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A Behaviorally-Driven Software Architecture for E-Government Adoption in Pakistan

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Abstract

E-Government services were launched in Pakistan in October 2002, marking a significant step toward digital governance. While policy initiatives and infrastructure development have continued, the successful adoption of these services remains constrained by several socio-technical and behavioral challenges. This study presents a user-driven software framework for e-government adoption in Pakistan, aimed at bridging the gap between user behavior and system design. By integrating behavioral insights into system architecture, the framework emphasizes the importance of user acceptance, trust, and perceived ease of use in shaping e-government adoption. A theoretical model was developed based on an enhanced combination of three established models—Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and the Information System Success Model—to explore the critical success factors influencing e-government implementation. The model was validated through empirical data collected from computer professionals working in Pakistan's government sector, particularly in education and health departments. A structured questionnaire comprising 42 items across 10 constructs was distributed to 650 respondents, yielding 508 valid responses. The results revealed strong support for all proposed hypotheses and confirmed the role of behavioral intention as a key driver of adoption. This study not only confirms the relevance of behavioral factors in e-government adoption but also proposes a modular and scalable software framework that can inform the design of more user-centric, secure, and behaviorally-aligned e-government platforms. The findings offer practical implications for policy makers, developers, and system designers seeking to improve e-government engagement and digital service delivery in developing countries like Pakistan.

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1 Introduction

The concept of e-government emerged widely in the 1990s, but its roots trace back to the early use of computers in public administration as early as the 1970s [1][2][3][4]. In Pakistan, e-government services were formally introduced in October 2002, initially through a dedicated directorate. This later merged with the Pakistan Computer Bureau to form the National Information Technology Board (NITB) in 2014, which now oversees key services such as online tax filing and digital public service platforms [5–11]. While Pakistan's historical journey in e-government is relatively recent, the technical limitations of software platforms—rather than just policy-level issues—have emerged as a major barrier to widespread adoption. These limitations include complex system interfaces, lack of integration among departments, poor usability, and limited scalability. For example, digital tax systems were introduced to reduce direct interaction between taxpayers and officials, yet their adoption remains limited partly due to confusing user flows and inadequate software support [12].

Although e-government has been a popular research topic over the past two decades, most studies have emphasized social, political, or governance-related dimensions [13]. However, as recent literature increasingly reveals, technical design flaws, such as overly complex interfaces, lack of mobile responsiveness, or insufficient backend integration directly influence user trust, satisfaction, and adoption [32–34]. From a Computer Science perspective—particularly in software engineering and human-computer interaction (HCI)—these issues represent critical failures in system requirements specification, user experience (UX) design, and architectural scalability. From a software engineering standpoint [72][74], the goal of e-government is not merely to digitize bureaucracy but to design citizen-centric systems that are accessible, secure, and efficient [14–16]. A well-designed system must ensure visibility, transparency, and interactivity, allowing users to navigate services with minimal cognitive load. In contrast, poorly designed systems contribute to frustration, low engagement, and eventual project failure—outcomes frequently seen in underdeveloped countries, where e-government success rates can be as low as 15% [26–28]. A major contributor to this low success rate is the gap between user expectations and technical implementations. Usability issues such as system lag, interface clutter, or non-intuitive workflows make government services inaccessible to large portions of the population. Likewise, the absence of interconnectivity between government platforms hinders data sharing and efficient service delivery [18–21]. These issues are particularly relevant in Pakistan, where many digital government platforms operate in silos, increasing complexity for end users and decreasing operational efficiency.

This study addresses these concerns by proposing a user-driven software framework for e-government adoption in Pakistan. The framework is rooted in core software engineering principles, including modularity, maintainability, and security, and is guided by behavior-driven requirements engineering. It emphasizes the alignment of technical design with behavioral insights to reduce system complexity and enhance usability. The framework is informed by three well-established models: the Technology Acceptance Model (TAM) [36], the Unified Theory of Acceptance and Use of Technology (UTAUT) [16], and the Information Systems Success Model [38]. These models collectively capture the influence of system quality, service quality, perceived usefulness, and behavioral intention on adoption. Survey data were collected from 508 respondents (out of 650 distributed questionnaires) using 42 questions mapped to 10 constructs. The study particularly investigates the role of system efficiency, data security, reliability, complexity, and compatibility in shaping user perceptions and intentions. By integrating these constructs into system-level software requirements, such as UI responsiveness, architectural scalability, data security. Ultimately, this study contributes to the literature by shifting the lens toward technical usability and integration challenges in e-government systems. It presents a path forward for developers, policymakers, and system architects [76] to collaborate in building more intuitive, efficient, and scalable digital public services especially in the context of developing countries like Pakistan.

The aim of this study is to determine the relationship between and among service quality, system quality, perceived usefulness, perceived ease of usefulness, and behavioral intention. From a Computer Science perspective, these constructs are used to derive behavior-driven non-functional software requirements, which directly inform the architectural and interface-level decisions of digital platforms. Despite this, the aim is broken down into nine objectives which are given as below:

1. To identify the relationship between efficiency and perceived usefulness.
2. To identify the relationship between data security and perceived usefulness.
3. To identify the relationship between reliability and perceived usefulness.
4. To identify the relationship between performance expectancy and perceived usefulness.
5. To identify the relationship between compatibility and perceived ease of usefulness.
6. To identify the relationship between complexity and perceived ease of usefulness.
7. To identify the relationship between facilitating condition and perceived ease of usefulness.
8. To identify the relationship between perceived usefulness, service quality, and behavioral intention.
9. To identify the relationship between perceived ease of usefulness, system quality, and behavioral intention.

2 Literature Review

2.1 SERVICE QUALITY

The quality of the resulting system is measured in the variable called service quality; The user is capable of selecting or giving the choice whether the service is given with standards. The variable can be estimated with [41] indicators like insurance, empathy, quick responsiveness, follow up and other online services effectively.

2.2 EFFICIENCY

IS framework has been proposed by the [42] in application of the outsourcing situation. Efficiency and efficacy have been tested for the understanding of the working mechanism of a system in order to measure the right job to be done at the right time for an organization.

2.3 DATA SECURITY

The ongoing increase in the use of new technology in healthcare practices has resulted in the modification of traditional approaches to dealing with patient information [43]. IT practitioners in today's Technology Services have many privileges and can access digital information from any device at any time in the cloud.

2.4 RELIABILITY

Over time and across different situations, the measure is checked for reliability and the reliability is the measurement of different situations. This ensures consistency and ensures the reliability of the construction under certain circumstances, and it is not because of the error.

2.5 PERFORMANCE EXPECTANCY

The expectancy theory is illustrated as theory of process. Various studies including Victor Vroom and Edward Tolman; the two early research illustrate the reasons when a person is selecting one activity over the other one. The theory comes with the idea that a person is doing anything or something in a manner that his or her actions will provide a desired result in accordance with his or her efforts or activities. The theory also explains the level of task and the way that a person is performing a particular level of tasks. It can be called that a particular motivation potential is achieved, and this approach can help the leaders so that they can organize the programs and methods to increase the level of motivation at the place of work. A person's internal motivation comes from thinking that something will be achieved in the form of a reward. The theory does not explain all of the factors included even though the theory provides some basic building blocks which may help the leaders to improve the motivation of their subordinates and provide some good and supportive environment at their workplace. The theory of process or the expectancy theory is considered as the successful motivation theory in which the person's individual. Keeping in view the importance of this variable we have selected to include this factor in our study.

2.6 Perceived Usefulness (PU)

It is the understanding of a person when an individual trusts himself that a specific system or technology may increase the level of performance [44]. In use of the e-government services or any other technological product, it also has an additional effect on the educational and professional environment of user, perceived usefulness is considered an important element.

2.7 SYSTEM QUALITY

In perspective of information system, the quality is judged from the combinations of software and the hardware. The quality can be measured to test how this software, hardware, the policies, regulations and procedures are performing the actions as per information needs [41].

2.8 COMPATIBILITY

According to [45], system compatibility refers to aligning the present system with an individual's values. The researcher defined compatibility as the extent to which the e-government services align with education sector professionals' work habits or preferences.

2.9 COMPLEXITY

According to [46], system compatibility refers to aligning the present system versus old system or new system that the either system is challenging and easy to understand. The utilization of E-government services in the IT sector is evident, but it may present difficulties for individuals who lack technological proficiency. Consequently, the IT sector in Pakistan is more conducive to the integration of Digital information systems, which increases the likelihood of their utilization.

2.10 FACILITATING CONDITIONS (FC)

The degree of facilities or technological structure of organization available for the individual in an organization is called facilitating conditions [47]. Moreover, it is the level of the supportive infrastructure which is helpful and fair for an individual so that a person can use any form of technology. These facilities vary from speed, capabilities of data processing, mobile interface or shopping though mobile are provided in easy manner. [48] suggest if facilitating conditions are not available then technology will be in question and the technology acceptance process will be slower down. PEOU and Perceived Usefulness are the two factors affected by facilitating conditions as found by many of the researchers [47]. Similar results are also reported by [47] [49] [50] in which behavior intention of consumer is directly affected by facilitation conditions.

2.11 PERCEIVED EASE OF USEFULNESS (PEOU)

The word perceived ease-of-usefulness can be understood when a person is thinking of a particular system and the easiness in using that system and there will be less efforts to use a system [51]. PEOU and PU are considered at the same directional elements and many of the researchers found a positive relationship between both elements with empirical versification [52][49][53]. Moreover, many studies have confirmed the positive relation of BI and PU in this regard [53] [54].

Some studies claimed that PU and PEOU are the two similar and equal effecting elements and key determinants acceptance of technology [55]. PEOU was an interceding variable as indicated in one study. This, therefore, demonstrated a questionable relationship between PU and the initial utilization, which is a significant difference to the findings in the studies conducted by Davis [56].

2.12 BEHAVIORAL INTENTIONS

In TAM [57], the model for the technology acceptance and intention of a user's intention to purchase a system, a product or any other thing is thought a consideration variable as system acceptance. Information research literature contains a key variable called system usage to study the technology acceptance of a particular person. In the absence of objective usage measures, self-supported usage measurements are used in the field of IS research. Behavior Intention is normally used to estimate the usage or predict the IS / IT acceptance [50]. The user intention has been used as a dependent variable in this research. The current study can be considered relevant and adjacent to the various available research [49][57].

Some studies reported that the PEOU has equal effect as the PU in technology acceptance [59]. PEOU was validity of the TAM was not validated in the study conducted by Igbarria et al. [63]. However, their study was able to give another view regarding the contradicting results of the previous studies conducted. The insufficiency of the PU to produce an effect on the behavior of operators who lack skill was, likewise, exposed to the study conducted. The results of the study, therefore, were in contradiction of the TAM. Experience, on the other hand, proved to have more significant effect on the frequency of technology usage [64]. In addition, more recent studies displayed two types of PU, namely, (a) near-term PU, and (b) long-term PU. Near-term PU demonstrated that it has a greater effect on intention. The PEOU and intention demonstrated an absence of relationship between each other [65].

2.13 Mapping Behavioral Factors to Software Requirements

The success of e-government services relies not only on policy and infrastructure but also on the effective translation of user behavioral expectations into tangible software design specifications. Drawing upon the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and the Information System [70] Success Model, this section maps critical behavioral constructs such as Perceived Ease of Use (PEOU), Perceived Usefulness (PU), Performance Expectancy, and System Quality to corresponding functional and non-functional software requirements.

This mapping serves as a bridge between user-centered behavioral research and practical system engineering, ensuring that e-government platforms are designed not just for functionality but also for adoption, usability, and trust as shown in Table 1.

2.14 Implications for System Design

Mapping behavioral factors to software requirements ensures that system designers account for both user psychology and technical architecture [77]. For example, enhancing perceived ease of use through a responsive, minimal-click interface can significantly increase adoption rates [71]. Similarly, embedding security protocols like encryption and multi-factor authentication directly addresses user concerns about trust and data privacy. This user-driven approach to system specification is especially critical in developing countries like Pakistan, where user expectations and digital literacy levels vary widely. By grounding technical requirements in behavioral constructs, e-government platforms can become more usable, trusted, and widely adopted.

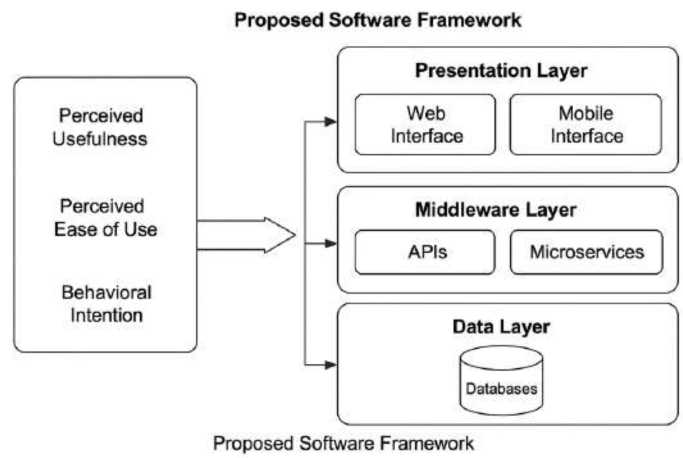

Figure 1. Proposed Software Framework

2.15 Proposed Software Framework

To bridge the gap between behavioral expectations and technical implementation, we propose a modular, user-driven software framework for e-government services in Pakistan. This framework is designed to be scalable, secure, and adaptable across departments, and directly addresses critical behavioral factors such as perceived ease of use, system quality, performance expectancy, and trust. The architecture consists of three major layers namely Frontend Layer, Middleware Layer and Backend Layer. The details of the layers are as follows:

2.16 Frontend Layer: Web/Mobile Interface

This is the primary touchpoint for users (citizens and government employees) [79]. It includes both a responsive web portal and mobile application. Some

Table 1. Behavior-Driven Software Requirements

Behavioral Factor	Mapped Software Requirement
Perceived Ease of Use (PEOU)	Intuitive, user-friendly interface Low click depth for task completion Mobile responsiveness and accessibility
Perceived Usefulness (PU)	Role-based dashboards Real-time data updates Integration with other government services for cross-functionality
Performance Expectancy	Fast system response time (<2 seconds average) Scalable architecture with load balancing
Reliability	Stable backend systems Redundant servers and failover mechanisms Uptime guarantee >99.9%
System Quality	Modular, maintainable codebase Clear navigation and functional workflows Real-time error logging
Service Quality	24/7 user support chatbot or helpdesk Auto-ticket generation for failed transactions
Data Security	End-to-end encryption Multi-factor authentication (2FA) Role-based access control
Trust	Transparent privacy policy Digital audit trails Secure data storage compliant with national standards
Compatibility	Cross-platform functionality (Windows, Android, iOS) Browser compatibility Legacy system integration
Facilitating Conditions	In-app help features and tutorials Offline data capture for low-connectivity regions Training support for government staff
Behavioral Intention	Personalized user experience Feedback and rating mechanisms Notification/reminder system for deadlines and tasks

of the User centric features are clean, minimal UI to reduce click depth (PEOU), adaptive design for accessibility (compatibility) [69], Local language support and personalized dashboards (user satisfaction) and in-app help tutorials and service tracking (facilitating conditions)

2.17 Middleware Layer: API Gateway and Microservices

The middleware handles business logic and service orchestration via an API gateway and containerized microservices. The technical features include API Gateway which ensures centralized routing, load balancing, rate limiting, and security token validation. The other feature is Microservices Architecture that allows separation of modules (e.g., tax filing, birth registration, healthcare records), improving scalability and maintainability [78].

2.18 Backend Layer: Database and Security Modules

The backend supports persistent data storage, security, and audit mechanisms in which the technical features are Relational and NoSQL Databases for structured and semi-structured data and security modules include Role-based access control (RBAC), End-to-end encryption, multi-factor authentication (2FA) and activity logging and digital audit trails. The system Benefits are shown in Table 2.

This proposed framework ensures that both end-user experience and software engineering standards are addressed [74][75]. It supports interoperability across government sectors, enhances service delivery efficiency, and promotes higher citizen engagement

Table 2. System Benefits

Aspect	How It's Addressed
Ease of Use (PEOU)	Intuitive interfaces, responsive design, user guidance
Usefulness (PU)	Integrated services, real-time feedback, personalized features
Performance Expectancy	Scalable architecture, fast response via microservices
Security & Trust	Strong encryption, audit logs, secure authentication
System/Service Quality	Modular backend, centralized API gateway, automated error handling

through trustworthy and usable digital platforms.

3 PROPOSED RESEARCH FRAMEWORK

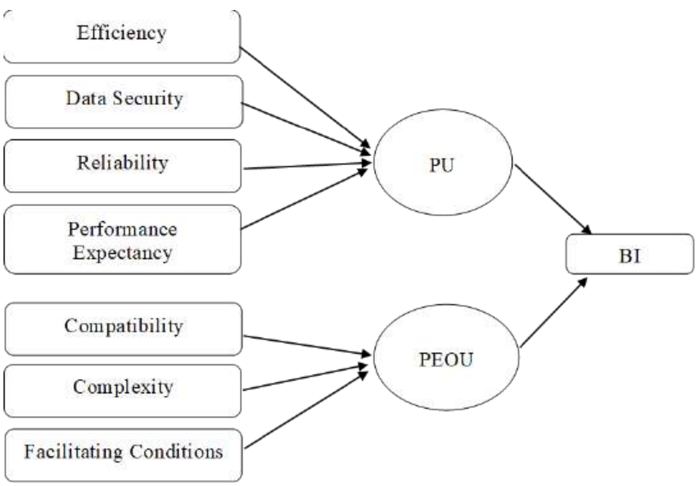

Figure 2. Proposed Research Framework

4 Hypotheses

H1. Efficiency is positively related to Perceived Usefulness.
H2. Data Security is positively related to Perceived Usefulness.
H3. Reliability is positively related to Perceived Usefulness.
H4. Performance Expectancy is positively related to Perceived Usefulness.
H5. Compatibility is positively related to Perceived Ease of Usefulness.
H6. Complexity is positively related to the Perceived Ease of Usefulness.
H7. Facilitating Condition is positively related to Perceived Ease of Usefulness.
H8. Perceived Usefulness is positively related to Service Quality and Behavioral Intention.
H9. Perceived Ease of Usefulness is positively related to System Quality and Behavioral Intention.

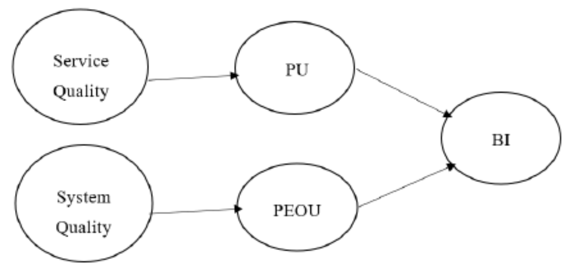

Figure 3. Proposed Mediation Model

5 Research Design

5.1 Target population:

Population is the overall universe of the samples from which the sample is selected [66]. The target population in this study is the various subjects working in the education sector. As per the statistics of the Higher Education Commission of Pakistan (HEC, 2023-2024) a total of 220 universities and higher education institutions are in Pakistan. Along with 220 universities, seventeen teachers training institutes are there. Taking samples from all over the population is not feasible, in this case, convenient sampling has been used for data collection.

5.2 Sample size:

The most cited rules of thumb have been used for data analysis. Structural modeling equation. Some other data analysis approaches have also been used in PLS smart software. The targeted sample was expected to 700 whereas a total of 650 came into practical and subjects were working in education department of government of Pakistan.

5.3 Instrument development:

For the development of the current study, variables from various models have been adopted by selecting some of the variables from the models including UTAUT [16], TAM [36] and Information Success Model. The instrument has been developed by adopting the variables selected from these models.

5.4 Scale used:

The current study used five-point Likert proposed by Rensis Likert in the year 1932 [67]. The twofold reasons are the easy method and the approachable [68] and it is used widely with 5 and 7 Likert scales. Many of the studies resemble this current study [16] [62].

5.5 Data collection procedure:

The data collation has been done in a traditional approach and a questionnaire has been distributed and the subjects were asked to fill the form [37]. Pakistan has been selected for data collection area especially focusing on the Sindh province due to the fact that the researcher is from Sindh Province. The research personally visited many of the respondents and they were also requested by email and google forms to submit their opinions which were received and analyzed proceeded by the fine tuning.

Demography profile is presented in Table 3. Most of the participants were male with a total number of 345 out of 508 with the percentage of the 67.91%. Rest of the participants were female. The married participants were 421 with a percentage of 82.87%. Rest of the 87 participants were single. No respondents were less than the intermediate and all of the respondents were more than intermediate. This is the reason why the highest number of respondents were bachelor's with a 52.76%. The highest number of respondents possessed experience from 2 to 5 years. With a 480 number of respondents with a percentage of 94.49%, respondents were permanent.

In Table 4, the Cronbach's alpha for all the variables involved in the study are presented. All ten variables have been tested for the validity and the validity value of 0.7 of Cronbach's alpha is considered as the standard and in this case the current study has proved it and Table 3 shows all the variables reliably more than the standard value of Cronbach's alpha.

Table 3. Demographic profile of the respondents

Gender	Frequency	Cumulative Percentage
Male	345	67.91
Female	163	32.09
Total	508	100%
Marital Status	Frequency	Cumulative percentage
Married	421	82.87
Single	87	17.13
Total	508	100%
Age Group	Frequency	Cumulative percentage
20-29 years	172	33.85
30-39 years	198	38.98
40-49 years	122	24.02
50 years and above	16	03.15
Total	508	100%
Education	Frequency	Cumulative percentage
Intermediate or Less	00	00.00
Bachelor (14 years)	268	52.76
Master (16 years)	215	42.32
MBA/MS/M.Phil/PhD	25	04.92
Total	508	100%
Experience	Frequency	Cumulative percentage
Less than 1 year	12	2.36
2 to 5 years	250	49.21
6 to 10 years	136	26.77
11 to 20 years	56	11.03
20 and above years	54	10.63
Total	508	100%
Position/Rank	Frequency	Cumulative percentage
Contract	28	05.51
Permanent	480	94.49
Total	508	100%

Table 6. Construct Reliability and Validity with Average Variance Extracted and R square

Variable(s)	CBA	CR	AVE	R Square
Efficiency	0.821	0.887	0.725	0.000
Data Security	0.851	0.893	0.678	0.000
Reliability	0.884	0.919	0.740	0.000
Performance Expectancy	0.846	0.904	0.759	0.000
Perceived Usefulness	0.907	0.919	0.722	0.128
Compatibility	0.929	0.940	0.759	0.000
Complexity	0.911	0.934	0.778	0.000
Facilitating Condition	0.921	0.944	0.808	0.000
Perceived Ease of Usefulness	0.858	0.902	0.697	0.130
Behavioral Intention	0.905	0.918	0.795	0.142

CBA= Cronbach's Alpha CR= Composite Reliability AVE= Average Variance Extracted

The three measurements along with average have been shown. This table provides an assessment of construct reliability and validity for a research model, com-

Table 4. Cronbach' Alpha (CBA)

Variable (s)	Cronbachs Alpha
Efficiency	0.820
Data Security	0.850
Reliability	0.883
Performance Expectancy	0.871
Perceived Usefulness	0.906
Compatibility	0.928
Complexity	0.927
Facilitating Condition	0.920
Perceived Ease of Usefulness	0.858
Behavioral Intention	0.905

monly used in structural equation modeling (SEM) or PLS-SEM. It evaluates the quality of measurement for each variable (construct) in proposed model using four indicators.

CBA stands for Cronbach's Alpha measures internal consistency (how well the items in a construct measure the same concept and the threshold is typically from greater or equal to 0.70 is acceptable whereas the value greater than or equal to 0.80 is good and in this case, all constructs of our proposed model have been recorded as greater than 0.82 indicating the high internal reliability.

Composite Reliability is a more accurate measure of internal consistency than Cronbach's Alpha in SEM and the threshold of 0.70 is good. In our proposed model, all constructs exceed 0.88, showing excellent composite reliability. In another measurement, the average variance extracted indicates the convergent validity is the degree to which a construct explains the variance of its indicator and its threshold value AVE 0.50 is acceptable. In our study, all constructs have AVE > 0.67, confirming strong convergent validity. R^2 reflects how much variance in a dependent (endogenous) variable is explained by other constructs. For the interpretation of R^2, constructs with $R^2 = 0.000$ are independent (exogenous) variables and constructs with $R^2 > 0.000$ are dependent (endogenous) variables. The formulae of these measurements are given below.

Eff= Efficiency DS= Data SecurityRel= ReliabilityPE= Performance ExpectancyPU= Perceived Usefulness-COM= CompatibilityCMP= ComplexityFC= Facilitating ConditionPEOU= Perceived Ease of UsefulnessBI= Behavioural Intention

CBA	$\rho_T = \frac{k^2 \overline{\sigma_{ij}}}{\sigma_X^2}$
CR	$\frac{\left(\sum_{i=1}^{p} \lambda_i\right)^2}{\left(\sum_{i=1}^{p} \lambda_i\right)^2 + \sum_{i}^{p} \mathrm{V}(\delta)}$
R Square	$R^2 = 1 - \frac{RSS}{TSS}$

Figure 4. Formulae of the CBA, CR, and R square

Table 7 represents the correlation matrix for constructs in a structural model (e.g., a technology acceptance model), along with the diagonal elements representing the square roots of the AVE (Average Variance Extracted) for each construct. This kind of matrix is used to assess discriminant validity using the Fornell-Larcker criterion.

Table 8. Path Coefficients (Direct Effects)

Path Coefficients	P-Value	Standard Error	T-Statistics	Sig:/Insig:
Eff=>PU	0.048	0.112	1.981	Sig:
DS=>PU	0.042	0.076	3.542	Sig:
Rel=>PU	0.002	0.054	1.963	Sig:
PE=>PU	0.245	0.130	1.165	Insig:
COM=>PEOU	0.036	0.108	2.337	Sig:
CMP=>PEOU	0.083	0.211	1.735	Insig:
FC=>PEOU	0.014	0.134	2.468	Sig:

Table 8 presents the structural model results, specifically the path coefficients, their statistical significance, and the interpretation of their impact on the dependent variables: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU).

Table 9 presents indirect path relationships in a structural equation model (SEM) especially how two latent variables, Service Quality and System Quality influence Behavioral Intention indirectly through Perceived Usefulness and Perceived Ease of Use, respectively.

Table 5. Factor Analysis

Variable(s)	Eff:	DS	Rel	PE	PU	COM	CMP	FC	PEOU	BI
Eff-1	0.768									
Eff-2	0.872									
Eff-3	0.908									
DS-1		0.785								
DS-2		0.779								
DS-3		0.839								
DS-4		0.885								
Rel-1			0.858							
Rel-2			0.863							
Rel-3			0.854							
Rel-4			0.866							
PE-1				0.860						
PE-3				0.904						
PE-4				0.849						
PU-1					0.810					
PU-2					0.845					
PU-3					0.839					
PU-4					0.880					
PU-5					0.874					
COM-1						0.947				
COM-2						0.724				
COM-3						0.920				
COM-4						0.824				
COM-5						0.923				
CMP-1							0.883			
CMP-2							0.904			
CMP-4							0.869			
CMP-5							0.872			
FC-1								0.903		
FC-2								0.893		
FC-3								0.874		
FC-4								0.924		
PEOU-1									0.764	
PEOU-2									0.852	
PEOU-3									0.840	
PEOU-4									0.880	
BI-1										0.820
BI-2										0.768
BI-3										0.934
BI-4										0.905

Table 9. Path Coefficients (Specific Indirect Effects)

Path Coefficients	P-Value	Standard Error	T-Statistics	Sig:/Non-Sig:
SER QTY=>PU=>BI	0.022	0.112	2.980	Sig:
SYS QTY=>PEOU=>BI	0.042	0.188	3.115	Sig:

Figure 5 is a PLS-SEM (Partial Least Squares Structural Equation Modeling) output, showing the structural and measurement model results. This reflects the causal relationships between latent constructs (blue circles), including, data security, efficiency, reliability, performance expectancy and perceived usefulness. Each arrow between constructs shows the path coefficient (like a regression weight), with the strength and direction of influence. The number 0.128 in the PU node is the R-squared (R^2) value which indicates that 12.8% of the variance in PU (Perceived Usefulness) is explained by DS, Eff, Rel, and PE.

This reflects how well each observed variable (yellow boxes) loads onto its latent construct (blue circles). The values on the arrows from constructs to indicators (e.g., PU1, DS2, RE3) are factor loadings. Good loadings are typically > 0.7, which indicates strong reliability of the indicators as PU, DS and others.

Figure 6 is another PLS-SEM (Partial Least Squares Structural Equation Modeling) output, showing both the measurement model and structural model. This figure models how three latent constructs influence

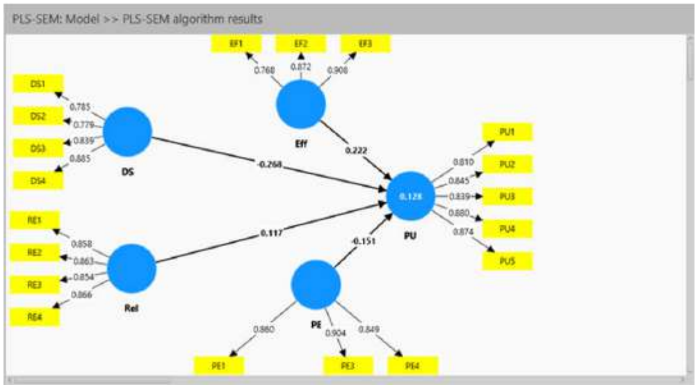

Figure 5. Algorithm representation of the proposed model.

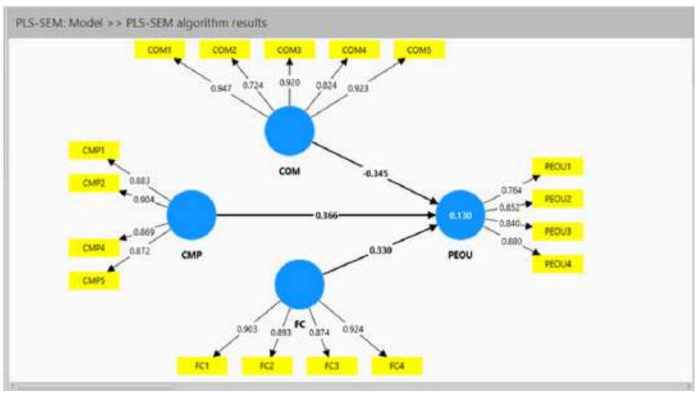

Figure 6. Another calculation illustration of proposed model.

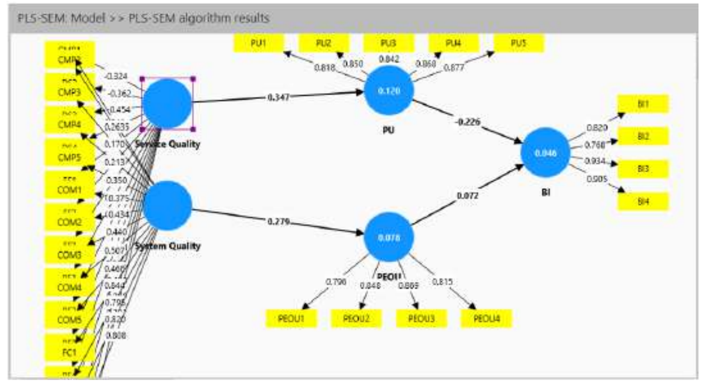

Figure 7. All variable illustrations of the model.

Perceived Ease of Usefulness (PEOU).

Figure 7 shows a PLSSEM (Partial Least Squares Structural Equation Modeling) diagram showing both the measurement model (outer model) and the structural model (inner model). It evaluates how Service Quality and System Quality influence Perceived Usefulness, Perceived Ease of Use, and Behavioral Intention.

5.6 Technical Discussion on Implementation

To ensure the successful realization of the proposed e-government software framework, it is critical to adopt a structured, iterative, and quality-assured development lifecycle. This section outlines the technical strategies and development practices required to implement, test, scale, and continuously improve the system in line with international software engineering standards.

5.7 Agile Development Practices

The answer that Why Agile has been used for the current research is the E-government projects involve evolving user needs, policy adjustments, and multi-stakeholder inputs. Agile methodologies (e.g., Scrum or Kanban) are ideal for managing such complexity by promoting Iterative development in short sprints, Continuous stakeholder feedback, early delivery of functional modules and flexible scope changes

Implementation Strategy where Scrum teams are used consisting of developers, UI/UX designers, testers, and domain experts. Bi-weekly sprint reviews are conducted with government stakeholders and end users. And the product backlog is maintenance organized by priority behavioral and functional requirements.

5.8 Usability Testing

The Purpose of the usability testing is to validate that the system meets behavioral expectations such as Perceived Ease of Use (PEOU) and Perceived Usefulness (PU). The approach is to conduct moderate usability tests with citizens from diverse backgrounds (urban, rural, low digital literacy). Another approach is to use task-based scenarios (e.g., "apply for a birth certificate") to evaluate click paths, comprehension, and success rates. The final approach is to capture quantitative metrics (completion time, error rate) and qualitative feedback (user satisfaction).

5.9 CI/CD Pipelines and DevOps Integration

Continuous Integration/Deployment (CI/CD) typically Automate the build, test, and deploy cycle using tools like Jenkins, GitLab CI, or GitHub Actions. It also implements unit, integration, and regression tests for every code commitment. It also ensures secure code with static code analysis tools like SonarQube or Snyk.

5.10 DevOps Best Practices:

Maintain Infrastructure as Code (IaC) using tools like Terraform or Ansible use Docker for consistent development and deployment environments. Set up staging environments that mirror production for final testing before deployment. Log and monitor errors using ELK Stack or Splunk, enabling quick rollback or fixes. As final words, by integrating agile development, usability testing, cloud-native architecture, and DevOps practices, the proposed e-government system will not only align user behavioral expectations, but also meet modern standards for performance, reliability, and maintainability. These practices collectively ensure that the system can evolve with user needs, scale with national demand, and maintain high service quality throughout its lifecycle.

6 Conclusion and Future Directions

The pilot study validated the proposed model, and subsequent data collection yielded 508 usable responses. Analysis confirmed strong relationships between key variables; perceived ease of use, perceived usefulness, system quality, and behavioral intention indicating that technical usability and service design significantly influence e-government adoption [73][74]. From a software engineering perspective, these findings underscore the importance of aligning user behavior models with technical system requirements. For developers and engineering teams, the results highlight the need to prioritize user-centric design, system responsiveness, security, and interoperability when building or enhancing e-government platforms. Technical Implications for Developers and System Architects including usability in which interfaces must be intuitive and accessible, particularly for users with low digital literacy. For scalability, Systems should support national-scale deployment through microservices and cloud-native infrastructure. For security: Data protection through encryption, secure authentication, and audit trails are critical to building user trust. For maintainability: Modular and loosely coupled architectures facilitate long-term system evolution and adaptability. For automation: CI/CD pipelines and automated testing frameworks should be standard to ensure fast, reliable updates.

Suggestions for Future Software Engineering Research

Future studies can explore frameworks for evaluating and benchmarking e-government systems under different load conditions and usage scenarios. Investigate the integration of AI-driven chatbots, predictive analytics, and automated service delivery to improve responsiveness and reduce manual workloads. Explore context-aware UI/UX that adapts to user behavior and preferences, improving perceived ease of use and satisfaction. Research technical standards and APIs that support seamless data exchange between government systems to reduce redundancy and improve efficiency.

Examine the challenges and benefits of embedding security practices directly into the DevOps lifecycle for e-government systems. Use simulation models to test new services and policies in a virtual environment before real-world deployment. While this study offers valuable insights, it is limited by its scope, focusing primarily on government employees within the education sector and using a cross-sectional design. Future studies could include other sectors, conduct longitudinal assessments, or apply experimental design for deeper insights into causality. In conclusion, advancing e-government in Pakistan and similar developing countries requires a concerted focus on software engineering excellence. By translating behavioral insights into robust technical solutions, and by leveraging emerging technologies, developers and researchers can play a pivotal role in creating inclusive, reliable, and intelligent public service systems.

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Bushra Memon: Conceptualization, data collection, and writing – original draft. **Dil Nawaz Hakro:** Methodology design, supervision, and editing. **Imran Ujjan:** Statistical analysis and data interpretation. **Shazia Abbasi:** Literature review, proofreading, and formatting.

Compliance with Ethical Standards

It is declare that all authors don't have any conflict of interest. It is also declare that this article does not contain any studies with human participants or animals performed by any of the authors. Furthermore, informed consent was obtained from all individual participants included in the study.

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