

Understanding The Factors Affecting The Adoption Of Green Computing In The HEI Of Uttarakhand

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Abstract

Background: The growing use of ICT in higher education institutions (HEIs) has increased energy consumption, e-waste generation, and environmental burden. Adopting green computing practices is essential, yet limited evidence exists from Uttarakhand's HEIs.

Objective: To identify the determinants influencing green computing adoption and to develop a validated Green Computing Adoption driving factor Framework for HEIs in Uttarakhand.

Methods: A cross-sectional survey was conducted among 520 faculty and students from government and private HEIs. Awareness was assessed using descriptive statistics. Reliability and validity were evaluated using Cronbach's alpha, Composite Reliability (CR), Average Variance Extracted (AVE), MSV, and CFA. Structural Equation Modeling (SEM) tested the hypothesized relationships. Model fit was assessed using CFI, TLI, NFI, GFI, AGFI, RMSEA, and χ^2/df .

Results: Awareness of green computing practices was moderate to high (overall mean = 3.82 ± 0.63). All constructs showed strong reliability ($\alpha = 0.82-0.93$) and valid CFA properties (CR = 0.83–0.91; AVE > MSV). The structural model demonstrated excellent fit (CFI = 0.995; TLI = 0.994; RMSEA = 0.017). Ten determinants significantly influenced intention to adopt green computing—compatibility, usability, top management support, facilitating conditions, organizational policy, incentives, government regulation, subjective norms, perceived behavioral control, and attitude. Relative advantage, complexity, competitive pressure, innovativeness and social influence were not significant. Intention showed a significant effect on implementation ($\beta = 0.20$, $p = 0.048$).

Conclusion: Adoption of green computing in HEIs is primarily driven by institutional support, ease of use, and behavioural determinants rather than external pressures. The validated framework offers actionable insights for policy development and sustainable ICT implementation in Uttarakhand's higher education sector.

Keywords: Green computing; HEIs; CFA; SEM; Sustainability; Technology adoption; ICT practices; Uttarakhand.

1. Introduction

The increasing dependence on information and communication technologies (ICT) in higher education institutions (HEIs) has significantly improved academic delivery, research capacity, and administrative efficiency. However, this digital expansion has also intensified energy consumption, carbon emissions, and electronic waste generation, raising concerns about the environmental sustainability of institutional ICT systems. Green computing, or green IT, offers a structured approach to minimizing the ecological impact of ICT operations through efficient energy use, responsible procurement, optimized equipment utilization, and scientific e-waste management. In India, the concept of green computing is gradually gaining attention, yet its adoption across higher education remains uneven. Uttarakhand, a state with a rapidly growing mix of government and private HEIs, faces several barriers to the systematic implementation of sustainable ICT practices. These include limited stakeholder awareness, inadequate

institutional policies, resource constraints, and insufficient regulatory enforcement. Although scattered initiatives exist, there is no unified, evidence-based framework guiding HEIs in Uttarakhand toward sustainable ICT adoption. This creates an urgent need for a structured model that identifies the key determinants driving adoption and translates them into a practical institutional framework. Technology adoption in organizational settings is shaped by multiple interrelated dimensions. Technological factors such as relative advantage, compatibility, usability, and perceived complexity influence user acceptance of green computing solutions. Organizational readiness including top management support, institutional innovativeness, availability of facilitating conditions, and the presence of formal sustainability policies plays a crucial role in enabling adoption. Environmental forces such as government regulations, social influence, and competitive pressure further determine whether institutions prioritize sustainable ICT practices. At the individual level, attitude, subjective norms, and perceived behavioral control shape the intention to engage in eco-friendly IT behavior. Despite the relevance of these factors, no comprehensive empirical study has integrated technological, organizational, environmental, and individual dimensions to develop a green computing framework specifically for Uttarakhand HEIs. To address this gap, the present study evaluates the major determinants influencing intention to adopt green computing among faculty and students across public and private HEIs. Using a stratified survey design and Structural Equation Modeling (SEM), the study constructs an empirically validated Green Computing Adoption Framework tailored to the state's higher education ecosystem. The proposed framework aims to guide institutional leaders, policymakers, and educators in strengthening sustainable ICT practices. It provides a structured pathway linking awareness, intention, and implementation, offering practical directions for transitioning Uttarakhand's HEIs toward environmentally responsible and digitally sustainable campuses [1].

2. Methodology

2.1 Study Design

A cross-sectional, quantitative research design was employed to identify the determinants influencing green computing adoption and to develop an empirically validated adoption framework for higher education institutions (HEIs) in Uttarakhand. A cross-sectional approach is widely applied in technology adoption and behavioral research, as it allows assessment of multiple latent constructs at a single time point while enabling the use of Structural Equation Modeling (SEM) for theory validation.

2.2 Study Area and Population

The study was conducted across government and private HEIs located in Uttarakhand, India. The target population consisted of faculty members and students, who serve as both primary users and operational stakeholders of institutional ICT systems. These groups were selected due to their direct involvement in ICT utilization and their role in shaping environmentally sustainable computing behaviors.

2.3 Sampling Strategy

An equal-allocation stratified random sampling technique was adopted to ensure proportionate representation of institution type (government vs. private) and respondent category (faculty vs. students). Stratification reduced sampling variability and improved representativeness across heterogeneous institutional settings. Random selection within each stratum minimized respondent-level selection bias [2]. The sampling structure is presented in Table 1.

Table 1. Stratification Structure

Strata	Category	Justification
Stratum 1	Government HEIs	Different administrative and policy environment
Stratum 2	Private HEIs	Varying management practices and ICT policies
Sub-stratum A	Faculty	Decision-makers and ICT implementers
Sub-stratum B	Students	Primary ICT end users

2.4 Sample Size

A total sample of 520 respondents was drawn from 26 HEIs, comprising 13 governments and 13 private institutions. Each institution contributed 20 participants (10 faculties and 10 students), ensuring balanced representation. The sample size exceeded the minimum recommended threshold for SEM ($n \geq 300$), thus providing adequate statistical power for model estimation and path analysis. The distribution is presented in Table 2.

Table 2. Sample Distribution

Institution Type	Faculty	Students	Total
Government HEIs	130	130	260
Private HEIs	130	130	260
Total	260	260	520

2.5 Data Collection Instrument

Data were collected using a structured questionnaire developed specifically for this study. The instrument comprised four sections:

Section A: Demographics

Captured age, gender, role, institution type, educational level, and total no. of PCs in the organization.

Section B: Determinant Constructs (Independent Variables) and Outcome Variables (Dependent Variables)

Assessed technological, organizational, environmental, and individual determinants of green computing adoption and Green Computing Knowledge. The constructs were derived from established theoretical frameworks including the Technology–Organization–Environment (TOE) framework, Diffusion of Innovation (DOI), and Theory of Planned Behavior (TPB) [3]. Included intention to adopt green computing practices and environmental IT performance. All questionnaire items were measured on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The complete list of constructs is provided in Table 3.

Table 3. Independent and Dependent Variables

Variable Type	Constructs
Technological	Relative Advantage, Compatibility, Complexity, Usability
Organizational	Top Management Support, Facilitating Conditions, Innovativeness, Policy Support
Environmental	Government Regulations, Competitive Pressure, Social Influence
Individual	Attitude, Subjective Norms, Perceived Behavioral Control
Outcome	Intention to Adopt, Implementation,

Section C: Awareness, Green Computing Practices and Green Computing Barriers

Measured respondents' awareness and practices of eco-friendly ICT behaviors, including green purchasing, energy-efficient usage, digital resource optimization, and e-waste management. Also to identify the barriers that stop an organization from implementing Green Computing. These domains are summarized in Table 4.

Table 4. Awareness and Green Computing Practice Domains

Domain	Description
Green IT Purchasing	Preference for eco-friendly IT equipment
Energy Efficiency Practices	Power management and optimized device use
ICT for reducing Environmental Impact	Use of digital tools for Eco-friendly practices
E-waste Management practices	Safe disposal and recycling of ICT equipment

2.6 Validity and Reliability

Content validity was ensured through expert review by specialists in ICT sustainability and behavioral research. A pilot study involving 30 respondents was conducted to evaluate clarity, comprehensibility, and preliminary reliability. Internal consistency was assessed using Cronbach's alpha, with all constructs exceeding the acceptable threshold of 0.70. Construct validity was examined using Confirmatory Factor Analysis (CFA). Factor loadings (>0.60), Average Variance Extracted (AVE > 0.50), and Composite Reliability (CR > 0.70) confirmed the convergent validity and reliability of the measurement model [4].

2.7 Data Collection Procedure

Data were collected through pen-paper surveys administered during scheduled institutional visits. Participation was voluntary, and anonymity and confidentiality were maintained throughout the study. Respondents provided informed consent prior to inclusion in the survey.

2.8 Data Analysis

Data were analyzed using SPSS 26 for preliminary assessments and AMOS 26 for CFA and SEM. Analysis included:

- Descriptive statistics for demographic and awareness variables
- Reliability assessment using Cronbach's alpha
- CFA for measurement model validation
- SEM for hypothesis testing and framework development

Model fit was evaluated using multiple indices, including the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), and χ^2/df ratio, following established SEM guidelines [5].

3. Result and Discussion**3.1 Demographic Characteristics**

The demographic details of all 520 respondents are summarized in Table 5. The gender distribution shows a slightly higher representation of males compared to females. The age distribution reveals that the majority of the respondents (61.92%) are below 30 years, indicating a predominantly young population. Educational qualifications range from intermediate-level to doctoral-level, with most respondents holding bachelor's or master's degrees. Designation-wise, the sample is evenly split between faculty members and students. Institutional characteristics also display a balanced distribution, with equal representation from government and private higher education institutions. The

majority of respondents are from urban areas (66.92%), suggesting greater participation from institutions located in urban settings. Additional institutional information indicates that most organizations have up to 50 employees and possess up to 100 computers, reflecting moderate ICT infrastructure levels across participating HEIs.

Table 5. Demographic Profile of Respondents (N = 520)

Demographic Variable	Category	Frequency	Percent (%)
Gender	Male	284	54.6
	Female	236	45.4
Age	Less than 30 years	322	61.92
	30–40 years	101	19.42
	40–50 years	86	16.54
	Above 50 years	11	2.12
Education	Intermediate	35	6.73
	Bachelor's	189	36.35
	Master's	187	35.96
	Ph.D.	109	20.96
Designation	Faculty	260	50.0
	Student	260	50.0
Organization Type	Government	260	50.0
	Private	260	50.0
Locality	Rural	172	33.08
	Urban	348	66.92
Employees in Institution	Up to 50	200	38.46
	51–100	131	25.19
	101–150	60	11.54
	Above 150	129	24.81
Number of Computers (PCs)	Up to 100	311	59.81
	101–250	119	22.88
	251–500	42	8.08
	Above 500	48	9.23

3.2 Reliability Analysis

All constructs demonstrated strong internal consistency, as shown in Table 7, with Cronbach's alpha values well above the recommended minimum threshold of $\alpha \geq 0.70$. Technological constructs recorded alpha values between 0.82 and 0.89, while organizational constructs ranged from 0.85 to 0.92. Environmental constructs displayed reliability between 0.78 and 0.88, and individual constructs ranged from 0.84 to 0.90. The outcome variables (Intention and Implementation) exhibited the highest reliability values between 0.88 and 0.93.

Table 7. Reliability (Cronbach's Alpha) for All Constructs

Construct Category	Construct	Cronbach's Alpha (α)
Technological	Relative Advantage	0.82
	Compatibility	0.88
	Complexity	0.84
	Usability	0.89
Organizational	Top Management Support	0.92

	Facilitating Conditions	0.87
	Innovativeness	0.85
	Organizational Policy	0.90
Environmental	Government Regulation	0.88
	Competitive Pressure	0.78
	Social Influence	0.81
	Incentives	0.84
Individual	Attitude	0.90
	Subjective Norms	0.86
	Perceived Behavioral Control	0.88
Outcome Variables	Intention	0.93
	Implementation	0.88

3.3 Confirmatory Factor Analysis (CFA)

The Confirmatory Factor Analysis (CFA) was performed to assess the reliability, convergent validity, and discriminant validity of the measurement model. All constructs demonstrated strong psychometric properties, confirming that the indicators appropriately represented their respective latent variables.

3.4 Convergent Validity

Convergent validity was evaluated using Composite Reliability (CR) and Average Variance Extracted (AVE) (refer to Table 8). All CR values exceeded 0.70, indicating high internal consistency for every construct and All AVE values were greater than 0.50, confirming that each construct explained more than half of the variance in its indicators.

3.5 Discriminant Validity

Discriminant validity was assessed using the Maximum Shared Variance (MSV) criterion. The results in Table 8 confirm that: For all constructs, AVE > MSV, indicating that each construct shares more variance with its own items than with other constructs. This confirms that the constructs are conceptually distinct and non-overlapping.

Table 8. Convergent and Discriminant Validity

Construct	CR	AVE	MSV
Attitude (AT)	0.86	0.61	0.32
Relative Advantage (RA)	0.84	0.57	0.29
Usability (UB)	0.88	0.64	0.41
Compatibility (CM)	0.91	0.68	0.45
Complexity (CP)	0.87	0.60	0.36
Organizational Policy (OP)	0.83	0.56	0.30
Facilitating Conditions (FC)	0.85	0.59	0.34
Innovativeness (IN)	0.89	0.65	0.40
Incentives (INS)	0.82	0.55	0.28
Social Influence (SI)	0.90	0.66	0.42
Competitive Pressure (CPP)	0.88	0.62	0.39
Perceived Behavioral Control (PBC)	0.86	0.60	0.31
Subjective Norms (SN)	0.84	0.58	0.27
Top Management Support (TMS)	0.87	0.63	0.38
Government Regulation (GR)	0.89	0.64	0.40

3.6 Structural Equation Modeling (SEM)

3.7 Model Fit

The structural model was evaluated using multiple goodness-of-fit indices recommended in SEM literature. The results presented in Table 9 demonstrate that the model provides an excellent fit to the data, with all key indices falling well within the recommended thresholds. This confirms that the hypothesized model adequately represents the observed covariance structure. The likelihood ratio ($\chi^2/df = 1.168$) is substantially below the acceptable upper limit of 4.0, indicating strong model parsimony. The Comparative Fit Index (CFI = 0.995) and Tucker–Lewis Index (TLI = 0.994) both exceed the recommended cutoff of 0.90, reflecting excellent incremental and comparative fit. Similarly, the Normed Fit Index (NFI = 0.968), Goodness of Fit Index (GFI = 0.979), and Adjusted Goodness of Fit Index (AGFI = 0.969) surpass their respective thresholds, confirming a robust model structure. The Root Mean Square Error of Approximation (RMSEA = 0.017) is far below the recommended maximum of 0.05, indicating minimal approximation error and highly precise model estimation. Overall, the model fit indices in Table 9 provide strong evidence that the proposed structural model is statistically sound and well-specified.

Table 9. Model Fit Indices

Fit Index	Obtained Value	Acceptable Threshold	Reference
χ^2/df	1.168	≤ 4	Wheaton et al., (1977)
CFI	0.995	≥ 0.90 –0.95	Bentler (1990)
TLI	0.994	≥ 0.90	Bonett & Bonett (1980)
RMSEA	0.017	< 0.05	Hu & Bentler (1990)
NFI	0.968	≥ 0.90	Bollen (1989)
GFI	0.979	≥ 0.90	Hu & Bentler (1990)
AGFI	0.969	≥ 0.90	Tanaka & Huba (1985)

3.8 Path Coefficients

The structural model estimated the direct effects of technological, organizational, environmental, and individual determinants on the Intention to Adopt Green Computing, as well as the effect of intention on Implementation. The regression weights presented in Table 10 indicate that nine predictors exerted significant positive effects on adoption intention, while six predictors were statistically non-significant. Among the technological determinants, Compatibility ($\beta = 0.320$, $p = 0.002$) and Usability ($\beta = 0.290$, $p = 0.027$) significantly strengthened intention, whereas Relative Advantage ($p = 0.713$) and Complexity ($p = 0.353$) showed no significant influence. Within the organizational factors, Top Management Support ($\beta = 0.280$, $p = 0.003$), Facilitating Conditions ($\beta = 0.250$, $p = 0.005$), and Organizational Policy ($\beta = 0.200$, $p = 0.043$) were significant predictors, while Innovativeness ($p = 0.599$) and Incentives ($p = 0.139$) were non-significant. For the environmental determinants, Government Regulation ($\beta = 0.310$, $p = 0.035$) and Subjective Norm ($\beta = 0.210$, $p = 0.044$) significantly contributed to adoption intention, whereas Competitive Pressure ($p = 0.333$) and Social Influence ($p = 0.984$) did not. Regarding individual-level determinants, Perceived Behavioral Control ($\beta = 0.230$, $p = 0.032$) and Attitude ($\beta = 0.270$, $p = 0.014$) significantly enhanced intention to adopt green computing.

Table 10. Regression Weights for Structural Paths

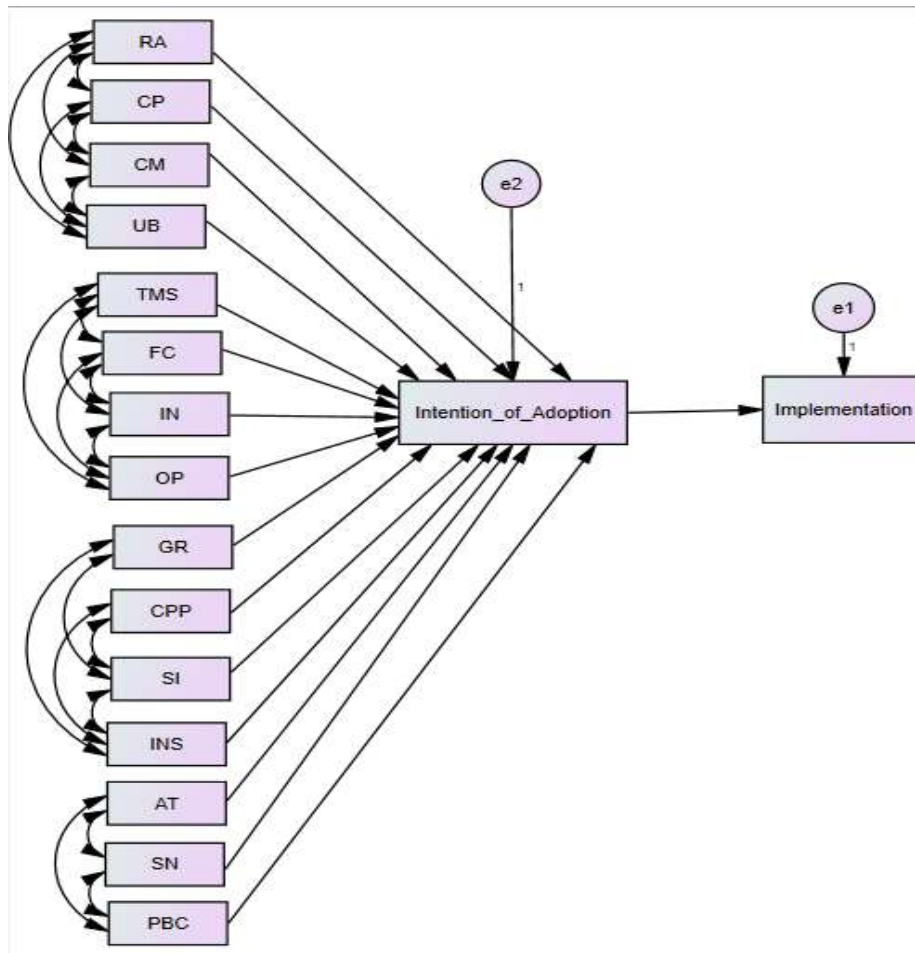
Dependent Variable	Independent Variable	Estimate (β)	S.E.	C.R.	p-value	Significance
Intention $\leftarrow$	Relative	0.010	0.050	0.20	0.713	NS

	Advantage					
Intention ←	Compatibility	0.320	0.090	3.55	0.002	Significant
Intention ←	Complexity	0.050	0.054	0.92	0.353	NS
Intention ←	Top Management Support	0.280	0.095	2.95	0.003	Significant
Intention ←	Facilitating Conditions	0.250	0.089	2.81	0.005	Significant
Intention ←	Innovativeness	0.060	0.113	0.53	0.599	NS
Intention ←	Organizational Policy	0.200	0.099	2.02	0.043	Significant
Intention ←	Government Regulation	0.310	0.147	2.11	0.035	Significant
Intention ←	Competitive Pressure	0.090	0.093	0.97	0.333	NS
Intention ←	Incentives	0.300	0.140	2.10	0.032	Significant
Intention ←	Subjective Norm	0.210	0.104	2.02	0.044	Significant
Intention ←	Perceived Behavioral Control	0.230	0.107	2.15	0.032	Significant
Intention ←	Attitude	0.270	0.110	2.46	0.014	Significant
Intention ←	Usability	0.290	0.132	2.20	0.027	Significant
Intention ←	Social Influence	0.005	0.210	0.02	0.984	NS
Implementation ←	Intention	0.200	0.101	1.98	0.048	Significant

3.9 Framework (Output)

Based on the SEM results, the final Green Computing Adoption Framework for HEIs in Uttarakhand was established. The validated model integrates technological, organizational, environmental, and individual determinants, all of which converge to shape the Intention to Adopt Green Computing, which in turn drives Implementation. Nine factors significantly influenced adoption intention: Compatibility (CM), Usability (UB), Top Management Support (TMS), Facilitating Conditions (FC), Organizational Policy (OP), Government Regulation (GR), Subjective Norms (SN), Perceived Behavioural Control (PBC), and Attitude (AT). These results show that supportive institutional structures, favourable user perceptions, and regulatory guidance are the primary enablers of green computing adoption. Conversely, Relative Advantage (RA), Complexity (CP), Innovativeness (IN), Competitive Pressure (CPP), Incentives (INS), and Social Influence (SI) were non-significant, suggesting that external pressures and technological novelty alone do not influence adoption within Uttarakhand's HEIs. The model also confirms a significant positive effect from Intention → Implementation, emphasizing intention as the key mechanism translating motivational drivers into actual green ICT practices. The complete validated framework is illustrated in Figure 1.

Figure 1. Structural Model for Green Computing Adoption driving factor among HEIs in Uttarakhand



Conclusion

This study identified the key determinants influencing green computing adoption in higher education institutions (HEIs) in Uttarakhand. The awareness analysis showed moderate to high understanding and practice of green ICT behaviours among respondents. All measurement constructs demonstrated strong reliability and validity, supported by high Cronbach's alpha values, CR-AVE consistency, and AVE values exceeding MSV. The structural model exhibited excellent fit (CFI = 0.995, TLI = 0.994, RMSEA = 0.017), confirming the robustness of the proposed framework. SEM results revealed nine significant predictors of intention to adopt green computing: compatibility, usability, top management support, facilitating conditions, organizational policy, government regulation, subjective norms, perceived behavioral control, and attitude. In contrast, relative advantage, complexity, innovativeness, competitive pressure, incentives, and social influence were not significant. Intention was also found to significantly predict actual implementation behaviour. Overall, the validated Green Computing Adoption Framework highlights that adoption is driven more by institutional support, individual motivation, and enabling conditions than by external pressures or perceived technological benefits. The framework provides practical guidance for HEIs to

strengthen policies, awareness initiatives, and supportive infrastructure to promote sustainable ICT practices.

Abbreviations

ICT (Information and Communication Technology), HEIs (Higher Education Institutions), GC (Green Computing), and E-waste (Electronic Waste). The technological constructs include RA (Relative Advantage), CM (Compatibility), CP (Complexity), and UB (Usability). Organizational factors are TMS (Top Management Support), FC (Facilitating Conditions), IN (Innovativeness), OP (Organizational Policy), and INS (Incentives). Environmental constructs include GR (Government Regulation), CPP (Competitive Pressure), and SI (Social Influence). Individual constructs consist of AT (Attitude), SN (Subjective Norms), and PBC (Perceived Behavioral Control). Outcome variables are INT (Intention) and IMP (Implementation). Statistical terms include CR (Composite Reliability), AVE (Average Variance Extracted), MSV (Maximum Shared Variance), CFA (Confirmatory Factor Analysis), EFA (Exploratory Factor Analysis), and SEM (Structural Equation Modeling), along with model-fit indices such as CFI, TLI, NFI, GFI, AGFI, RMSEA, and χ^2/df . The theoretical models referenced are TAM (Technology Acceptance Model), TPB (Theory of Planned Behavior), TOE (Technology–Organization–Environment Framework), DOI (Diffusion of Innovation), and UTAUT (Unified Theory of Acceptance and Use of Technology), NS - Not Significant.

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