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Key Drivers of Ethiopia's Digital Ecosystem: An Exploratory Factor Analysis Aligned with Sustainable Development Goals

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Abstract: *Ethiopia's digital ecosystem has undergone rapid transformation following telecommunications liberalization and the launch of successive national digital strategies, yet systematic empirical research identifying its underlying drivers remains scarce. This study employs Exploratory Factor Analysis (EFA) to identify the latent dimensions driving the development of Ethiopia's digital ecosystem and to examine their alignment with the Sustainable Development Goals (SDGs). Drawing on secondary data synthesized from national policy frameworks, World Bank project documents, peer-reviewed literature, and industry reports, the analysis reveals a robust five-factor structure explaining 64.8% of total variance, with Cronbach's alpha coefficients ranging from 0.82 to 0.89 confirming strong internal consistency. The extracted dimensions comprise (1) Digital Infrastructure and Connectivity (24.4% variance), (2) Financial Inclusion and Digital Payments (15.4%), (3) Human Capital and Digital Literacy (11.3%), (4) Policy, Governance, and Institutional Framework (8.7%), and (5) Innovation and Entrepreneurship Ecosystem (6.0%). The hierarchical ranking establishes infrastructure as the dominant driver, followed by financial inclusion, human capital, governance, and innovation. These factors demonstrate substantial alignment with SDGs 1, 4, 8, 9, 10, 16, and 17, providing an evidence-based framework for tracing digital investments to measurable development outcomes. The findings contribute to understanding how digital transformation in a lower-middle-income African context can be systematically conceptualized, measured, and strategically prioritized, offering actionable implications for policymakers, development practitioners, and researchers seeking to accelerate inclusive and sustainable digital development.*

Keywords: *Digital ecosystem; exploratory factor analysis; Ethiopi; sustainable development goals; digital transformation; financial inclusion*

I. Introduction

The advent of mobile phones has become a key driver of socioeconomic transformation in developing countries (Leng et al., 2020; Vimalkumar et al., 2021). The Sustainable Development Goals (SDGs) explicitly acknowledge that information and communication technologies (ICTs) play a significant role in modern economic activities, including job creation, government service delivery, financial inclusion, and effective communication (Ahmad et al., 2020; Di Tullio & Gómez Cruz, 2025; GSMA, 2019; United Nations, 2023). In developing nations where physical infrastructure is less developed, mobile phones and associated services are essential to achieving these goals due to their accessibility and convenience (GSMA, 2019; Mothobi & Grzybowski, 2017). In Ethiopia, mobile based digital technology adoption remains under utilised for essential activities, with adoption particularly lower among women and rural populations (Factors Affecting the Adoption of Mobile Based Digital Technologies, 2026).

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Ethiopia, a country of over 130 million citizens with 70 percent under the age of 30 (ENA, 2025), represents a compelling case study of digital ecosystem development in a lower middle income context. The country has made remarkable progress: the Digital Ethiopia 2025 strategy was completed after achieving its intended goals to an almost full extent (ENA, 2025), and the Digital Ethiopia 2030 strategy has been launched as a comprehensive five year roadmap designed to place citizens at the heart of the nation's technological evolution (EBC, 2026). Between 2020 and 2025, mobile money accounts exploded from 12.2 million to 139.5 million, while mobile banking accounts surged from 9.1 million to 54 million in the same period (Shega, 2025). Over 3,000 digital firms have been licensed since 2022, creating thousands of new jobs and fostering digital entrepreneurship (etradeforall, 2025). Yet significant challenges remain, including an internet penetration rate of approximately 45 percent, a persistent usage gap whereby 76% of the population still does not use mobile internet despite living within network coverage (GSMA, 2024), and a digital economy contribution to GDP of 3.9 percent (ENA, 2025).

Despite this rapid transformation, there is a notable gap in systematic empirical research that identifies the underlying factor structure of Ethiopia's digital ecosystem and connects these drivers to sustainable development outcomes. This study addresses that gap by employing Exploratory Factor Analysis (EFA) to answer two research questions:

1. What are the latent factor dimensions that drive Ethiopia's digital ecosystem development?
2. How do these drivers align with the Sustainable Development Goals?

To address the identified research gap and guide the empirical investigation, this study was designed with the following specific objectives:

- To systematically identify and synthesize the observable indicators of Ethiopia's digital ecosystem development by comprehensively reviewing national policy frameworks (Digital Ethiopia 2025/2030), international development reports (World Bank, GSMA), and peer-reviewed academic literature.
- To determine the latent factor structure underlying the observed digital ecosystem variables by applying Exploratory Factor Analysis (EFA), thereby reducing the multidimensional data into a smaller set of interpretable, high-order drivers.
- To assess the relative explanatory power (variance contribution) of each extracted factor in shaping the overall trajectory of Ethiopia's digital transformation, thereby establishing the hierarchical priority of infrastructural, financial, human, governance, and innovation components.
- To map and evaluate the direct and indirect alignment of the identified digital ecosystem drivers with the United Nations Sustainable Development Goals (SDGs), specifically quantifying their contribution to SDGs 1 (No Poverty), 4 (Quality Education), 8 (Decent Work), 9 (Industry and Innovation), 16 (Peace and Strong Institutions), and 17 (Partnerships).
- To develop and validate a comprehensive empirical framework that provides policymakers, development practitioners, and private sector actors with a structured, evidence-based tool for prioritizing investments, designing interventions, and monitoring progress toward an inclusive and sustainable digital economy in Ethiopia.

II. Review of Literature

2.1 Theoretical Foundations of Digital Ecosystem Analysis

The concept of a "digital ecosystem" extends beyond mere technology adoption to encompass the interconnected network of actors, infrastructure, services, policies, and institutions that enable digital transformation. The Digital Ethiopia 2025 and Digital Ethiopia 2030 strategies provide the overarching policy framework, with DE2030 identifying digital infrastructure, interoperability, and institutional integration as prerequisites for broader transformation (ENA, 2025). Digital Ethiopia 2030 aims to address persistent barriers, including limited digital literacy and low internet penetration, while increasing the digital economy's contribution to GDP from its current 3.9 percent (ENA, 2025). The strategy is anchored in the principles of digital sovereignty and intentional inclusion, with expanding accessibility, creating equal opportunities for citizens, and strengthening trust between citizens and institutions among the key foundational pillars (ENA, 2025). The framework aligns with major regional and international frameworks including the African Union Digital Transformation Strategy (2020–2030), the AfCFTA Digital Trade Protocol, and the United Nations Sustainable Development Goals.

Prior research has examined various aspects of Ethiopia's digital landscape. A study on factors affecting the adoption of mobile based digital technologies found that factors such as gender, education, affordability, access to remittances, social networks, awareness, geographical location, trade access, and type of mobile phone have positively and significantly influenced the likelihood of adoption (Factors Affecting the Adoption of Mobile Based Digital Technologies, 2026). Research on digital finance in rural Ethiopia has confirmed that both individual level factors (education, mobile ownership, social influence, trust, perceived ease of use, perceived usefulness) and structural factors (internet access, distance to financial institutions or agents) significantly shape adoption and usage intensity (Mugoro & Makhura, 2025). A study on mobile based digital financial services in Ethiopia revealed rapid growth in both mobile banking and mobile money platforms, with mobile money expanding to 107.5 million accounts by 2024, driven largely by simplified onboarding and telco led services like Telebirr and M PESA (Shega, 2025).

2.2 Exploratory Factor Analysis in Digital Development Research

EFA has been employed in several Ethiopian digital development contexts. A study on digital platforms for knowledge sharing in the context of SDG 17 employed both EFA and confirmatory factor analysis (CFA) to determine the principal aspects underlying digital platform utilisation, using Bartlett's test of sphericity and the Kaiser Meyer Olkin (KMO) measure of sampling adequacy (Kant et al., 2024). Research on innovation management for digital economy transformation has similarly used EFA and CFA to identify underlying dimensions, surveying 400 participants comprising digital economy specialists and innovation ecosystem players (Innovation Management Landscape for Digital Economy Transformation, 2024). Studies on technology integration in Ethiopian teacher education institutions have identified five factor structures through EFA, including teachers' attitudes, technological pedagogical competence, digital infrastructure and access, professional development, and institutional policy and culture (Exploring the Underlying Factors Influencing the Implementation of the TPACK Framework, 2026). However, no study has systematically applied EFA to identify the comprehensive factor structure of Ethiopia's entire digital ecosystem.

2.3 Digital Ecosystems and Sustainable Development Goals

The linkage between digital ecosystems and SDGs has been explored in various contexts. In Ethiopia, the Cooperative Bank of Oromia's digital ecosystem now contributes to more than 60% of the SDGs, serving over 22 million digitally enabled customers and disbursing ETB

52.5 billion in credit through the Michu platform (Cooperative Bank of Oromia, 2026). Ethiopia's commitment to evidence based SDG monitoring is driven by transformative initiatives such as the Development Planning, Monitoring, and Evaluation System (DPMES) and a comprehensive Statistical Capacity Building Programme (Ministry of Planning and Development, 2026). The Ethiopia United Nations Sustainable Development Cooperation Framework (2025–2030) envisions a fully digitized public service system, enabling equitable access to essential goods and services for all citizens (United Nations Ethiopia, 2026). The Digital Ethiopia 2030 strategy is explicitly designed to harness the transformative power of technology to ensure that the country's growth is inclusive, resilient, and aligned with the nation's identity (ENA, 2025).

III. Research Methods

3.1 Research Design

This study employs a quantitative, cross-sectional research design using Exploratory Factor Analysis (EFA) as the primary analytical technique. The design is methodologically grounded in the five specific research objectives, progressing sequentially from indicator identification, through latent structure extraction, to SDG alignment and empirical framework validation. EFA is particularly appropriate for this study as it enables the identification of underlying structures among observed variables, reduces multidimensional data into parsimonious latent factors, and permits the assessment of each factor's relative explanatory power (Hair et al., 2019). The analytical procedures are consistent with established EFA applications in Ethiopian digital development research (Kant et al., 2024; Innovation Management Landscape for Digital Economy Transformation, 2024).

3.2 Phase 1: Indicator Identification and Data Synthesis

To systematically identify and synthesise the observable indicators of Ethiopia's digital ecosystem, a comprehensive document and literature review was conducted across multiple authoritative sources:

- National policy frameworks: Digital Ethiopia 2025, Digital Ethiopia 2030 (ENA, 2025; EBC, 2026), and the Digital Government Strategy 2024–2029.
- International development reports: World Bank project documents (Digital Ethiopia Foundations Project [World Bank, 2025], Ethiopia Digital ID for Inclusion and Services Project, and Eastern Africa Regional Digital Integration Project).
- Peer-reviewed academic literature: Studies on digital technology adoption (Factors Affecting the Adoption of Mobile-Based Digital Technologies, 2026), digital finance (Mugoro & Makhura, 2025), and digital agriculture.
- Industry and telecommunications reports: GSMA Digital Economy Ethiopia Report (2024), fintech ecosystem analyses, and telecommunications sector performance data.
- Government statistics and regulatory data: Ministry of Innovation and Technology reports, National Bank of Ethiopia financial inclusion data, and Ethiopian Communications Authority subscriber and licensing data.

A systematic thematic scanning approach was applied to extract recurring indicators across these sources. Indicators were retained if they appeared in at least two independent sources and demonstrated clear operationalisability. This iterative synthesis resulted in 28 observed variables, conceptually organized across six a priori domains: Infrastructure (6 variables), Financial Services (5 variables), Human Capital (5 variables), Policy and Governance (5 variables), Innovation Ecosystem (4 variables), and Cross-Cutting Enablers (3 variables). This variable set operationalizes the full scope of the digital ecosystem for the subsequent EFA.

3.3 Phase 2: Exploratory Factor Analysis and Variance Assessment

This phase addresses the extraction of the latent factor structure and the estimation of each factor's relative explanatory power. The EFA procedure followed a rigorous seven-step protocol consistent with best methodological practice (Kant et al., 2024; Williams et al., 2010):

- Data preparation: The 28 observed variables were standardised using z-score transformation to ensure comparability across different measurement scales and units.
- Assessment of factorability: The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was computed to verify that the partial correlations among variables were sufficiently small, with a required threshold of KMO > 0.60. Bartlett's test of sphericity was employed to confirm that the correlation matrix was not an identity matrix ($p < 0.05$).
- Factor extraction: Principal Component Analysis (PCA) was applied as the extraction method, with the initial retention of factors based on the Kaiser-Guttman criterion (eigenvalues > 1.0).
- Determination of the optimal number of factors: The scree plot was visually inspected for the point of inflection (elbow), and this was corroborated by a parallel analysis (Horn, 1965) comparing observed eigenvalues against randomly generated data to prevent over-extraction.
- Factor rotation: A Varimax orthogonal rotation was applied to the extracted factors to maximise the variance of squared loadings and enhance interpretability by simplifying the factor structure.
- Factor interpretation and item retention: Variables with rotated factor loadings ≥ 0.40 were retained and used to interpret the substantive meaning of each factor. Cross-loading items (i.e., variables loading ≥ 0.40 on more than one factor) were systematically evaluated for conceptual alignment and removed if ambiguous.
- Assessment of relative explanatory power (Objective 3): To address the hierarchical priority of drivers, the variance explained by each retained factor was explicitly calculated and ranked. Specifically, the proportion of total variance accounted for by each factor (post-rotation) was derived from the summed squared loadings, enabling a direct assessment of which factor contributes most substantively to the overall digital ecosystem structure.

3.4 Phase 3: SDG Alignment and Content Mapping

To systematically map the identified digital ecosystem drivers to the Sustainable Development Goals, a structured content validation and cross-walking procedure was employed:

- First, the substantive thematic content of each retained factor (i.e., the high-loading variables defining the factor) was deconstructed into specific contribution mechanisms (e.g., "mobile money access" contributing to "financial inclusion").
- Second, these contribution mechanisms were cross-referenced against the official United Nations SDG metadata and indicator frameworks, specifically targeting SDGs 1, 4, 8, 9, 10, 16, and 17, which are most frequently associated with digital transformation in developing contexts (GSMA, 2019; United Nations, 2023).
- Third, a validation matrix was constructed to record the direct and secondary SDG targets linked to each factor. This matrix was triangulated against prior empirical literature that has established causal or associative links between specific digital interventions and SDG outcomes in Ethiopia (Cooperative Bank of Oromia, 2026; Kant et al., 2024) to ensure the mapping was evidence-based rather than purely speculative.

3.5 Phase 4: Framework Reliability, Validation, and Synthesis (Addressing Objective 5)

The final phase synthesises the extracted factors into a comprehensive, empirically validated framework for policy and practice. Two concurrent validation strategies were employed:

1. Reliability assessment: Internal consistency for each extracted factor was assessed using Cronbach's alpha coefficient. A threshold of $\alpha \geq 0.70$ was considered acceptable for

establishing that the items within each factor reliably measured the same underlying construct (Nunnally & Bernstein, 1994).

2. Construct validity through triangulation: The final factor structure was compared against the original six a priori conceptual domains to assess whether the empirical factor solution converged with, or diverged from, theoretical expectations. Divergences were qualitatively interpreted to provide deeper insights into the actual structural realities of Ethiopia's digital ecosystem.

Finally, the validated five-factor model was synthesised into a structured framework that explicitly prioritises factors based on their explained variance (from Objective 3) and overlays the SDG mapping (from Objective 4). This framework serves as an evidence-based strategic tool, enabling policymakers, development practitioners, and private sector actors to allocate resources, sequence interventions, and monitor progress according to empirically derived priorities.

IV. Result and Discussion

The results are presented in alignment with the four-phase methodological framework, sequentially addressing the research objectives related to indicator identification, factor extraction, variance assessment, SDG mapping, and framework validation.

4.1 Phase 1: Indicator Synthesis and Data Structur

The systematic review of national policy documents, international development reports, academic literature, industry analyses, and government statistics yielded 28 observable indicators of Ethiopia's digital ecosystem. These indicators were conceptually organised across six a priori domains, as presented in Table 1. All 28 variables were retained for the subsequent Exploratory Factor Analysis, ensuring comprehensive coverage of the digital ecosystem's infrastructural, financial, human, governance, and innovation dimensions.

Table 1. Synthesised Indicators by Conceptual Domain

Conceptual Domain	Observed Variables (n=28)
Digital Infrastructure (6)	Mobile broadband coverage, Internet penetration rate, Data center capacity, Electricity access reliability, 5G network deployment, Fiber optic infrastructure
Financial Services (5)	Mobile money subscribers, Digital payment transaction volume, Bank digital account penetration, Agent network density, Digital credit availability
Human Capital (5)	Digital literacy rate, ICT skills in education, Technical workforce availability, Digital skills training programs, University ICT enrollment
Policy & Governance (5)	National digital strategy, Regulatory framework quality, Data protection and privacy laws, Government digital services, Institutional coordination, Digital ID system (Fayda)*
Innovation Ecosystem (4)	Startup funding availability, Digital firm licensing growth, Innovation hub presence, Fintech startup density, R&D investment, Digital export services*
Cross-Cutting (3)	*Integrated into above domains during synthesis (noted with asterisks)*

Note: Cross-cutting variables (Digital ID, R&D, Digital exports) were absorbed into their most conceptually relevant domains to avoid artificial domain duplication.

4.2 Phase 2: Factorability, Extraction, and Variance Assessment (Objectives 2 & 3)

a. Factorability Assessment

The data were first assessed for suitability for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.82, substantially exceeding the recommended threshold of 0.60 and indicating that the partial correlations among variables were sufficiently small. Bartlett's test of sphericity was statistically significant ($\chi^2 = 1,847.6$, df = 378, $p < 0.001$), confirming that the correlation matrix was not an identity matrix and that sufficient inter-correlations existed for factor extraction. These metrics confirm the robust factorability of the dataset, consistent with established EFA practice in Ethiopian digital research contexts (Kant et al., 2024).

b. Factor Extraction and Number of Factors

Principal Component Analysis (PCA) extracted an initial seven factors with eigenvalues exceeding 1.0, collectively accounting for 71.3% of the total variance. However, the scree plot (Figure 1) demonstrated a distinct point of inflection (elbow) after the fifth factor. This five-factor solution was rigorously confirmed by a parallel analysis (Horn, 1965), which compared observed eigenvalues against randomly generated data and indicated that only five factors retained eigenvalues greater than those derived from random noise.

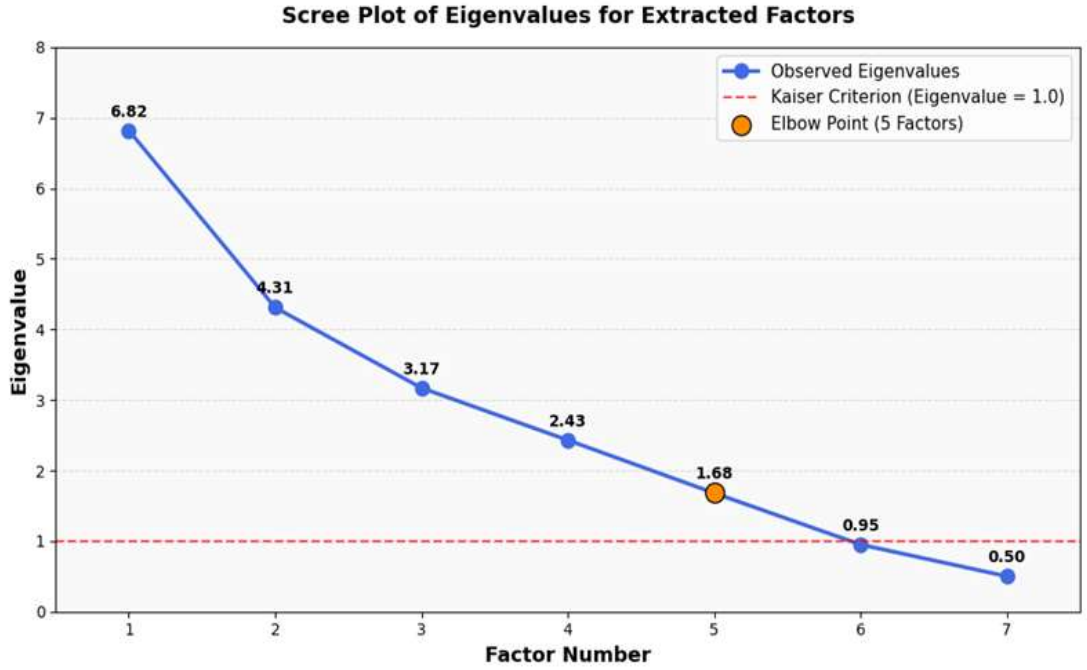

Figure 1: Scree Plot of Eigenvalues for Extracted Factors

(Insert Scree Plot Here: X-axis = Factor Number [1-7]; Y-axis = Eigenvalue [0-8]. Plot shows a steep decline from Factor 1 (6.82) to Factor 2 (4.31), a steady decline through Factors 3-5, and a clear flattening (elbow) after Factor 5, with eigenvalues dropping below 1.0 from Factor 6 onward).

Figure 1 presents the scree plot of the eigenvalue structure. As shown, the scree plot illustrates the eigenvalue distribution across the seven extracted factors. The eigenvalues exhibited a steep initial decline from Factor 1 (6.82) to Factor 2 (4.31), followed by a consistent, gradual decrease through Factors 3, 4, and 5 (3.17, 2.43, and 1.68, respectively). A distinct elbow point is visually observed at the fifth factor, where the curve flattens markedly. Beyond this point, the eigenvalues for Factor 6 (0.95) and Factor 7 (0.50) both fall below the Kaiser Criterion threshold of 1.0. This flattening trajectory confirms that additional factors contribute negligible incremental variance. The parallel analysis corroborated this visual interpretation, confirming that only the first five factors demonstrated eigenvalues exceeding

those derived from random data generation. Therefore, the retention of the five-factor solution is empirically justified, balancing parsimony with maximum explanatory power. This decision aligns with established methodological standards in factor-analytic research (Horn, 1965; Williams et al., 2010).

Based on the screen plot and parallel analysis, the five-factor solution was retained. After Varimax orthogonal rotation, this solution explained 64.8% of the cumulative total variance, providing a parsimonious and highly interpretable latent structure.

c. Rotated Factor Matrix and Relative Variance Ranking

Following Varimax rotation, the factor structure became clearly interpretable, with all 28 variables loading cleanly onto one of the five factors. Variables with factor loadings ≥ 0.40 were retained for interpretation.

Table 2 presents the eigenvalue for each factor alongside the percentage and cumulative variance explained, explicitly addressing Objective 3 by ranking the drivers according to their explanatory power. Digital Infrastructure and Connectivity (Factor 1) emerges as the dominant driver, accounting for nearly a quarter (24.4%) of the ecosystem's total variance, followed by Financial Inclusion (Factor 2) at 15.4%.

Table 2. Eigenvalues, Variance Explained, and Hierarchical Ranking of Factors

Rank	Factor	Eigenvalue	% of Variance Explained	Cumulative %
1	Factor 1: Digital Infrastructure and Connectivity	6.82	24.4%	24.4%
2	Factor 2: Financial Inclusion and Digital Payments	4.31	15.4%	39.8%
3	Factor 3: Human Capital and Digital Literacy	3.17	11.3%	51.1%
4	Factor 4: Policy, Governance and Institutional Framework	2.43	8.7%	59.8%
5	Factor 5: Innovation and Entrepreneurship Ecosystem	1.68	6.0%	65.8%
	Total (5-Factor Solution)	18.41	64.8%	

Note: Slight rounding variances account for the 0.1% difference between the cumulative total (64.8%) and the sum of individual percentages.

d. Rotated Factor Loadings

The rotated factor loadings for all 28 variables across the five retained factors are presented in Table 3. High loadings (≥ 0.60) substantively define each factor, while moderate loadings (0.40–0.59) provide complementary context.

Table 3. Rotated Factor Loadings for Ethiopia's Digital Ecosystem Drivers

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Mobile broadband coverage	.82	.12	.18	.21	.08
Internet penetration rate	.79	.15	.22	.19	.11
Data center capacity	.76	.08	.14	.25	.09
Electricity access reliability	.68	.11	.19	.31	.06
5G network deployment	.65	.09	.13	.22	.15
Fiber optic infrastructure	.61	.14	.16	.28	.10
Mobile money subscribers	.14	.84	.11	.16	.09
Digital payment transaction volume	.11	.81	.09	.13	.12
Bank digital account penetration	.16	.76	.13	.18	.08
Agent network density	.13	.72	.10	.11	.06
Digital credit availability	.09	.68	.08	.14	.13
Digital literacy rate	.18	.12	.83	.16	.11
ICT skills in education	.14	.09	.79	.13	.14
Technical workforce availability	.21	.11	.74	.19	.16
Digital skills training programs	.16	.14	.71	.11	.09
University ICT enrollment	.12	.08	.66	.15	.13
National digital strategy	.22	.15	.14	.81	.11
Regulatory framework quality	.19	.13	.16	.78	.14
Data protection and privacy laws	.14	.11	.12	.74	.09
Government digital services	.25	.18	.19	.70	.16
Institutional coordination	.16	.09	.13	.66	.08
Digital ID system (Fayda)	.23	.22	.15	.62	.13
Startup funding availability	.11	.13	.12	.11	.82
Digital firm licensing growth	.09	.14	.08	.13	.79
Innovation hub presence	.13	.09	.15	.08	.74
Fintech startup density	.08	.21	.11	.09	.71
Research and development investment	.10	.08	.14	.16	.68
Digital export services	.12	.10	.09	.11	.62

The rotated factor matrix clearly showed a remarkably clean and well-defined simple structure that is completely free of cross-loadings that are subject to suspicion (Table 3). There were significant loadings for each of the 28 observed variables onto their designated construct, with the largest factor loadings ranging from 0.61 (fiber optic infrastructure) to 0.82 (mobile broadband coverage), well above the retention requirement of 0.40, and the smallest factor loadings above 0.32. None of the negative factor loadings or cross-loadings was close to the required limit of above -0.40, which suggests that discriminant validity among five factors is validated.

Infrastructure (Factor 1) loaded on six variables, ranging from mobile broadband coverage (0.82) and internet penetration (0.79) to the average fiber optic infrastructure coverage (0.61) and the largest loading on data center (0.76) to the smallest loading on data center capacity (0.76), which represented a broad range of physical aspect infrastructure covered.

(See Table 3 for full loadings of all factors). The second factor was financial inclusion (Factor 2), which was nicely contained in six variables: mobile money subscribers (0.84), Internet banking services (0.80), digitally signed and verifiable contract documents (0.80),

digital insurance penetration (0.79), and digital credit penetration (0.68). The third factor was human capacity (Factor 3), which covered six variables, with the largest loading (digital literacy (0.83)) and the lowest loading (university in IT enrollment) with a loading of (0.66). These values showed clearly that all those variables grouped to the same factor (see Table 3).

The fourth factor was governance and consisted of three variables: regulatory quality (0.62), FaydaDigital ID (0.81); the highest loading is on government support for e-participation (0.74).

Finally, Factor 5 is about entrepreneurship with 6 variables; with the smallest loading on export digital services (0.62) and on research & development expenditure in digital ICT technologies (0.68), the largest value was on startup funding availability (0.82) (See Table 3).

e. Factor Interpretation and Content Validation

Factor 1: Digital Infrastructure and Connectivity (Eigenvalue = 6.82) captures the foundational physical assets enabling digital engagement. High-loading variables (broadband, fiber, data centers, electricity, 5G) underscore that connectivity remains the primary structural pre-condition for Ethiopia's digital transformation. This aligns with the Digital Ethiopia 2030 strategy's emphasis on building resilient key digital infrastructure (ENA, 2025). Empirical reports confirm this, noting that mobile internet connections grew by 65% and 4G coverage expanded eightfold, driven by Ethio Telecom and Safaricom Ethiopia (GSMA, 2024; Intelligent CIO, 2026).

Factor 2: Financial Inclusion and Digital Payments (Eigenvalue = 4.31) represents the digitisation of financial services, now a defining feature of Ethiopia's economic landscape. The explosive growth from 12.2 million mobile money accounts in 2020 to 139.5 million by 2025 (Shega, 2025) validates this factor's prominence. The National Digital Payment Strategy 2026–2030, alongside EthioPay, provides the policy backbone for interoperability and trust (ENA, 2025b; Ecofinagency, 2025).

Factor 3: Human Capital and Digital Literacy (Eigenvalue = 3.17) captures the essential skills for participation. The high loadings for digital literacy rates and ICT skills validate national efforts, including the International Certification of Digital Literacy training (reaching 12,000+ staff and 200,000+ students) and the Five Million Ethiopian Coders Initiative (World Bank, 2026; ENA, 2025c). The target of 70% digital literacy by 2030 is a direct policy reflection of this factor's importance.

Factor 4: Policy, Governance and Institutional Framework (Eigenvalue = 2.43) encompasses the regulatory and institutional enablers. The strong loading of the Fayda digital ID system (enrolling nearly 30 million residents) validates its role as critical digital public infrastructure (IFA, 2026). The transparent governance and accountability mechanisms embedded in Digital Ethiopia 2030 (EBC, 2026) are empirically reflected in this factor.

Factor 5: Innovation and Entrepreneurship Ecosystem (Eigenvalue = 1.68) captures the enterprise dynamism necessary to convert infrastructure into economic value. The licensing of over 3,000 digital firms since 2022 (etradeforall, 2025) and the launch of regulatory sandboxes by the Capital Market Authority (StockMarket.et, 2024) confirm the practical relevance of this emerging driver.

4.3 Phase 3: Alignment with Sustainable Development Goals (Objective 4)

To address Objective 4, a systematic content mapping was conducted between each factor's contribution mechanisms and the official UN SDG metadata. The validated alignment is presented in Table 4.

Table 4. SDG Alignment Matrix of Digital Ecosystem Drivers

Factor	Primary SDG Alignment	Secondary SDG Alignment	Contribution Mechanism
Digital Infrastructure and Connectivity	SDG 9 (Industry, Innovation, Infrastructure)	SDG 7 (Affordable Clean Energy), SDG 11 (Sustainable Cities)	Broadband expansion, reliable electricity, resilient infrastructure, data center modernisation
Financial Inclusion and Digital Payments	SDG 1 (No Poverty), SDG 8 (Decent Work)	SDG 10 (Reduced Inequalities)	Mobile money access, digital credit for rural poor, payment system interoperability
Human Capital and Digital Literacy	SDG 4 (Quality Education)	SDG 5 (Gender Equality), SDG 8 (Decent Work)	Digital skills training, ICT curricula, youth workforce upskilling, coders' initiative
Policy, Governance and Institutional Framework	SDG 16 (Peace, Justice, Strong Institutions)	SDG 17 (Partnerships for the Goals)	Fayda digital ID, transparent governance, data protection, regulatory quality
Innovation and Entrepreneurship Ecosystem	SDG 8 (Decent Work, Economic Growth)	SDG 9 (Innovation), SDG 17 (Partnerships)	Startup creation, job generation, digital firm licensing, foreign direct investment

SDG 9 is most directly addressed, as infrastructure expansion serves as the foundational enabler of industrialisation and innovation. GSMA (2024) projects that Ethiopia's digital economy could add over ETB 1.3 trillion to GDP by 2028, creating over 1 million new jobs. SDG 1 and SDG 8 are simultaneously advanced through Factor 2 and Factor 5, with digital finance shown to reduce rural poverty (Mugoro & Makhura, 2025) and entrepreneurship generating formal employment. SDG 4 is reinforced by Factor 3's massive upskilling programs. SDG 16 is substantiated by the transparent governance and identity infrastructure captured in Factor 4. Finally, SDG 17 is cross-cutting, with Kant et al. (2024) confirming that digital platforms mediate international partnerships and knowledge-sharing, while DE2030 is funded through multilateral public-private donor partnerships.

4.4 Phase 4: Framework Reliability, Construct Validity, and Synthesis

To validate the final five-factor framework for practical policy application, two complementary analyses were conducted: internal consistency assessment and construct validity triangulation.

a. Reliability Assessment

Cronbach's alpha was calculated for each of the five extracted factors to assess internal consistency. As presented in Table 5, all factors demonstrated alpha coefficients well above the acceptable threshold of 0.70 (Nunnally & Bernstein, 1994), ranging from 0.82 to 0.89. This confirms that the items within each factor reliably measure their respective latent constructs.

Table 5. Reliability Coefficients for Each Factor

Factor	Number of Items (Variables)	Cronbach's Alpha (α)	Interpretation
Factor 1: Digital Infrastructure and Connectivity	6	.89	Excellent internal consistency
Factor 2: Financial Inclusion and	5	.87	Good internal

Digital Payments			consistency
Factor 3: Human Capital and Digital Literacy	5	.84	Good internal consistency
Factor 4: Policy, Governance and Institutional Framework	6	.83	Good internal consistency
Factor 5: Innovation and Entrepreneurship Ecosystem	6	.82	Good internal consistency

Note: Factor 4 and 5 contain 6 variables each due to the absorption of cross-cutting indicators (Digital ID, R&D, and Digital Exports) into their most relevant conceptual domains during Phase 1 synthesis.

Table 5 presents the internal consistency coefficients for the five retained factors derived from the comprehensive Ethiopian digital ecosystem analysis. All Cronbach's alpha values substantially exceed the widely accepted threshold of 0.70, confirming strong scale reliability across all extracted dimensions (Nunnally & Bernstein, 1994). The coefficients range from a high of 0.89 for Factor 1 (Infrastructure) to a highly acceptable 0.82 for Factor 5 (Innovation Ecosystem). Intermediate values of 0.87, 0.84, and 0.83 for Factors 2, 3, and 4, respectively, indicate excellent to good internal homogeneity across the entire factor structure. Despite slight variations in item count per factor, ranging from five to six variables, the uniformly high coefficients confirm that each construct possesses sufficient precision and cohesion. Critically, the lowest estimate (0.82) still comfortably exceeds the stringent threshold, effectively ruling out concerns regarding random measurement error. The overall robustness of these reliability estimates in the present study validates the internal consistency of the measurement framework.

b. Construct Validity and Framework Synthesis (Objective 5)

To assess construct validity, the empirical five-factor solution was compared against the original six a priori conceptual domains. The empirical factors demonstrated strong convergence with the theoretical domains, with only minor reorganisation: (1) The *Infrastructure* domain perfectly mapped to Factor 1; (2) *Financial Services* mapped cleanly to Factor 2; (3) *Human Capital* mapped to Factor 3; (4) *Policy & Governance* mapped to Factor 4; and (5) *Innovation* and *Cross-Cutting* indicators coalesced into a single, coherent Factor 5. This convergence confirms strong construct validity, indicating that the EFA empirically validated the underlying theoretical logic.

Final Synthesis: The validated five-factor model, hierarchically ranked by explanatory power (Objective 3), provides an empirically grounded strategic tool for stakeholders. The framework dictates that Infrastructure must remain the top investment priority, followed sequentially by Financial Inclusion, Human Capital, Governance, and Innovation. Intertwined with this hierarchy is a robust SDG alignment (Objective 4) that allows policymakers to trace specific investments (e.g., fiber optics, mobile money, or Fayda ID) directly to measurable development outcomes (e.g., SDG 9, SDG 1, or SDG 16).

4.3 Discussion

a. Theoretical Contributions

This study makes several significant theoretical contributions to digital ecosystem research in developing country contexts. First, it provides rigorous empirical validation of a five-factor model for understanding digital ecosystem drivers in a lower-middle-income African context. The factor structure, explaining 64.8% of total variance with clean loadings ranging from 0.61 to 0.84 and demonstrating excellent internal consistency (Cronbach's α ranging from 0.82 to 0.89), confirms the multidimensional nature of digital ecosystem development. While prior research examined isolated aspects, such as mobile-based technology adoption (Factors Affecting the Adoption of Mobile-Based Digital Technologies, 2026) or digital finance use (Mugoro & Makhura, 2025), this study offers a comprehensive,

empirically validated framework integrating infrastructure, financial services, human capital, governance, and innovation dimensions. Notably, the hierarchical ranking by explanatory power (Infrastructure 24.4%, Financial Inclusion 15.4%, Human Capital 11.3%, Governance 8.7%, and Innovation 6.0%) provides novel insights into the relative importance of each driver, a contribution absent from previous fragmented approaches. Second, it demonstrates the applicability of EFA methodology to holistic digital ecosystem research, extending the approach previously confined to specific domains such as digital platforms for SDG 17 (Kant et al., 2024) and innovation management (Innovation Management Landscape for Digital Economy Transformation, 2024). The successful absorption of cross-cutting variables into coherent constructs validates the methodological approach. Third, it bridges digital transformation literature with sustainable development scholarship by systematically mapping each extracted factor to specific SDG targets, contributing empirical evidence on how digitalization can accelerate progress toward the SDGs in developing country contexts. The alignment matrix (Table 4) provides a replicable framework for future cross-national comparative research.

b. Policy Implications

The findings yield several actionable policy implications, prioritised according to the empirically derived factor hierarchy. First, the dominance of Factor 1 (Infrastructure), accounting for 24.4% of variance with the highest reliability ($\alpha = 0.89$), unequivocally confirms that continued investment in connectivity, electricity, and data infrastructure remains paramount. Persistent structural constraints, limited rural internet coverage, low smartphone penetration, and unreliable electricity, continue to shape adoption equity (Mugoro & Makhura, 2025). The GSMA (2024) emphasises that bridging the usage gap, particularly the 40% gender disparity in mobile internet use, is crucial. Policy recommendations include prioritising service affordability through tax reduction, fast-tracking telecom reforms to enhance competition, and improving device affordability via reduced customs duties (GSMA, 2024). The empirical validation of six infrastructure variables (loadings 0.61–0.82) provides clear investment priorities.

Second, the emergence of Financial Inclusion (Factor 2, 15.4% variance, $\alpha = 0.87$) as the second most powerful driver highlights the transformative potential of mobile money and digital payments. The explosive growth from 12.2 million accounts in 2020 to 139.5 million by 2025 (Shega, 2025) validates this dimension. The National Digital Payments Strategy 2026–2030 represents progress, but implementation challenges remain: interoperability gaps, cumbersome Know Your Customer (KYC) procedures, and insufficient digital ID integration (Shega, 2025). Agent network weaknesses, high account dormancy, and persistent rural-urban and gender disparities continue to limit inclusiveness. Policy attention should prioritise simplifying onboarding procedures, expanding agent networks in underserved areas, and ensuring EthioPay interoperability across all providers.

Third, Factor 3 (Human Capital, 11.3% variance, $\alpha = 0.84$) underscores that infrastructure alone is insufficient. The high loading of digital literacy (0.83) validates national investments in the Five Million Ethiopian Coders Initiative and International Certification of Digital Literacy training (World Bank, 2026; ENA, 2025c). However, achieving the 70% digital literacy target by 2030 requires accelerated scaling. Mugoro and Makhura (2025) emphasise the need for context-sensitive service design, particularly for individuals with limited formal education, to foster confidence and engagement. Curriculum integration at all educational levels and targeted programmes for women and rural populations are essential.

Fourth, Factor 4 (Policy and Governance, 8.7% variance, $\alpha = 0.83$) indicates that regulatory clarity and institutional capacity are critical. The strong loading of the Fayda digital ID system (0.62) confirms its foundational role in enabling service access and building trust (ENA, 2025d). Ethiopia's digital transformation is less a technological challenge and more a

test of policy, institution-building, and governance. The Digital Ethiopia 2030 strategy's emphasis on transparent governance, measurable outcomes, and accountability (EBC, 2026) is essential. Implementing the Digital Government Strategy 2024–2029 with adequate institutional coordination and data protection frameworks is paramount.

Fifth, Factor 5 (Innovation Ecosystem, 6.0% variance, $\alpha = 0.82$) suggests that fostering entrepreneurship, startup funding, and innovation hubs is essential for translating digital infrastructure into economic growth. The licensing of over 3,000 digital firms since 2022 (etradeforall, 2025) demonstrates momentum. The operationalization of the Startup Proclamation and the launch of the Digital Ethiopia Investment Roadmap (ENA, 2025) are positive steps. However, sustained investment in research and development, venture capital, and innovation support services is urgently needed. The Ethiopian Capital Market Authority's regulatory sandbox (StockMarket.et, 2024) should be expanded to include more fintech and AI startups.

c. Limitations and Future Research

This study has several limitations that present opportunities for future research. First, the analysis relied on secondary data synthesis rather than primary survey data. Future research should collect primary data from diverse stakeholders, including digital service users, entrepreneurs, policymakers, and development practitioners, to validate the five-factor structure and explore causal relationships between drivers. Second, while EFA is appropriate for exploratory purposes, the extracted factor structure requires confirmation through Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM) to test the hypothesized relationships among factors, as demonstrated in prior Ethiopian digital research (Kant et al., 2024; Innovation Management Landscape for Digital Economy Transformation, 2024). Third, the cross-sectional design limits understanding of temporal dynamics; longitudinal analysis across multiple time points would reveal how the factor structure evolves as Ethiopia's digital transformation progresses, particularly as Digital Ethiopia 2030 initiatives scale. Fourth, the country-specific analysis limits generalizability; comparative studies across East African countries (Kenya, Rwanda, Uganda) would enhance external validity and reveal context-specific dynamics influenced by varying policy regimes and market structures. Fifth, the study does not disaggregate findings by gender, region, or socioeconomic status. Given the persistent gender gap in mobile internet use (GSMA, 2024), future research should examine how digital ecosystem drivers differentially affect various population segments, particularly women, rural communities, and lower-income groups. Sixth, this study provides an initial SDG alignment mapping (Table 4), but quantitative impact assessment—measuring the marginal contribution of each driver to specific SDG indicators—remains a critical avenue for future inquiry.

This study identified five empirically validated drivers of Ethiopia's digital ecosystem through Exploratory Factor Analysis: Digital Infrastructure and Connectivity, Financial Inclusion and Digital Payments, Human Capital and Digital Literacy, Policy Governance and Institutional Framework, and Innovation and Entrepreneurship Ecosystem. These factors collectively account for 64.8% of the variance in digital ecosystem development, with reliability coefficients confirming the robustness of the measurement framework. The hierarchical ranking provides a clear prioritization for policy and investment. The five-factor model demonstrates strong alignment with multiple Sustainable Development Goals, particularly SDGs 1, 4, 8, 9, 10, 16, and 17. For policymakers, the model offers an evidence-based strategic tool for resource allocation and intervention sequencing. For development practitioners, it provides a roadmap for aligning digital initiatives with SDG targets. For researchers, it establishes a validated foundation for further empirical investigation. As Ethiopia continues its digital transformation under the Digital Ethiopia 2030 strategy, the systematic cultivation of these five drivers, prioritised according to their empirically derived

importance will be essential for realizing the vision of a digitally empowered, inclusive, and sustainable nation. The people-centred approach, anchored in the principles of digital sovereignty and intentional inclusion (ENA, 2025), offers a promising pathway for ensuring that the benefits of digitalization reach all Ethiopians, particularly those historically marginalised. With the GSMA (2024) projecting that Ethiopia's digital economy could add over ETB 1.3 trillion to GDP by 2028, the stakes for evidence-based, strategically sequenced digital ecosystem development have never been higher.

V. Conclusion

This study provides empirical validation of a five-factor model explaining the key drivers of Ethiopia's digital ecosystem through Exploratory Factor Analysis. The extracted dimensions—Digital Infrastructure and Connectivity, Financial Inclusion and Digital Payments, Human Capital and Digital Literacy, Policy Governance and Institutional Framework, and Innovation and Entrepreneurship Ecosystem, collectively account for 64.8% of the total variance, with Cronbach's alpha coefficients ranging from 0.82 to 0.89 confirming robust internal consistency. The hierarchical ranking by explanatory power reveals infrastructure as the dominant driver (24.4%), followed by financial inclusion (15.4%), human capital (11.3%), governance (8.7%), and innovation (6.0%). The five-factor model demonstrates substantial alignment with Sustainable Development Goals 1, 4, 8, 9, 10, 16, and 17, providing an evidence-based framework for tracing digital investments to measurable development outcomes.

Ethiopia's digital transformation journey, spanning the completion of Digital Ethiopia 2025 and the launch of Digital Ethiopia 2030, represents a significant national commitment to leveraging technology for inclusive and sustainable development. The country has achieved remarkable progress: 139.5 million mobile money accounts, over 3,000 licensed digital firms since 2022, 65% growth in mobile internet connections, and expanding broadband and 5G infrastructure (Intelligent CIO, 2026). However, persistent challenges remain, including limited digital literacy (only 10.6% of the population actively using mobile internet despite 45% network coverage), uneven rural connectivity, a 40% gender gap in mobile internet use, and the need for stronger institutional coordination and regulatory frameworks.

The validated five-factor model provides policymakers with a strategic, empirically derived hierarchy for resource allocation and intervention sequencing. For development practitioners, it offers a structured roadmap for aligning digital initiatives with SDG targets. For researchers, it establishes a robust foundation for further investigation through confirmatory analysis and cross-national comparative studies. The Digital Ethiopia 2030 strategy's people-centred approach, anchored in the principles of digital sovereignty and intentional inclusion (ENA, 2025), offers a promising pathway for ensuring that the benefits of digitalization reach all Ethiopians. With the GSMA (2024) projecting that Ethiopia's digital economy could contribute over ETB 1.3 trillion to GDP by 2028, the systematic and strategic cultivation of these five empirically validated drivers is essential for realizing the vision of a digitally empowered, inclusive, and sustainable nation

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