthcare professionals in Nigerian PHCs has been slow and fraught with difficulties (Awotiwon, et al, 2017). Existing qualitative studies have cited barriers such as poor electricity supply, inadequate training, resistance to change, and low digital literacy (Folaranmi, 2019, Mohammed & Ojo, 2022). However, a significant gap exists in the quantitative and mathematical modelling of these challenges to understand their relative magnitude and interrelationships. A purely descriptive analysis is insufficient for policymakers to prioritize interventions effectively.

This study addresses this gap by applying the Unified Theory of Acceptance and Use of Technology (UTAUT) model (Venkatesh, et al, 2003) to mathematically model the determinants of technology adoption. The UTAUT model posits that four core constructs—Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions—directly determine users' behavioural intention and use behaviour. By employing Structural Equation Modelling (SEM), a robust multivariate technique, this study quantifies the precise impact of each factor on the intention of healthcare professionals in North-Eastern Nigeria to adopt technology. The resulting model provides an evidence-based framework for designing targeted, data-driven strategies to overcome the most critical barriers.

2. REVIEW OF RELATED LITERATURE

Studies carried out Previously in developing countries identify critical barriers to health information technology (HIT) adoption as lack of adequate technology infrastructure (hardware, software, networks), IT literacy and experience among health workers, financial constraints, and security concerns (WHO, 2016, ojo, 2017)]. In North Eastern Nigeria, low literacy levels (around 17% versus 79% in the Southwest) and inadequate infrastructure highlight the digital divide affecting healthcare service delivery [(ojo, 2017)]. The Unified Theory of Acceptance and Use of Technology (UTAUT) model, augmented with variables such as staff experience and infrastructure quality, has proven effective in similar healthcare contexts to understand intentions to use digital tools [(WHO, (2016)].

Significant challenges are posed by Security and data privacy concerns, as healthcare institutions often lack capacity and resources to implement robust cybersecurity protections. This increases the risks of data breaches which may undermine trust in HIT systems [(ojo, 2017)]. There is also limited interoperability between existing health IT systems, further complicating adoption and efficient data sharing [(ojo, 2017)].

3. METHODOLOGY

3.1 Study Design and Setting

A cross-sectional study design was employed, and data were collected between June and August 2025. The study was conducted in PHCs across three states of North-Eastern Nigeria: Adamawa, Borno, and Yobe. This region is characterized by its unique socio-economic and security challenges, providing a critical context for this investigation.

3.2 Population and Sampling

The target population was healthcare workers/professionals (Community Health Officers, Nurses, Midwives, and Junior Community Health Extension Workers) working in PHCs. A multi-stage sampling technique was used. First, 15 LGAs were randomly selected from the six states. Second, three PHCs were randomly selected from each LGA, totaling 45 PHCs. Finally, a convenience sample of 6-7 healthcare professionals was recruited from each PHC. The minimum sample size of 264 was determined using the Cochran formula for a finite population, with a 5% margin of error and 95% confidence level. A total of 284 questionnaires were administered and used for the final analysis, yielding a response rate of 93%.

3.3 Data Collection Instrument and Measures

A structured, self-administered questionnaire was developed based on the UTAUT model constructs. The questionnaire consisted of two sections:

Section A: Socio-demographic characteristics of respondents (age, gender, profession, years of experience, previous IT training).

Section B: The items measuring the five UTAUT constructs on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) were:

Performance Expectancy (PE): 5 items

Effort Expectancy (EE): 4 items

Social Influence (SI): 4 items

Facilitating Conditions (FC): 5 items

Behavioural Intention (BI): 3 items

The questionnaire was validated by a panel of experts in public health and health informatics. A pilot study was conducted in 5 PHCs not included in the main study, and Cronbach's alpha for all constructs was above 0.7, indicating good internal consistency.

(See Appendix for the full questionnaire)

3.4 Data Analysis

IBM SPSS Statistics v.26 and AMOS v.23 were used to analyse the collected data. Descriptive statistics (frequencies, means, standard deviations) were used to summarize demographic data. The two-step approach to SEM was followed [(Anderson & Gerbing, 1988). First, a Confirmatory Factor Analysis (CFA) was carried out to assess the reliability of the measurement model, and its convergent validity, and discriminant validity. Second, the structural model was evaluated to test the hypothesized relationships between the constructs. Model fit was assessed using common indices: Chi-square/degree of freedom (CMIN/DF < 3), Comparative Fit Index (CFI > 0.90), Tucker-

Lewis Index (TLI > 0.90), and Root Mean Square Error of Approximation (RMSEA < 0.08).

4. RESULTS

4.1 Descriptive Statistics

Of the 284 respondents, 58.1% were female. The mean age of the respondents was 38.4 years (SD = 7.2). Most of them were Nurses/Midwives (52.8%), followed by Community Health Officers (31.0%). Only 28.5%of the respondents had received formal training on any health technology in the past two years.

4.2 Measurement Model Assessment

The CFA showed that the measurement model had a good fit with the data: $\chi^2 = 285.67$, df = 133, CMIN/DF = 2.15, CFI = 0.94, TLI = 0.92, RMSEA = 0.06. All factor loadings were significant and greater than 0.6. The Average Variance Extracted (AVE) for each construct was above 0.5, and the Composite Reliability (CR) was above 0.7, confirming convergent validity and reliability. Discriminant validity was established as the square root of the AVE for each construct was greater than its correlation with other constructs (Fornell-Larcker criterion).

Table 1: Reliability and Validity of Constructs

Construct	Items	Cronbach's Alpha	Composite Reliability (CR)	Ave Var. Extr. (AVE)
(PE)	5	0.89	0.91	0.67
(EE)	4	0.85	0.87	0.63
(SI)	4	0.82	0.84	0.57
(FC)	5	0.91	0.92	0.70
(BI)	3	0.88	0.89	0.73

(PE) Performance Expectancy (EE)Effort Expectancy (SI)Social Influence Facilitating (FC) Facilitating Conditions (BI) Behavioural Intention

4.3 Structural Model and Hypothesis Testing

The structural model also demonstrated a good fit. The path coefficients (standardized regression weights, β) were used to test the research hypotheses. The results are summarized in Table 2.

Table 2: Hypothesis Testing Results

Hypothesis	Path	Std. Estimate(β)	P-value	Result
H1	PE → BI	0.28	0.003	Supported
H2	EE → BI	0.11	0.154	Not Supported
H3	SI → BI	0.09	0.221	Supported
H4	FC → BI	0.42	<0.001	Supported

The model explained 58% ($R^2 = 0.58$) of the variance in Behavioural Intention. The results indicate that:

Facilitating Conditions (FC) had the strongest significant positive influence on Behavioural Intention ($\beta = 0.42$, $p < 0.001$).

Performance Expectancy (PE) also had a significant, though weaker, positive influence ($\beta = 0.28$, $p < 0.01$).

Effort Expectancy (EE) and Social Influence (SI) were not statistically significant predictors in this context.

5. DISCUSSION

This research work has successfully developed a mathematical model to clearly outline the main challenges to technology adoption in the PHCs located in the North-Eastern region of Nigeria. The most striking discovery is the overwhelming dominance of Facilitating Conditions as the principal predictor of behavioural intention. This indication, which involves the availability of reliable infrastructure (electricity, internet), technical support, and other necessary resources, accounted for the largest share of influence in our model. This aligns with the reality on the ground, where chronic power outages and poor internet connectivity are endemic (Adepoju & Alabi, 2020). Without these initial elements, healthcare professionals cannot form a desire to use technology, regardless of its perceived usefulness or ease of use.

The significant role played by Performance Expectancy shows that healthcare professionals are sensible, and thus are more likely to want to use a technology if it has the potential to genuinely help them perform their jobs better.

The lack of significant impact of Effort Expectancy is a somewhat surprising but perceptive result. It points to the fact that in this environment, the perceived ease of use of a system is of lesser concern when there is a lack of basic enabling environment. Healthcare professionals may be willing to contend with a complex system if they are assured of unswerving support. This finding clearly shows differences with studies in more developed settings where usability is a primary driver (Holden & Karsh, 2010). Similarly, the non-significance of Social Influence implies that the opinions of superiors and peers have little or no impact on an individual's intention in the face of real, practical constraints they are saddled with on a daily basis.

5.1 Implications for Policy and Practice

The mathematical evidence gathered from this model points to a clear course of action:

a. Highlight Infrastructure: Government and development partners must invest in sustainable energy solutions (e.g., solar power, wind turbine etc.) and robust internet connectivity for PHCs as an essential first step.

b. Systemic Support over Software Features: When procuring or developing Health Information Technology (HIT) systems for the region under study, the focus should be on robustness, offline functionality, and low maintenance costs, rather than on advanced features that may be impracticable to sustain.

c. Implement Structured Training and Support: Establish dedicated, on-call technical support teams to cater for the region, and provide continuous, hands-on training for healthcare professionals to build confidence and resolve issues promptly.

5.2 Limitations and Future Research

This study is limited by its cross-sectional design, which excludes underlying inferences. The data were also self-reported, which may introduce some bias in respect of social appeal. Future research should employ designs to track adoption over period and take into consideration additional related variables, such as the specific type of technology and the security situation, into the model.

6. CONCLUSION

This research has tried to present a quantifiable, model-based analysis of the barriers to the adoption of technology in a challenging healthcare environment. The mathematical model unmistakably identifies the insufficiency in Facilitating Conditions as the gravest challenge. For technology to succeed in transforming primary healthcare in North-Eastern Nigeria, policymakers need to try and lay the foundation of reliable infrastructure and sustained support. Only then can the full benefits of Performance Expectancy and other factors be realized. This evidence-based approach offers a clear blueprint for strategic intervention to bridge the digital divide in rural and underserved healthcare systems.

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APPENDIX: Research Questionnaire

Title: Survey on Technology Adoption in Primary Healthcare Centres (PHCs) in North-Eastern Nigeria

Introduction: Dear Participant, this questionnaire is designed and administered to understand the factors influencing the adoption of technologies related to health (e.g., computers for records, mobile health apps, etc.) in PHCs. Your participation is voluntary and anonymous. Thank you for your time.

SECTION A: DEMOGRAPHIC INFORMATION (Please tick [√] the appropriate option)

1. State: Adamawa [ ] Borno [ ] Yobe [ ]

2. Gender: Male [ ] Female [ ]

3. Age: 20-29 [ ] 30-39 [ ] 40-49 [ ] 50 and above [ ]

4. Profession: Community Health Officer [ ] Nurse/Midwife [ ] Junior CHEW [ ] Other (Specify) _____

5. Years of Experience: Less than 2 [ ] 2-5 [ ] 6-10 [ ] Above 10 [ ]

6. Have you received any formal training on using health technology (computers, specific software, etc.) in the last 2 years? Yes [ ] No [ ]

SECTION B: Please indicate your level of agreement with the following statements.

(Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Performance Expectancy (PE)

PE1 Using technology would enable me to accomplish tasks more quickly.

PE2 Using technology would improve the quality of my work.

PE3 Using technology would make it easier to do my job.

PE4 Using technology would enhance my effectiveness on the job.

PE5 | would find technology useful in my job.

Effort Expectancy (EE)

EE1 Learning to operate the available technology would be easy for me.

EE2 My interaction with the technology would be clear and understandable.

EE3 I would find the technology easy to use.

EE4 It would be easy for me to become skillful at using the technology.

Social Influence (SI)

SI1 People who influence my behaviour (e.g., supervisors) think I should use the technology.

SI2 People who are important to me (e.g., colleagues) think I should use the technology.

SI3 The management of this facility has been helpful in the use of the technology.

SI4 In general, the organization has supported the use of the technology.

Facilitating Conditions (FC)

FC1 I have the resources necessary to use the technology.

FC2 I have the knowledge necessary to use the technology.

FC3 The technology is compatible with other systems I use.

FC4 A specific person (or group) is available for assistance with technical difficulties.

FC5 We have a reliable power supply and internet connection to use the technology.

Behavioural Intention (BI)

BI1 I intend to use the available technology at the earliest possible time.

BI2 I plan to use the technology frequently in my job.

BI3 I will be using the technology in my daily work.

Thank you for your participation