

Smart Villages and Digital Inclusion: A New Paradigm for Rural Development in Bangladesh

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Abstract

This research examines how digital inclusion contributes to sustainable rural development in Bangladesh, focusing on the implementation of smart village strategies. The study investigates four core variables such as smart infrastructure, e-governance-services, access to ICT tools, and digital literacy to determine their collective and individual impact on rural transformation. Based on data collected from rural populations and analyzed through correlation and regression techniques, the findings reveal that each factor has a statistically significant positive influence on development outcomes. Notably, smart infrastructure and digital literacy emerged as the most impactful elements, highlighting the need for both physical access and human capability. Additionally, digital literacy plays a mediating role in enhancing the effectiveness of ICT-based interventions. The study contributes to policy and

academic discourse by offering an integrated framework that aligns with the “Digital Bangladesh” vision and supports broader goals of inclusive and technology-driven rural progress.

Keywords: Smart village, rural development, digital literacy, e-governance, digital inclusion.

1. Introduction

1.1 Background of the Study

In the rapidly evolving digital age, rural development is no longer confined to traditional models of agricultural support and infrastructure enhancement. Rather, the integration of technology into the rural fabric, under the concept of “smart villages,” is gaining momentum as a transformative strategy to bridge the rural-urban divide. In countries like Bangladesh, where a significant portion of the population resides in rural areas, the relevance of digital inclusion as a tool for sustainable rural advancement has never been more urgent (World Bank, 2023). The concept of a smart village encompasses the application of modern information and communication technologies (ICTs) in rural settings to enhance quality of life, improve access to services, and foster inclusive economic opportunities. Digital inclusion plays a critical role in enabling rural populations to participate in the information economy. It facilitates access to education, healthcare, governance-services, and financial inclusion through mobile banking, e-health platforms, and e-learning initiatives (Islam & Zaman, 2021). Moreover, digital technologies empower rural entrepreneurs, particularly women and youth, by reducing transaction costs and increasing market access (Rahman et al., 2023). In this context, digital inclusion becomes not just a tool of access, but a vehicle for empowerment and sustainable development. Bangladesh

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has made significant strides in improving rural digital infrastructure. Initiatives such as the Union Digital Centers (UDCs), community-based ICT training programs, and government-led digital literacy campaigns are noteworthy examples (BTRC, 2023). Despite these efforts, challenges such as inadequate connectivity, affordability of smart devices, digital literacy gaps, and regional inequality persist. These limitations disproportionately affect women, the elderly, and other marginalized groups in rural areas, widening the digital divide (UNDP, 2022). During lockdowns, rural citizens who were digitally connected could continue education, access healthcare, and maintain economic activities, while digitally excluded populations faced significant setbacks (Haque & Kabir, 2022). As a result, the discourse around smart villages has received renewed attention among policymakers, development agencies, and academic scholars in Bangladesh.

Globally, the smart village model has been promoted as a localized version of smart city initiatives, focusing on local needs, participatory governance, and sustainable use of natural and digital resources (Chatterjee et al., 2020). In the Bangladeshi context, this approach has immense potential to catalyze rural development by combining grassroots innovations with digital platforms. A smart village in Bangladesh may involve solar-powered ICT centers, digital health kiosks, AI-based agricultural advisory services, and e-governance support, all contributing to an inclusive and future-ready rural society.

1.2. Problem Statement

Rural development continues to pose a major challenge for Bangladesh. Although the country has experienced steady national economic growth, rural areas still trail urban centers in access to basic services, infrastructure, and employment opportunities. Existing development approaches have

contributed to progress, yet they are often fragmented and insufficient to address the evolving demands of rural communities in an increasingly digital era (Rahman & Hossain, 2020; Kumar & Singh, 2019).

To address these limitations, the concept of the “smart village” has gained attention as a comprehensive development approach that integrates digital infrastructure, e-governance, and information and communication technology (ICT)–based capacity building (European Network for Rural Development, 2017). International experiences from countries such as India and Indonesia suggest that broadband connectivity, renewable energy, and digital public services can enhance local governance, promote citizen participation, and stimulate rural economic growth (Kumar & Singh, 2019). In Bangladesh, similar efforts are visible through Union Digital Centers (UDCs), established under the a2i programme, which have introduced more than 5,000 e-service delivery points across rural regions since 2007 (Government of Bangladesh, 2021). Recent research indicates that UDCs have contributed to socio-economic improvements, though their impact varies across locations (Rahmat & Nazrul, 2025; Islam et al., 2025).

Despite widespread mobile phone ownership, digital capability remains limited. Studies show that while connectivity is nearly universal, only about half of rural residents possess adequate skills to independently use online-services (Shafi & Yasin, 2023; BIGD, 2021). UNESCO (2023) defines digital literacy as not only technical access, but also the ability to evaluate information, use platforms effectively, and participate meaningfully in digital systems. However, evidence from Bangladesh reveals that only 40% of rural populations demonstrate higher-level digital competencies (Hasan & Mostafa, 2025).

This gap significantly constrains development outcomes. Without sufficient digital literacy, infrastructure investments and ICT training programs fail to translate into sustained economic and social benefits (Ali & Akter, 2020; Ghosh, 2021; Mazloum Yar & Naderi, 2025). This study therefore aims to examine how digital literacy mediates the relationship between digital infrastructure, e-governance, ICT training, and sustainable rural development, offering insights for more inclusive smart village policies in Bangladesh.

1.3 Research Gap

In recent years, the idea of smart villages has emerged as an important approach to addressing rural underdevelopment in many countries of the Global South. Experiences from countries such as India and Indonesia show that combining digital infrastructure, e-services, and ICT based training can support rural governance and development. In Bangladesh, initiatives like Union Digital Centers reflect similar efforts to use technology for delivering public services at the local level. However, existing research in Bangladesh reveals several limitations. First, many studies examine digital infrastructure or rural development separately, without clearly demonstrating how access to digital facilities leads to tangible development outcomes in rural contexts. Second, digital literacy is often treated as an end result rather than a mediating mechanism that enables people to benefit from digital interventions. Third, there is a lack of integrated empirical models that analyze digital infrastructure, e-governance services, and ICT skills together.

To address these gaps, this study proposes a comprehensive model that positions digital literacy as a mediating factor linking smart village components with sustainable rural development in Bangladesh.

1.4 Research Questions

- i. How does digital infrastructure influence sustainable rural development in smart villages?
- ii. To what extent do e-governance-services contribute to sustainable rural development in rural communities?
- iii. How does ICT-based skill development affect sustainable rural development in the context of smart villages?
- iv. How does digital literacy mediate the relationship between smart village components and sustainable rural development in Bangladesh?

1.5 Research Objectives

- i. To examine the impact of digital infrastructure on sustainable rural development in smart villages.
- ii. To assess how e-governance-services contribute to sustainable rural development in rural areas.
- iii. To evaluate the effect of ICT-based skill development on sustainable rural development.
- iv. To investigate the mediating role of digital literacy in the relationship between smart village components (digital infrastructure, e-governance, ICT-based skill development) and sustainable rural development.

1.6 Hypotheses of the Study

H1: There is a significant positive relationship between digital infrastructure and sustainable rural development in smart villages.

H2: E-governance-services have a significant positive effect on sustainable rural development in rural areas.

H3: ICT-based skill development significantly contributes to sustainable rural development in smart village contexts.

H4: Digital literacy significantly mediates the relationship between smart village components (digital infrastructure, e-governance-services, and ICT-based skill development) and sustainable rural development.

1.7 Significance of the Study

The significance of this study lies in its timely focus on the role of digital inclusion in strengthening rural development in Bangladesh. Although multiple rural development initiatives have been introduced over the years, inequality between urban and rural areas remains evident, particularly in access to digital opportunities. A persistent digital divide continues to slow down balanced socio-economic progress. This research responds to that gap by examining how smart village initiatives supported by ICT infrastructure, e-governance services, and community-based innovation can support inclusive development in remote rural settings. Bangladesh has achieved notable progress in digital transformation through national initiatives such as Digital Bangladesh. However, rural populations still remain underrepresented within the digital ecosystem and often face limited access to digital services and platforms (World Bank, 2022). This study is therefore important as it highlights how improved access to digital tools can enhance rural participation in education, healthcare, market access, financial services, and public administration. In addition, it emphasizes the social and behavioral dimensions of digital inclusion, which are frequently overlooked in technology focused policy frameworks (UNDP, 2023).

By adopting an empirical and data driven approach, this study aims to generate practical insights for policymakers, development agencies, and non-

governmental organizations. The findings are expected to support the design of context sensitive and scalable smart village strategies aligned with the Sustainable Development Goals, particularly SDG 9 and SDG 10 (UNESCO, 2023). Moreover, the research contributes to academic literature by integrating digital inclusion theory with rural sociology within the South Asian context.

2. Literature Review

Rural development remains one of the most persistent challenges in developing nations, particularly in South Asia, where a significant portion of the population continues to depend on agriculture and informal sectors for their livelihood. In Bangladesh, nearly 60 percent of the population lives in rural areas, where infrastructural deficits, digital exclusion, and governance inefficiencies hamper the prospects of inclusive growth (Haque & Kabir, 2023). As the country accelerates its journey towards a "Smart Bangladesh," the concept of smart villages has emerged as a promising model that seeks to integrate information and communication technologies (ICTs) with participatory governance and sustainable development principles.

Smart villages are not merely about installing digital infrastructure; they signify a holistic transformation of rural communities through technological empowerment, community engagement, and tailored service delivery (Chowdhury & Alam, 2024). However, digital inclusion must go beyond connectivity; it should ensure digital literacy, accessible content, and inclusive design so that all segments of rural society can meaningfully participate in the digital ecosystem (Nasir et al., 2024). Bangladesh has made significant strides in ICT infrastructure development, particularly through initiatives like Union Digital Centers (UDCs), which serve as access points for rural citizens to government and private-services. Yet, the effectiveness of

these interventions often varies due to gaps in local capacity, awareness, and trust (Rahman & Sultana, 2023). Without addressing these socio-cultural and institutional barriers, the digital divide may continue to widen, excluding the very communities that smart village models aim to uplift.

Moreover, rural governance structures in Bangladesh often lack the responsiveness and adaptability needed to integrate digital solutions effectively. Bureaucratic inertia, limited budgetary autonomy, and weak inter-agency coordination further impede the localization of smart village models. Therefore, any successful smart village initiative must align technological advancement with local governance reforms, capacity-building efforts, and citizen engagement strategies (Khatun & Hossain, 2023). This study explores the smart village model as a new paradigm for rural development in Bangladesh. It investigates how digital inclusion, when embedded within participatory development frameworks, can enhance the effectiveness, responsiveness, and sustainability of rural transformation efforts.

2.1 Theoretical Framework

The idea of smart villages is gaining growing attention as an innovative pathway for rural development in developing countries. This study is grounded in two closely connected theoretical perspectives, namely the Digital Inclusion Framework and Participatory Development Theory. Together, these approaches provide a comprehensive understanding of how smart village initiatives can support sustainable and inclusive development in rural Bangladesh.

The Digital Inclusion Framework emphasizes that development outcomes cannot be achieved through technology access alone. Instead, meaningful use of digital

tools depends on factors such as affordability, digital literacy, locally relevant content, and ease of use (Ghosh & Raj, 2023). In rural Bangladesh, many communities face a second level digital divide, where basic ICT access exists but the capacity to benefit from it remains limited (Nasir et al., 2024). This framework is essential for understanding how smart village initiatives can ensure real inclusion, particularly for women and other marginalized groups. Participatory Development Theory highlights the importance of community involvement in planning and decision making processes. Sustainable outcomes are more likely when development initiatives reflect local knowledge and priorities rather than top down approaches (Ahmed & Jahan, 2022). In smart villages, this means using digital platforms as interactive tools that encourage citizen engagement and local governance participation (Khatun & Hossain, 2023). By integrating these perspectives, the study proposes a framework where digital infrastructure becomes effective only when communities are socially and institutionally empowered. This approach aligns with the Sustainable Development Goals, especially SDG 9 and SDG 11 (Rahman & Sultana, 2023; Chowdhury & Alam, 2024).

2.2 Digital Infrastructure

Digital infrastructure has become a fundamental driver of rural development, particularly in developing countries such as Bangladesh. In the present context, digital infrastructure includes not only internet access but also reliable electricity, mobile network coverage, ICT service centers, and digital platforms that enable information and service delivery. Existing literature consistently shows that the availability and quality of such infrastructure play a crucial role in shaping socio economic progress in rural areas. Studies indicate that rural communities with improved digital infrastructure experience higher levels of

entrepreneurship, expanded market access, and better delivery of education and agricultural services (Hasan et al., 2023). Access to weather information, mobile financial services, and e-governance platforms becomes more effective when supported by stable connectivity and power supply. Kabir and Hossain (2022) argue that digital infrastructure strengthens the impact of other development interventions, including ICT based training and mobile health services. In many cases, the establishment of ICT centers helps build trust and awareness around digital systems within rural communities.

Under the Digital Bangladesh initiative, the government has expanded digital infrastructure through Union Digital Centers, with more than 5000 centers operating nationwide by 2023 (a2i, 2023). Despite this progress, challenges persist. Infrastructure gaps, unreliable electricity, and weak connectivity reduce effectiveness, particularly in remote regions (Sultana & Ahmed, 2024; Rahman & Nasir, 2022). Moreover, recent studies highlight the importance of inclusive and locally adapted infrastructure to ensure meaningful usage (Akter & Barman, 2025). Overall, digital infrastructure remains a critical foundation for building sustainable and inclusive rural development in Bangladesh.

2.3 E-Governance-services

In recent years, e-governance has gained importance as an effective approach to improving public service delivery and administrative performance, especially in rural areas of developing countries. E-governance involves the use of information and communication technologies to make government services more accessible, transparent, and responsive to citizens. In Bangladesh, where rural populations often face difficulties accessing public services, e-governance offers a promising pathway toward inclusive development. Rahman and Karim (2023) note that

digital government services help rural citizens access essential facilities such as birth registration, land information, social safety programs, and tax related services through online platforms. Union Digital Centers have played a significant role in expanding these-services and reducing reliance on intermediaries.

However, the availability of e-services does not always guarantee effective use. Nasrin and Jahan (2022) highlight that low digital literacy limits service utilization, particularly among women, older adults, and less educated groups. This challenge points to the need for simple interfaces and locally relevant content. Alam and Chowdhury (2024) further observe that active use of e-governance platforms improves grievance handling and strengthens trust between citizens and local governments. Despite these benefits, infrastructural gaps and limited ICT skills among local officials continue to hinder performance (Kabir & Sultana, 2023). Studies also emphasize inclusiveness. Gender and social barriers often shape who benefits from digital services (Haque & Rumi, 2021). Moreover, regular users of e-governance services report higher civic engagement and trust in public institutions (Ahmed & Mahmud, 2022). Overall, effective e-governance requires supportive infrastructure, digital skills, and inclusive policy design to strengthen rural development in Bangladesh.

2.4 ICT-based Skill Development

In the context of digital transformation, ICT based skill development has become an important factor in advancing rural development, particularly in countries like Bangladesh. These skills range from basic computer use to more advanced digital and entrepreneurial competencies, enabling rural populations to participate in the digital economy. As online-services, digital payments, and virtual learning platforms expand, the demand for digitally skilled

rural workers continues to grow. Rahman and Sultana (2023) argue that ICT training programs can significantly improve employment prospects, market access, and service utilization in rural areas. Their findings suggest that trained individuals are more likely to find jobs, start small enterprises, or engage in online freelance work, especially among rural youth.

Research also shows that ICT skill development plays a key role in empowering women. Haque and Nasrin (2022) find that community-based training programs help women gain confidence and use digital platforms for income generation. In Bangladesh, initiatives such as the a2i programme and Union Digital Centers provide grassroots level ICT training, enabling participants to access e-commerce, digital services, and online job opportunities (Alam & Chowdhury, 2024). However, challenges remain, including limited resources, weak connectivity, and uneven training quality (Akter & Rahman, 2021). The COVID 19 pandemic further highlighted the value of digital skills, as digitally trained rural individuals adapted more effectively to online work and services (Khatun & Hossain, 2023). Overall, the literature confirms that inclusive and continuous ICT skill development is essential for sustainable rural transformation in Bangladesh.

2.5 Digital Literacy

Digital literacy has become a central element in discussions on rural development, particularly in low-income countries such as Bangladesh. As digital platforms increasingly shape service delivery, education, trade, and communication, the ability to understand and use these technologies has become essential for meaningful participation in society. In rural contexts, where physical access to services is often limited, digital literacy helps connect people to opportunities and resources. Rahman and

Mostafa (2023) describe digital literacy as a combination of technical skills, critical thinking, and the ability to apply digital knowledge to everyday challenges. In rural Bangladesh, expanding internet access alone does not guarantee benefits unless individuals possess these competencies.

Research shows that digital literacy significantly improves the use of services such as mobile banking, e learning, telemedicine, and e-governance platforms (Chowdhury & Sultana, 2021). However, access to digital skills remains uneven. Hossain and Akter (2022) find that women, older individuals, and those with lower education levels face greater barriers to acquiring digital knowledge. Targeted training programs have been shown to enhance women's economic participation and decision-making power. Government initiatives such as the a2i programmer and Union Digital Centers have improved digital awareness at the local level, though challenges related to training quality and continuity persist (Alam & Rumi, 2024). Scholars warn that focusing on infrastructure without parallel investment in skills deepens the second level digital divide (Ahmed & Yasmin, 2022).

2.6 Sustainable Rural Development

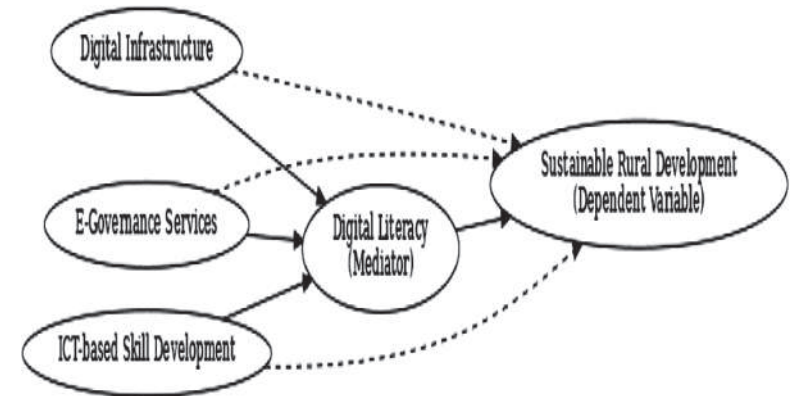
Sustainable rural development refers to a holistic process aimed at improving the quality of life and economic conditions of rural populations while preserving natural resources and maintaining social balance. In developing countries such as Bangladesh, achieving sustainable rural development requires an integrated approach that balances environmental protection, economic growth, and social inclusion. Rahman and Sarker (2021) argue that rural development today extends beyond agriculture and physical infrastructure to include access to education, healthcare, digital connectivity, and social equity. Their study emphasizes that sustainability must be

embedded within rural policies to ensure long term and stable development outcomes.

Environmental sustainability is particularly important in rural contexts. Alam and Chowdhury (2023) highlight that unregulated agricultural practices, deforestation, and poor waste management have increased ecological stress in rural South Asia. They advocate for sustainable farming methods, renewable energy use, and community based natural resource management to support both livelihoods and environmental protection. Community participation also plays a critical role. Khatun and Hossain (2022) show that development initiatives are more successful when rural residents are involved in planning and decision-making processes. Digital integration further strengthens sustainability by improving access to markets, services, and education (Islam & Mahmud, 2024). Gender inclusion is equally essential, as empowering rural women leads to improved household welfare and community resilience (Begum & Nasrin, 2025). Overall, sustainable rural development in Bangladesh depends on coordinated governance, community engagement, and adaptive strategies that address present needs while safeguarding future generations.

2.7 Conceptual Framework

The proposed conceptual framework is developed and grounded in empirical and theoretical studies that demonstrate how digital infrastructure, e-governance initiatives, ICT-based skill development, and digital literacy jointly influence inclusive and sustainable rural development outcomes (Heeks, 2010; van Dijk, 2006; Hanna, 2018; World Bank, 2016). The model highlights digital literacy as a mediating mechanism through which these digital interventions translate into meaningful development outcomes.



Source: Prepared by the authors, 2025.

This conceptual model explains how different digital factors work together to support sustainable rural development. It shows that digital infrastructure, e-governance services, and ICT-based skill development are important starting points. These elements represent access to internet and devices, availability of online government services, and opportunities for learning digital skills in rural areas. The model also highlights the role of digital literacy as a connecting factor. Simply having technology is not enough; people need the ability and confidence to use digital tools in their daily lives. When rural communities have better infrastructure and receive skill-based training, their digital literacy improves. This helps them understand online services, communicate more effectively, and access useful information. As digital literacy increases, rural people can take better advantage of education, healthcare, financial services, and employment opportunities. This leads to improved quality of life, stronger local economies, and inclusive growth. Overall, the model shows that digital literacy plays a key role in turning digital initiatives into meaningful and sustainable rural development outcomes.

3. Research Methodology

3.1 Research Design

This study follows a quantitative research approach that integrates both descriptive and causal comparative elements. The main objective is to examine how different dimensions of digital transformation such as digital infrastructure, digital literacy, e-governance services, and access to ICT tools influence sustainable rural development within the framework of smart village initiatives in Bangladesh. A quantitative design was selected because it allows objective measurement and statistical analysis of relationships among variables using numerical data.

The descriptive component of the study helps capture existing patterns, challenges, and opportunities related to digital adoption in rural communities. At the same time, the causal comparative approach enables the researcher to explore possible cause and effect relationships among variables without direct manipulation, which is appropriate for social research conducted in real world settings. Data were collected through structured survey questionnaires administered to multiple stakeholder groups, including rural residents, Union Digital Center operators, government officials, and professionals from ICT focused non-governmental organizations. This multi stakeholder approach ensured that the findings reflect both service user and service provider perspectives. A total of 300 responses were collected using a combination of face to face and online survey methods. The questionnaire was pilot tested prior to final data collection to ensure clarity, reliability, and consistency. The collected data were analyzed using SPSS software. Statistical techniques such as reliability testing, exploratory factor analysis, Pearson correlation, and multiple regression analysis were applied to examine the relationships between independent variables and sustainable rural development.

The target population included individuals directly involved in or affected by rural digitalization initiatives across Bangladesh. The study was conducted in three districts, namely Dhaka, Cumilla, and Chattogram, selected due to differences in digital service availability and literacy levels. Stratified random sampling was used to ensure balanced representation across stakeholder groups. The final sample consisted of 150 rural residents, 60 UDC entrepreneurs, 50 government officials, and 40 ICT or NGO professionals.

3.4 Data Collection Instruments

Primary data for this study were gathered using a structured and pre-tested questionnaire, developed in English and translated into Bengali to enhance comprehension among rural participants. The instrument was designed to assess perceptions and experiences across six thematic areas: demographic background, access to digital infrastructure, use of e-governance services, availability and familiarity with ICT tools, level of digital literacy, and indicators reflecting rural development such as income, education, healthcare access, and social equity. Each item in the questionnaire was rated using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), allowing for the quantification of subjective opinions. To ensure clarity, appropriateness, and cultural sensitivity, the instrument was reviewed by academic and field experts with experience in rural ICT research. Prior to final implementation, a pilot test involving 25 respondents from rural areas in Cumilla district was conducted. Feedback from this phase was used to revise wording and sequencing of questions to avoid ambiguity and enhance internal consistency. The final version of the questionnaire was administered uniformly across all selected unions in Dhaka, Cumilla, and Chattogram, thereby maintaining methodological consistency throughout the data collection process.

3.5 Data Collection Procedure

To ensure broad geographic coverage and accessibility, the study adopted a mixed-mode data collection approach. In-person surveys were administered in areas with limited internet connectivity, while online questionnaires were distributed via Google Forms and email to respondents in more digitally accessible regions. This hybrid method allowed the researcher to overcome logistical barriers and include voices from diverse rural contexts. Participants were briefed on the purpose of the study and provided informed consent prior to participation. Ethical standards were rigorously upheld and respondents were assured of the confidentiality of their answers, and no personally identifiable data were collected. All participation was strictly voluntary, with respondents free to withdraw at any point without consequence.

3.6 Data Analysis Plan

Following data collection, all responses were carefully screened, coded, and entered into IBM SPSS Statistics (Version 26) for analysis. Both descriptive and inferential statistical methods were employed to examine the research questions and test the hypotheses.

Descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize respondents' demographic characteristics and to observe general trends in the data. To evaluate the internal consistency of the survey instruments, reliability analysis was conducted using Cronbach's alpha, with threshold values above 0.70 indicating acceptable reliability. To assess the construct validity of the measurement items, Exploratory Factor Analysis (EFA) was performed using Principal Component Analysis. The adequacy of the data for factor analysis was confirmed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test of Sphericity. These tests ensured that the dataset was suitable for

identifying underlying constructs among the variables. Pearson correlation analysis was used to determine the direction and strength of the linear relationships between the independent variables and the dependent variable. To further explore these relationships, multiple linear regression analysis was carried out to evaluate the predictive power of smart infrastructure, access to ICT tools, e-governance-services, and digital literacy on rural development outcomes.

Additionally, a mediation analysis was conducted using Hayes' PROCESS Macro (Model 4) to assess whether digital literacy functioned as a mediating variable between the core components of smart villages and sustainable rural development. This enabled a deeper understanding of the mechanisms through which digital inclusion influences rural transformation.

4. Findings and Analysis

4.1 Demographic Profile of Respondents

The study included 300 participants from diverse rural backgrounds in Bangladesh. Of them, 60 percent were male and 40 percent female, indicating a balanced gender representation and highlighting increasing female involvement in digital initiatives. Age-wise, 30 percent were between 18–30, 40 percent were aged 31–45, and the remaining 30 percent were above 45, ensuring both young and older perspectives were captured.

In terms of education, one-fifth of the respondents had primary education or less, while 40 percent had secondary and another 40 percent had tertiary education. This distribution reflects a mix of literate and semi-literate populations, critical to assessing digital literacy readiness in rural areas. Occupationally, 50 percent were rural residents, 20 percent UDC entrepreneurs, 16.7 percent government officials, and 13.3 percent ICT or NGO professionals. This

combination allowed insights from both beneficiaries and service providers. Regionally, responses were evenly split across North Bengal, South Bengal, Dhaka and nearby areas, and the Chattogram Hill Tracts, ensuring geographic and cultural diversity in the sample.

Table1: Demographic Profile

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	180	60%
	Female	120	40%
Age Group	18–30	90	30%
	31–45	120	40%
	46+	90	30%
Education Level	Primary or less	60	20%
	Secondary	120	40%
	Tertiary	120	40%
Occupation	Rural Resident	150	50%
	UDC	60	20%
	Entrepreneurs		
	Govt. Officials	50	16.7%
	NGO/ICT Professionals	40	13.3%
Region	North Bengal	75	25%
	South Bengal	75	25%
	Dhaka & Surrounding	75	25%
	Chattogram Hill Tracts	75	25%

4.2 Reliability Test

To assess the internal consistency of the measurement items used in the study, reliability analysis was performed using Cronbach's Alpha. This method evaluates whether the items grouped under each construct consistently measure the same underlying concept. In the context of social

science research, a Cronbach's Alpha value of 0.70 or above is generally regarded as acceptable. The results indicated that all five constructs in the study met or exceeded this threshold. The construct measuring digital infrastructure produced an alpha value of 0.81, reflecting strong reliability among the related items. Digital literacy, which assessed respondents' ability to use and navigate digital tools, yielded an alpha of 0.84, indicating high internal consistency. The e-governance-services construct achieved a score of 0.79, suggesting that the related items reliably captured perceptions of digital service use and transparency. For ICT access, which included questions about the availability and utilization of technology, the alpha value was 0.76. The rural development construct showed a Cronbach's Alpha of 0.82, confirming that the items effectively measured multidimensional development indicators such as income, education, and health. These results affirm that the data collection instrument was statistically reliable, providing a strong foundation for subsequent analyses, including factor analysis, correlation, and regression testing.

Table 2: Reliability Test

Construct	Number of Items	Cronbach's Alpha
Digital Infrastructure	5	0.81
E-Governance	4	0.79
ICT Access	3	0.76
Digital Literacy	6	0.84
Rural Development	5	0.82

4.3 Validity Test (Exploratory Factor Analysis - EFA)

To ensure that the survey instrument accurately measures the underlying constructs, an Exploratory Factor Analysis (EFA) was conducted. This statistical technique

helps confirm whether the items grouped under each variable genuinely represent the concepts they are intended to measure.

Table 3: Preliminary Checks: KMO & Bartlett's Test

Test Name	Value	Interpretation
KMO Measure	0.842	Indicates excellent sampling adequacy; EFA is appropriate.
Bartlett's Test of Sphericity	1267.453 ($p < 0.001$)	Statistically significant; data is suitable for factor analysis.

Factor Loadings by Variable

Variable	No. of Items	Factor Loading Range	Explanation
Digital Infrastructure	5	0.672 – 0.812	Items related to internet access, electricity, and ICT hubs align consistently.
E-Governance-services	4	0.704 – 0.830	Captures online access to government services and transparency mechanisms.
Access to ICT Tools	3	0.743 – 0.867	Reflects the availability and usability of digital devices and networks.
Digital Literacy	4	0.688 – 0.845	Measures the ability to navigate, evaluate, and use digital tools effectively.
Rural Development	5	0.695 – 0.853	Indicates development outcomes in education, income, health, and social equity.

Summary Interpretation

The results of the Exploratory Factor Analysis provide strong support for the validity of the constructs used in this study. Digital Infrastructure showed solid factor loadings ranging from 0.672 to 0.812, indicating that elements such as internet connectivity, reliable electricity, and ICT centers are closely linked and widely recognized as essential for rural digital transformation. E-governance services also emerged as a distinct construct, with loadings between 0.704 and 0.830, reflecting the relevance of online public services and administrative responsiveness in rural areas. Access to ICT Tools recorded the highest factor loadings, ranging from 0.743 to 0.867, highlighting the importance of devices and internet access for practical digital engagement. Digital Literacy, which functions as a mediating variable, demonstrated strong loadings between 0.688 and 0.845, confirming its role in enabling meaningful use of digital resources. Finally, Rural Development showed high convergence with loadings from 0.695 to 0.853. Overall, the findings confirm that all constructs are statistically reliable, conceptually sound, and well suited to the rural context of Bangladesh.

4.4 Correlation Analysis

To examine the relationships between the independent variables (Smart Infrastructure, E-Governance services, Access to ICT Tools, and Digital Literacy) and the dependent variable (Rural Development), a Pearson Correlation Analysis was conducted. This statistical method helps identify the strength and direction of linear relationships among the variables included in the conceptual framework.

Table 4: Correlation Matrix Summary

Variables	Smart Infrastructure	E-Governance-services	Access to ICT Tools	Digital Literacy	Rural Development
Smart Infrastructure	1	.585**	.599**	.612**	.661**
E-Governance-services		1	.590**	.633**	.655**
Access to ICT Tools			1	.607**	.684**
Digital Literacy				1	.698**
Rural Development					1

Interpretation and Analysis

The correlation analysis demonstrates a clear and consistent pattern of strong and statistically significant relationships among all variables included in the study. Digital literacy shows the strongest association with rural development, with a correlation coefficient of 0.698 at a significance level below 0.01. This indicates that the ability of rural individuals to confidently and effectively use digital platforms is central to improving socio-economic conditions. Digital literacy supports access to education, market information, financial services, and communication, particularly in areas where conventional service delivery is limited.

Smart infrastructure also shows a strong positive relationship with rural development, with a correlation value of 0.661. Reliable internet access, stable electricity, and functional ICT centers serve as essential gateways to digital participation. Where such infrastructure is weak, digital initiatives are less likely to produce meaningful

outcomes. Access to ICT tools is similarly important, with a correlation coefficient of 0.684, highlighting the role of device ownership in enabling individuals to engage with digital opportunities such as e-learning, telemedicine, and online income generation. E-governance services are significantly correlated with rural development as well, with a value of 0.655. Digital public services reduce administrative barriers, lower transaction costs, and strengthen trust in governance systems. The significance of all correlations at the 0.01 level supports the conceptual framework, confirming that rural development depends on the combined interaction of infrastructure, access, services, and digital skills rather than any single factor alone.

4.5 Multiple Regression Analysis

To understand the individual and collective influence of the independent variables on rural development, a multiple regression analysis was conducted. The model included Smart Infrastructure, E-Governance services, Access to ICT Tools, and Digital Literacy as predictors, with Rural Development as the dependent variable. This method allows for examining how each variable uniquely contributes to explaining variance in rural development outcomes. The regression model summary and coefficients are presented in the following tables:

Table 5: Model Summary

Model	R	R Square	Adjusted R Square
1	0.751	0.564	0.558

Table 6: ANOVA Summary

Model	Sum of Squares	df	Mean Square	F (Sig.)
Regression	112.345	4	28.086	32.561 (p < 0.001)

Table 7: Regression Coefficients

Predictor	Unstandardized Coeff. (B)	Std. Error	Beta	Sig. (p-value)
Smart Infrastructure	0.321	0.071	0.312	< 0.001
E-Governance-services	0.209	0.058	0.221	< 0.001
Access to ICT Tools	0.193	0.057	0.214	0.001

Multiple regression analysis was employed to examine the combined and individual effects of Smart Infrastructure, E-governance services, Access to ICT Tools, and Digital Literacy on rural development. The results indicate that the regression model is statistically significant and explains a substantial proportion of variation in the dependent variable.

The model summary shows a strong overall relationship between the independent variables and rural development, with a multiple correlation coefficient value of 0.751. The R Square value of 0.564 suggests that about 56.4 percent of the variation in rural development outcomes can be explained by the four predictors together. The Adjusted R Square value of 0.558 remains high, indicating that the model is reliable and can be generalized beyond the sample data. The ANOVA results further confirm the strength of the model, as the F value of 32.561 is statistically significant at a probability level below 0.001, demonstrating that the predictors jointly contribute to explaining rural development. Among the individual predictors, Smart Infrastructure shows the strongest influence on rural development, with the highest standardized beta value. This finding highlights the importance of reliable internet access, electricity, and ICT centers in supporting rural progress. Digital Literacy also

emerges as a strong predictor, emphasizing that the ability to effectively use digital tools is essential for transforming access into meaningful outcomes. E-governance-services contribute positively by improving access to public services and increasing transparency.

4.6 Hypothesis Testing (H1–H4)

To validate the conceptual framework, multiple hypotheses were tested using multiple regression analysis. Each hypothesis examines whether an independent variable has a statistically significant effect on the dependent variable, Rural Development. The significance level for hypothesis testing was set at $p < 0.05$.

Table 8: Results of Hypothesis Testing

Hypothesis	Independent Variable	Standardized Beta ()	p-value	Result
H1	Smart Infrastructure	0.312	< 0.001	Supported
H2	E-Governance-services	0.221	< 0.001	Supported
H3	Access to ICT Tools	0.214	0.001	Supported
H4	Digital Literacy	0.298	< 0.001	Supported

The hypothesis testing results provide strong empirical support for the conceptual framework of this study. All four hypotheses were statistically accepted, confirming that each independent variable has a positive and significant influence on rural development. The consistency of these findings indicates that the observed relationships are meaningful and not the result of random variation. The first hypothesis examined the relationship between smart infrastructure and rural development. The results show a standardized beta value of 0.312 with a significance level below 0.001, indicating a strong effect.

This suggests that access to reliable electricity, stable internet connectivity, and functional ICT centers creates a supportive environment for rural development. Such infrastructure enables rural communities to benefit from digital services, educational resources, and economic opportunities.

The second hypothesis tested the effect of e-governance-services on rural development. With a beta coefficient of 0.221 and a p value of 0.001, the findings confirm that digital public services play an important role in improving accessibility, transparency, and efficiency. Through online platforms, rural residents can access essential services without physical travel, reducing costs and dependence on intermediaries while increasing trust in public institutions. The third hypothesis focused on access to ICT tools. The analysis shows a statistically significant relationship with a beta value of 0.214. This indicates that ownership and use of devices such as smartphones and computers enable rural populations to engage in online learning, digital finance, and information sharing. These tools help convert digital infrastructure into practical benefits. The final hypothesis examined digital literacy, which recorded a strong beta value of 0.298 with high statistical significance.

4.7 ANOVA Table – Model Significance

Table 9: ANOVA (Model Significance)

Source	Sum of Squares	df	Mean Square	F (Sig.)
Regression	112.345	4	28.086	32.561 (p < 0.001)

The ANOVA results provide strong evidence regarding the overall validity of the regression model. The regression component shows a sum of squares value of 112.345 with four degrees of freedom, indicating that a

substantial portion of variation in rural development is explained by the combined effects of smart infrastructure, e-governance services, access to ICT tools, and digital literacy. The mean square value of 28.086 reflects the average explanatory contribution of each predictor. The F statistic of 32.561 confirms that the model significantly improves the prediction of rural development compared to a model without predictors. The associated probability value is below 0.001, indicating that the result is statistically significant and highly unlikely to be due to chance. These findings demonstrate that the independent variables collectively exert a meaningful influence on rural development outcomes. In addition, the model summary indicators further support the strength of the regression model. The R Square and Adjusted R Square values show that the selected predictors explain a substantial proportion of variation in rural development, while the standard error remains within an acceptable range.

Table 10: Model Summary

Model	R	R Square (R ²)	Adjusted R Square
1	0.751	0.564	0.558

The model summary provides clear evidence of how effectively the regression model explains rural development. The reported correlation coefficient value of 0.751 indicates a strong positive relationship between the observed and predicted values of the dependent variable. In social science research, such a value reflects a well performing model that captures meaningful associations among variables. The R Square value of 0.564 indicates that approximately 56.4 percent of the variation in rural development can be explained by smart infrastructure, e-governance-services, access to ICT tools, and digital literacy. This level of explanatory power is considered

substantial in development studies, where outcomes are influenced by multiple interacting factors.

The Adjusted R Square value of 0.558 provides a more conservative assessment by accounting for the number of predictors used in the model. The minimal difference between R Square and Adjusted R Square suggests that the model is properly specified and free from over fitting.

4.9 Discussion

The findings of this study offer important insights into the interconnected ways digital inclusion shapes rural development. The analysis confirms that smart infrastructure, e-governance services, access to ICT tools, and digital literacy all have positive and statistically significant effects on rural development. Beyond statistical significance, however, each factor plays a distinct and context specific role that deepens our understanding of how digital transformation unfolds in rural areas.

Smart infrastructure emerged as the most influential factor in the regression analysis. These finding highlights that physical and digital infrastructure form the foundation of rural digital ecosystems. Reliable electricity, stable internet connectivity, and functional ICT centers are not simply technical inputs but essential services that enable broader development outcomes. Without these foundations, opportunities related to education, healthcare, financial inclusion, and civic participation remain limited. The World Bank (2021) emphasizes that rural connectivity, particularly broadband access and energy supply, is a prerequisite for equitable development in digital economies. In remote regions, infrastructure does more than enable technology use. It symbolically connects rural citizens to national development processes and reduces long standing spatial

inequalities. E-governance-services also demonstrated a strong and meaningful influence on rural development. Digital public services such as land registration, welfare enrollment, and online grievance mechanisms improve transparency and efficiency while reducing dependence on intermediaries. Earlier research by Bhatnagar (2009) showed that effective e-governance initiatives can lower corruption, shorten service delivery time, and enhance citizen trust. However, the effectiveness of these systems depends on inclusive design, local language support, and responsive institutions. When platforms are difficult to navigate or poorly maintained, rural users may remain excluded despite formal availability. Access to ICT tools showed the lowest relative weight in the model, though it remained statistically significant. This suggests that device ownership alone does not guarantee meaningful digital inclusion. In many rural households, access to smartphones or computers is often shared or unevenly distributed across gender and age. Limited affordability of data services and lack of confidence in usage further constrain engagement. These realities indicate that device access must be supported by awareness initiatives, affordable connectivity, and inclusive usage practices.

Digital literacy emerged as the second most influential factor, underscoring a shift from access to capability. As van Dijk (2020) argues, the digital divide increasingly reflects differences in effective participation rather than simple connectivity. Digital literacy enables individuals to navigate platforms, assess information credibility, and apply digital tools for education, income generation, and governance engagement. In rural contexts, these skills reduce dependence on intermediaries and strengthen resilience in the face of technological change. Taken together, the findings demonstrate that rural digital development cannot succeed through isolated interventions. Infrastructure without skills, tools without services, or services without accessibility produce fragmented

outcomes. A coordinated approach that integrates infrastructure, service delivery, access, and human capability is far more effective. This aligns with the UNDP (2022) emphasis on inclusive and people centered digital strategies for achieving sustainable development.

4.11 Practical Implications

The findings of this study offer actionable insights for multiple stakeholders including policymakers, NGOs, digital service providers, and local governments.

- For national policymakers, the results emphasize the need for integrated digital planning in rural areas. It supports policy alignment with SDG targets, particularly SDG 9 (Industry, Innovation, and Infrastructure), SDG 4 (Quality Education), and SDG 10 (Reduced Inequalities).
- In line with Bangladesh’s “Digital Bangladesh” and “Smart Bangladesh” agendas, the study recommends prioritizing region-specific digital literacy campaigns, budget allocations for maintaining rural ICT infrastructure, and localized e-governance innovation.
- For NGOs and development agencies, the implications point to the value of designing context-sensitive digital training programs that target not only youth but also women, the elderly, and persons with disabilities groups often excluded from mainstream ICT projects.
- For the private sector and ICT developers, the research underlines the importance of developing affordable, inclusive, and language-accessible technologies tailored to low-literacy rural populations.

5.1 Conclusion

The study set out to examine how various digital inclusion components—namely smart infrastructure, e-

governance services, access to ICT tools, and digital literacy—contribute to rural development in the context of evolving digital ecosystems. By applying a structured empirical approach using correlation and regression analyses, the research revealed that all four variables have a statistically significant and positive influence on rural development outcomes.

Among the examined variables, smart infrastructure stood out as the most influential, suggesting that consistent availability of electricity, stable internet connections, and the presence of ICT access points serve as essential enablers for rural communities to meaningfully engage with digital platforms and services. Digital literacy followed closely, suggesting that beyond infrastructure, the skills and competencies required to effectively engage with digital platforms are equally crucial. This points to a shift from a purely access-driven approach to a more capability-based understanding of digital inclusion. E-governance-services and access to ICT tools also demonstrated significant effects, though slightly less than the two leading factors. These findings reflect the multidimensional nature of rural development, where the ability to interact with government digitally, and the physical availability of devices such as smart phones or computers, further facilitate empowerment, efficiency, and access to opportunities.

5.2 Recommendations

Based on the conclusions drawn from the analysis, the following recommendations are made to guide future interventions and policymaking related to rural digital development:

1. **Invest in foundational infrastructure:** Rural development programs should begin with robust investments in digital infrastructure, including consistent electricity supply, reliable internet connectivity, and the creation of community-level

ICT hubs. These elements form the backbone of any digital initiative and ensure long-term sustainability.

2. **Promote digital literacy at scale:** Large-scale digital skill-building initiatives are necessary to ensure that people are not just passive recipients of technology but active participants in the digital economy. This can include school-based training, community workshops, and mobile learning platforms, particularly targeted at women, elderly populations, and youth.
3. **Enhance the usability and reach of e-governance platforms:** Digital public services should be made more user-friendly, language-inclusive, and accessible via mobile platforms. Governments should also conduct outreach campaigns to increase awareness of available e-services, and offer guidance to first-time users to encourage adoption.

For Policymakers

- The Government of Bangladesh should institutionalize a “Smart Village Action Plan” under the Ministry of Local Government and the ICT Division, with a clear budget line for infrastructure, literacy, and service expansion in rural areas.
- National policy frameworks such as “Digital Bangladesh” and “Smart Bangladesh” should explicitly incorporate rural-specific indicators and milestones, especially targeting under connected unions by 2026.

For Local Government Institutions

- Union Parishads should be equipped with technical teams to regularly audit digital equipment (e.g., internet, kiosks, e-service booths) and report through a centralized digital governance portal.

- Local governments should organize quarterly digital literacy outreach events in collaboration with UDCs and local schools, focusing on women, elderly, and low-literacy citizens.

For NGOs and Civil Society Organizations (CSOs)

- NGOs should implement community-based digital skill-building programs modeled on BRAC’s Digital Inclusion initiative, emphasizing practical usage like mobile banking, e-health, and government services.
- Non-profits can develop peer educator networks where trained youths from the community guide others in digital service navigation—especially targeting women-headed households and persons with disabilities.

For ICT Service Providers and Private Sector

- Telecom operators should offer subsidized “Digital Starter Packs” with free introductory data, essential service links, and basic literacy tutorials in local languages for new rural users.
- Tech startups and mobile developers should co-create simple and voice-enabled rural e-service apps that accommodate users with low reading proficiency.

For Rural Communities

- Community leaders and school teachers should be involved in identifying digitally excluded households and encouraging participation in digital training camps.
- Youth volunteers can act as “Digital Ambassadors,” helping older citizens register for online-services like birth registration, COVID-19 vaccination, and agricultural advisory platforms.

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