

Digital transformation taxonomy in transitioning countries: A case study of Libya

Ibrahim Ejdayid Ajbarah Mansour *

Department of computing and informatics, Libyan Center for Engineering Research and IT,
Bani Walid, Libya

*Email: mansour1887@gmail.com

تصنيف التحول الرقمي في الدول الانتقالية: دراسة حالة ليبيا كمثال

ابراهيم اجديد اجبارة منصور*

قسم الحوسبة والمعلوماتية، المركز الليبي للبحوث الهندسية وتقنية المعلومات، بني وليد، ليبيا

Received: 12-05-2026	Accepted: 04-07-2026	Published: 17-07-2026
	Copyright: © 2026 by the authors. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).	

Abstract

This study addresses a critical gap in innovation systems literature concerning digital transformation (DT) in transitioning economies, where prevailing models inadequately address institutional instability and poorly sequenced reforms. It develops a new Six-Pillar Digital Transformation Maturity Framework (SDMF) as a contextual diagnostic tool for socio-technical readiness in fragile institutional settings.

Guided by two research questions, the study asks what analytical framework suits DT maturity assessment under institutional fragility, and how its application reveals systemic interdependencies and strategic constraints. A comparative institutional analysis of Libya, Tunisia, and Saudi Arabia is employed.

Findings reveal a structural imbalance in Libya's digital trajectory. Despite high internet penetration (88.4%), progress is severely constrained by governance weaknesses (scoring 25/100), including absent digital leadership and coordination. This governance–innovation decoupling undermines local technological capability and inclusive growth, demonstrating that institutional anchoring and sequenced reforms not technical investment alone, are central to sustainable DT.

The study contributes to African STI scholarship by advancing the tailored SDMF and providing comparative evidence to inform technology policy, emphasizing governance reform's critical role in aligning infrastructure with institutional development in post-conflict contexts

Keywords: Digital Transformation, Innovation Governance, Fragile States, Institutional Analysis, Digital Maturity.

المخلص

تعالج هذه الدراسة فجوةً جوهرية في طرق وأنظمة الابتكار المتعلقة بالتحول الرقمي في الاقتصادات الغير مستقرة، حيث إن النماذج السائدة لا تعكس بصورة كافية تحديات الهشاشة المؤسسية وعدم استقرار المؤسسات وضعف تسلسل تنفيذ الإصلاحات. وللتعامل مع هذه الفجوة، تطور الدراسة إطار النضج سداسي الركائز للتحول الرقمي (SDMF) بوصفه أداة تشخيصية نمطية لتقييم الجاهزية الاجتماعية-التقنية في البيئات ذات الهشاشة المؤسسية.

وانطلاقاً من سؤالين بحثيين رئيسيين، تبحث الدراسة في: ما الإطار التحليلي الأنسب لتقييم نضج التحول الرقمي في ظل الهشاشة المؤسسية؟ وكيف يكشف تطبيق هذا الإطار عن الترابطات المنهجية والقيود الاستراتيجية التي تؤثر في مسار التحول الرقمي؟ وللإجابة عن هذين السؤالين، تعتمد الدراسة تحليلاً مؤسسياً مقارناً بين ليبيا وتونس والمملكة العربية السعودية.

كشفت النتائج عن وجود خلل هيكلي في مسار التحول الرقمي في ليبيا. فعلى الرغم من ارتفاع نسبة انتشار الإنترنت إلى 88.4%، فإن التقدم لا يزال مقيداً بشكل كبير بضعف الحوكمة، التي حصلت على 25 من 100، نتيجة غياب القيادة الرقمية وآليات التنسيق المؤسسي. ويؤدي هذا الانفصال بين الحوكمة والابتكار إلى إضعاف القدرات التقنية المحلية وتقويض فرص النمو الشامل، مما يؤكد أن ترسيخ المؤسسات وتنفيذ الإصلاحات وفق تسلسل مدروس، وليس الاستثمار التقني وحده، يمثلان الأساس لتحقيق تحول رقمي مستدام.

وتسهم الدراسة في إثراء أدبيات العلوم والتقنية والابتكار (STI) في أفريقيا من خلال تقديم إطار النضج سداسي الركائز للتحول الرقمي (SDMF) المصمم خصيصاً لبيئات الدول الانتقالية، إلى جانب توفير أدلة مقارنة تدعم رسم سياسات التكنولوجيا، مع التأكيد على الدور المحوري لإصلاح الحوكمة في ملائمة تطوير البنية التحتية الرقمية مع التنمية المؤسسية في الدول الخارجة من النزاعات.

الكلمات المفتاحية: التحول الرقمي، حوكمة الابتكار، الدول الانتقالية، التحليل المؤسسي، النضج الرقمي.

1. INTRODUCTION

The Fourth Industrial Revolution has catalysed a global wave of digital transformation (DT), fundamentally reshaping economies, governance, and societal interactions [1], [2]. For nations in the Middle East and North Africa (MENA) region, embracing DT represents both a strategic necessity and a complex development challenge [3], [4]. Digital transformation is often framed as a technological or infrastructure challenge, comparative evidence from developing countries suggests that failures are more commonly rooted in institutional misalignment, fragmented authority, and poor reform sequencing rather than in technology scarcity. Recent cross-country analyses demonstrate that digital initiatives frequently stagnate where governance arrangements fail to provide a credible coordination anchor capable of aligning policy, implementation, and accountability across sectors [5].

While state-driven digital initiatives in stable Gulf Cooperation Council (GCC) nations are well-documented [6], the DT trajectories of fragile and post-conflict African states remain critically understudied in innovation systems literature [7]. Libya presents a pivotal case within this research gap, characterized by paradoxical indicators of progress amidst institutional fragmentation [8].

Libya's position on the United Nations e-Government Development Index (EGDI) reveals this duality: ranking 125th out of 193 countries in 2024 [9], representing a dramatic improvement

from 169th in 2022 [10]. Similarly, the nation has demonstrated unexpected progress in cybersecurity, achieving the third level of institutional maturity in the International Telecommunication Union's (ITU) Global Cybersecurity Index with a score of 68.1 out of 100 [11]. These achievements coexist with profound institutional challenges that conventional state-led DT models cannot adequately address [12].

This research argues that Libya's DT cannot be understood through technical metrics alone, nor through centralized planning models developed for stable institutional contexts. Instead, it requires an integrated analytical framework that accounts for the complex interplay between institutional development and technological adoption in fragile states. The study positions itself within African Science, Technology and Innovation (STI) scholarship [13] by addressing how digital infrastructure investments translate or fail to translate into sustainable innovation ecosystems in post-conflict environments.

1.1. *Research Questions and Contributions*

This investigation is structured by two interconnected research questions designed to bridge innovation theory with development practice in fragile African contexts:

- **RQ1.** What constitutes an appropriate analytical framework for assessing digital transformation maturity in institutionally fragile states, where conventional models assume stable governance structures?
- **RQ2.** How does the application of such a framework reveal the systemic interdependencies and strategic gaps in Libya's digital transformation compared to regional peers with varying institutional stability?

To address these questions, the study makes two corresponding contributions to African innovation and development scholarship:

- **Contribution 1 (Theoretical Framework):** The development and validation of a Six-Pillar Digital Transformation Maturity Framework (SDMF). This novel framework integrates infrastructure, governance, human capital, innovation, cybersecurity, and inclusion as interdependent components, providing a diagnostic tool specifically designed for fragile state contexts where institutional-technical alignment determines DT outcomes.
- **Contribution 2 (Empirical Analysis):** A comparative institutional analysis applying the SDMF to Libya, Tunisia, and Saudi Arabia. This analysis reveals how governance deficiencies fundamentally constrain digital maturity despite technical investments, providing evidence-based insights for technology policy formulation in transitioning African states. The findings demonstrate that institutional scaffolding not merely infrastructure investment enables sustainable innovation ecosystems.

1.2. *Paper structure*

The remainder of this paper is organized as follows:

- **Section 2 — Literature review:** Examines DT frameworks for fragile states and details the mixed-methods approach with multi-source data collection.
- **Section 3 — The SDMF Framework:** Presents the Six-Pillar Digital Transformation Maturity Framework for assessing digital maturity in institutionally constrained contexts.
- **Section 4 — SDMF based multi-nation comparative analysis:** Applies the SDMF to Libya, Tunisia, and Saudi Arabia, analysing inter-dependencies and strategic gaps.
- **Section 5 — Findings and discussion:** Interprets findings within African innovation theory and discusses STI policy implications for fragile states.
- **Section 6 — Conclusion:** Summarizes contributions and outlines future research on innovation governance in transitioning contexts.

2. LITERATURE REVIEW

Digital Transformation (DT) presents both an imperative and persistent challenge for developing nations, particularly within African innovation systems [14], [15], [16]. The prevailing scholarly discourse often frames this challenge through the lens of a widening technological divide between developed and developing economies [17], [18], where digital disruptions risk permanently embedding data economies within advanced nations, thereby exacerbating global inequality [19], [20].

Recent scholarship has increasingly questioned technology-centric and linear interpretations of digital transformation in developing contexts, emphasizing instead the role of institutional capacity, political authority, and coordination mechanisms. Comparative analyses across multiple developing countries show that digital initiatives often fail not due to technological deficiencies, but because reforms are poorly sequenced and lack an empowered governance anchor capable of aligning strategy, implementation, and accountability across sectors [5]. This perspective highlights a persistent disconnect between digital infrastructure expansion and innovation or service delivery outcomes, suggesting that maturity frameworks which overlook institutional interdependencies risk misdiagnosing transformation readiness [21]. A research work addresses the gap between diagnosis and implementation by developing effective guidance for developing economies; methodologically bridging static assessments with actionable diagnostics; and practically providing a structured framework and Performance-Knowledge Index (PKI) tool to diagnose contexts and prioritize interventions, moving from agnostic best practices to local strategies [16]. Consequently, there remains a need for diagnostic frameworks that explicitly surface governance (compliance & risk management) and institutional constraints as primary determinants of digital transformation trajectories [22].

However, the African DT narrative transcends deficit models, demonstrating remarkable innovation and strategic adaptation. A "mobile-first" revolution has emerged as a dominant paradigm, with seminal initiatives such as Kenya's M-Pesa illustrating how localized digital solutions can drive financial inclusion and economic growth [23]. Continental momentum is further institutionalized through frameworks like the African Union's Digital Transformation Strategy for Africa (2020–2030), which provides a comprehensive roadmap for regional cooperation and sustainable investment in innovation ecosystems [24].

Empirical evidence from pioneering African cases substantiates this strategic approach to systematically identify and deal with DT adoption barriers [25]. Rwanda's IremboGov platform has consolidated over 100 e-government services, significantly enhancing administrative efficiency and citizen accessibility [26], [27]. Similarly, Tunisia's E-Houwiya digital identity system establishes a legally recognized credential, underscoring the critical role of secure identity governance in modern digital states [28]. These exemplars illustrate a crucial transition from mere technical adoption to integrated, strategy-driven digitization, offering valuable comparative insights for post-conflict contexts. Furthermore, South Africa (2011-2021), showing a strong positive correlation between ICT adoption and economic competitiveness, including productivity, business growth, and GDP, arguing for targeted investment in infrastructure and skills to accelerate digital penetration [29].

2.1. *Libya's DT institutional constraints*

Despite significant academic neglect in peer-reviewed African innovation literature, practical DT efforts in Libya demonstrate notable progress. Key public institutions drive various

initiatives: the Libya Post Telecommunications and Information Technology Company (LPTIC) focuses on modernizing national infrastructure [30], while its subsidiary, the Libyan Academy for Telecom and Informatics (LATI), addresses critical ICT capacity building [31]. The General Information Authority (GIA) has articulated a national vision through the DT Strategy 2030, aiming to leverage technology for economic reconstruction and improve Libya's e-Government Development Index (EGDI) ranking [32].

Parallel developments within Libya's financial sector reveal emerging regulatory foundations. The Central Bank of Libya (CBL) has issued comprehensive directives on IT governance [33], a National Financial Inclusion Strategy (2025–2029) [34], and data protection regulations [35], establishing necessary conditions for digital economic development. Meanwhile, private enterprises like Libyan Spider (established 2002) and Awal (founded 2010) provide critical cybersecurity and internet services, forging partnerships with global technology leaders [36], [37].

To systematically analyse Libya's DT trajectory within its regional context, this study employs a mixed-methods approach combining systematic literature review with comparative institutional analysis. The methodology encompasses three distinct but interconnected phases:

2.2. Systematic literature identification

Two parallel search strategies were implemented using specific keyword combinations to ensure comprehensive coverage:

- **Libya-specific analysis:** Keywords included "Libya digital transformation," "Libya DT maturity," "digital transformation criteria," "DT success factors," and "crucial roles for digital transformation" to identify relevant peer-reviewed articles, technical reports, and policy documents.
- **Comparative regional analysis:** Keywords encompassed "e-Government development index 2024," "Global Cybersecurity Index 2024," "Human capital initiatives," "Infrastructure maturity," "National DT strategies," and "Inclusive digital development" to facilitate cross-country comparisons with regional peers Tunisia and Saudi Arabia.

2.3. Multi-source data collection

The search strategy targeted three complementary data source categories:

- **International databases and indices:**
 - United Nations e-Government Development Index (EGDI) [9] measuring scope and quality of online services, infrastructure, and human capital.
 - ITU Global Cybersecurity Index (GCI) [11] evaluating national cybersecurity preparedness and institutional capacity.
 - Speedtest Global Index [38] providing infrastructure quality data from user perspectives to identify bandwidth and latency constraints.
- **Governmental and policy documents:**
 - Strategy documents from Libya's General Information Authority (GIA) [32] providing insights into sector maturity and policy alignment.
 - Regulatory directives from the Central Bank of Libya (CBL) [33], [34], [35] demonstrating financial ecosystem readiness.
 - Publications from peer nations' government bodies [39], [40], [41] enabling comparative policy analysis.
- **Academic and industry sources:**
 - Peer-reviewed journal articles [42], [43], [44], [45] applying recognized theoretical models to digital adoption.

- Conference proceedings [46], [47], [48] capturing latest international practices and novel metrics.
- Reports from international organizations and private-sector analysts [49] providing standardized cross-country indicators.

2.4. Framework development

The selection process prioritized recent publications (2020–2025) to ensure contemporary relevance, supplemented by citation tracking from key studies. This comprehensive approach ensures coverage across six analytical dimensions: infrastructure, governance, human capital, innovation, cybersecurity, and inclusion. The subsequent analysis employs the derived Six-Pillar Digital Transformation Maturity Framework (SDMF) to systematically assess Libya's position relative to regional peers, identifying systemic inter-dependencies and strategic gaps in institutional-technical alignment.

2.5. Research gap

The growing activity within Libya's digital ecosystem, juxtaposed against incidents like the 2024 Google Cloud outage that erased UniSuper's private account [50], reveals urgent necessities for integration, strategic alignment, and data sovereignty. For Libyan providers, adopting international standards (e.g., PCI DSS, ISO 27001) represents not merely technical compliance but strategic positioning as trusted custodians of national data, enabling effective Public-Private Partnerships (PPPs) [51].

Despite expanding DT initiatives across Libya's public and private sectors, academic research particularly within African innovation journals lacks comprehensive frameworks to assess their maturity, interactions, and systemic inter-dependencies. This methodological and conceptual gap underscores the necessity for a multi-dimensional analytical approach that transcends conventional state-centered models. The following sections address this need by presenting and applying a diagnostic framework that evaluates digital transformation maturity in institutionally constrained environments while remaining adaptable for similar transitional contexts across Africa.

3. SIX-PILLAR DT MATURITY FRAMEWORK (SDMF)

Unlike conventional digital maturity models that implicitly assume linear progress toward predefined end states, the Six-Pillar Digital Maturity Framework (SDMF) is designed as a diagnostic instrument to surface binding institutional and governance constraints that condition digital outcomes. This diagnostic orientation reflects growing evidence that successful DT in developing contexts depends less on adopting best-practice technologies and more on identifying and sequencing reforms in line with existing political–institutional capacities [5].

Over time, critical success factors in DT for African developing nations have been identified which include mature leadership and vision, governance frameworks, capacity building, and infrastructure accessibility [24], [52], [53]. These factors have been systemically included in DT maturity frameworks that are tailored to the specific context of the Middle East and North Africa (MENA) region [49], [54], [55], [56].

This study is theoretically grounded in an institutional and governance-oriented understanding of digital transformation, which views technological change as embedded within political authority, administrative capacity, and coordination mechanisms. Recent comparative scholarship challenges technology-centric and linear maturity assumptions, demonstrating that digital transformation outcomes in developing countries are largely determined by the sequencing of institutional reforms and the presence of empowered coordinating actors rather than by infrastructure accumulation alone (Oxford University Press, 2023).

Building on this perspective and prior DT models [5], [12], [57], [58], [59], [60], the proposed Six-Pillar Digital Maturity Framework (SDMF) conceptualizes digital transformation as an interdependent system in which governance functions as the primary enabling condition for sustainable innovation, service delivery, and economic impact.

The six pillars of the proposed framework are: 1) Infrastructure, 2) Governance, 3) Human Capital, 4) Innovation, 5) Cybersecurity, and 6) Inclusion. This new framework has been used to evaluate the DT maturity of individual nations, including Libya, Tunisia, and Saudi Arabia, offering a comprehensive diagnostic tool for assessing readiness and implementation progress in national digital transformation.

The SDMF brings together leading models in the literature on e-Government, national digital strategies, and Industry 4.0 [17]. The pillars are mutually reinforcing, each enables and constrains the others and together they provide a comprehensive planning tool [61]. Together, these pillars constitute a holistic framework capable of measuring readiness, implementation progress, and sustainable impact across public and private sectors [11], [59], [62].

Figure 1 shows the relationships between the six pillars in the proposed framework. The relationships between the pillars are highlighted below:

1. **Infrastructure** : Foundation
 - Provides the physical and logical backbone (networks, cloud and data centres).
 - Enables all other pillars: governance platforms, cybersecurity measures, AI adoption, digital services, and inclusion initiatives rely on well-designed infrastructure.
2. **Governance** : Strategy driver
 - Establishes frameworks and policies.
 - Influences legal & regulations, ensures proper cybersecurity practices, and guides innovation in a place.
3. **Human capital** : Enabler
 - Skilled workforce drives innovation, ensures proper governance execution, and maintains cybersecurity.
 - Human expertise also supports the design and delivery of inclusive digital services.
4. **Innovation** : Value creation
 - Development of new services, business models, and technologies.
 - Relies on infrastructure for deployment, human capital for execution, and governance for compliance.
5. **Cybersecurity** : Trust & protection
 - Protects data, applications and infrastructure.

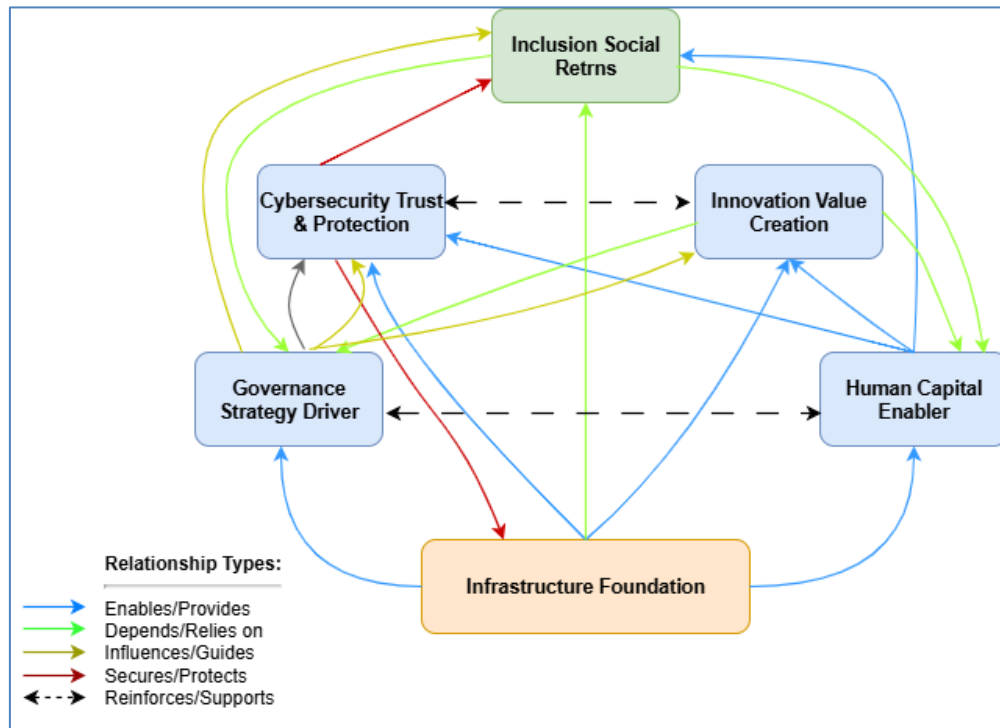


Figure 1: Six-pillar DT maturity framework

- Essential for innovation adoption, governance, and inclusion, since citizens and businesses must only engage in secure systems.

6. **Inclusion** : Social returns

- Ensures equal rights to access digital services.
- Dependent on infrastructure, human capital, innovation, and governance to provide accessible, available, and trusted services.

Each pillar represents a unique domain of capability, ranging from infrastructure and governance to human capital, innovation, cybersecurity, and inclusion, but none operates individually. Instead, these domains form a mature ecosystem in which strengths or weaknesses in one area directly influence the performance of others. The table illustrates how a holistic approach, not only investment in a single area, is essential to achieving stable DT at the national level.

Table 1: Distribution of references across the six pillars of Libya's DT and its regional peers

Pillar	Nation	References	Count
Infrastructure	Libya	[9], [44], [63]	3
	Tunisia	[64], [65]	2
	Saudi Arabia	[40], [66], [67]	3
Governance	Libya	[11], [35], [45], [68], [69], [70]	6
	Tunisia	[71]	1
	Saudi Arabia	[40], [72], [73], [74]	4
	Libya	[75], [76], [77], [78], [79]	5

Human Capital	Tunisia	[80]	1
	Saudi Arabia	[40], [81], [82]	3
Innovation	Libya	[77], [78], [83]	3
	Tunisia	[41], [84], [85]	3
	Saudi Arabia	[40], [86], [87], [88]	4
Cybersecuirty	Libya	[11], [70], [89]	3
	Tunisia	[11], [90]	2
	Saudi Arabia	[11], [47]	2
Inclusion	Libya	[76], [91], [92]	3
	Tunisia	[39], [93]	2
	Saudi Arabia	[40], [72], [87], [94]	4
Total			54

The comparative data across Libya, Tunisia, and Saudi Arabia indicate that an evaluating approach has been employed based on six interconnected dimensions, combining quantitative indices with qualitative governance indicators. On the one hand, digital infrastructure readiness (internet usage, mobile speeds, and 5G deployment) was assessed alongside standardized global measures such as the UN e-Government Development Index (EGDI) [9] and the Global Cybersecurity Index (GCI) [11], providing a view of e-Government maturity and cybersecurity readiness. On the other hand, the analysis examined private-sector digital adoption (cashless economy, SaaS endorsement, SME e-commerce), the legal environment (laws, regulations, and AI ethics frameworks), and governance leadership (strategy cohesion, sectors stability, and national coordination).

4. SDMF BASED MULTI-NATION COMPARATIVE ANALYSIS

4.1. Overview

To clearly evaluate Libya's position, this study employs a comparative analysis with two strategic regional peers: Tunisia and Saudi Arabia. Tunisia serves as a pertinent regional success story, consistently ranking among the top North African nations in digital governance. It placed 87th globally (3rd in Africa) on the 2024 e-Government Development Index and leads the region in the Digital Quality of Life Index, supported by notable strengths in human capital and infrastructure [95], [96].

The inclusion of Saudi Arabia provides a critical, high-performing benchmark. While not an African nation, it represents a highly relevant developmental model for resource-rich, institution-building contexts within the broader MENA region [97]. The rationale for this comparison is fourfold: The rationale for this comparison is fourfold: **Shared Structural Characteristics**, as both economies are historically shaped by hydrocarbon resources, presenting comparable diversification imperatives [98]; **Institutional Parallels** in state-centric governance traditions, offering insights into centralized strategic orchestration [99]; a common **Socio-Cultural Environment** within the Arab world, which informs approaches to digital adoption and trust [100]; and Saudi Arabia's role as an **Aspirational Benchmark**, demonstrating the potential trajectory for a MENA nation with substantial political will and investment [97].

This dual comparison enables a nuanced analysis of Libya's digital maturity, illuminating both immediate gaps and long-term institutional pathways for DT in fragile, post-conflict contexts [3].

4.2. *Source material identified*

Table 1 summarizes the distribution of references across the six DT pillars for Libya and its regional peers, highlighting the evidence base supporting each dimension.

4.3. *Analysis results*

The following section presents the analysis results that compare Libya, Tunisia, and Saudi Arabia:

1. **Infrastructure**

- **Libya (Low-Medium):** 88.4% internet users; average speed of 16.9 Mbps; UN EGD score of 0.5466 (125th); connectivity remains uneven with limited rural access [44], [63], [101].

- **Tunisia (Medium):** 79.6% internet users; average speed of 22.1 Mbps; EGD score of 0.6935 (87th); a national 5G roadmap and broadband extended to approximately 3,300 schools [64], [65].

- **Saudi Arabia (High):** 99% internet users; among Top-5 G20 nations for 5G; EGD score of 0.9602 (6th); hyperscale data centers and Vision 2030-led infrastructure improvements [40], [66], [67].

2. **Governance**

- **Libya (Low):** Fragmented governance, absence of an officially adopted anti-cybercrime law, and limited data protection measures confined mainly to banking [11], [35], [45], [68], [69], [70].

- **Tunisia (Medium):** Democratic framework with institutional instability, Startup Law in place, and draft data protection law under development [71].

- **Saudi Arabia (High):** Guided by Vision 2030 governance and the DGA, with mature PDPL, open data regulations, and AI ethics framework [40], [72], [73], [74], [102].

3. **Human Capital**

- **Libya (Low):** Significant skills gap with mismatch between available skills and labour needs [75], [76], [77], [79].

- **Tunisia (Low):** Inconsistent vocational training system and mismatch between education system and labor market requirements [80].

- **Saudi Arabia (High):** Consistent workforce development programs under Vision 2030 including HRDF, National Skills Platform, and Wa'ad Campaign [40], [81], [82].

4. **Innovation**

- **Libya (Low):** Nascent environment with low SaaS adoption, underdeveloped ecosystem, and support primarily through EU E-nable Project [77], [78], [83].

- **Tunisia (Medium-High):** Growing SME e-commerce sector, widespread mobile payments, and strong government backing for dynamic startup ecosystem with over 650 startups benefiting from Startup Act incentives [41], [84], [85].

- **Saudi Arabia (High):** Vision 2030-driven acceleration of cashless transactions and cloud adoption, with major investments in AI and emerging technologies through NEOM Innovation Hub [40], [86], [88].

5. **Cybersecurity**

- **Libya (Low):** GCI score of 68.1/100 (Tier 3); early stages with national CERT operational, drafting legislation but no comprehensive cybercrime strategy adopted [11], [70], [89].

- **Tunisia (Medium-Low):** GCI score of 82/100 (Tier 3); rising cybercrime, skills gap among professionals, need for greater investment in infrastructure [11], [90].

- **Saudi Arabia (High):** GCI score of 100/100 (Tier 1); proactive approach supported by significant governmental investment and robust regulatory framework led by NCA [11], [47].

6. Inclusion

- **Libya (Low):** Hindered by political instability, economic constraints, insufficient infrastructure, and skills gap; inconsistent digital integration in education and public services [76], [91], [92].

- **Tunisia (Low):** Obstacles include weak innovation capacities, limited public funding, insufficient stakeholder coordination, and missing impact data [39], [93].

- **Saudi Arabia (High):** Advancing equal access to digital services, education, and employment opportunities with attention to vulnerable groups; 99% internet usage and financial inclusion through digital payments [40], [87], [94].

4.4. Findings and discussion

The comparative analysis across the six digital transformation (DT) pillars reveals Libya's position as a nascent digital economy, with Tunisia serving as a transitional model and Saudi Arabia as the regional benchmark.

Libya demonstrates significant challenges across all dimensions, with particularly low scores in *Governance* (fragmented oversight, lack of a unified strategy) and *Innovation* (nascent private sector adoption and unclear academic research strategy). While *Infrastructure* shows potential with 88.4% internet penetration, it is hampered by low speeds and uneven access [44], [63], [101]. *Human Capital* development is critical, given the significant skills gap [75], [76], [77], and *Cybersecurity* readiness remains limited with legislative frameworks still under development [11], [70], [103]. Furthermore, efforts in *Inclusion* are constrained by economic and capacity limitations with insufficient online data [91], [92].

In contrast, **Saudi Arabia** exhibits advanced, balanced maturity, leading in *Infrastructure* (near-universal penetration, top-tier 5G) [40], [66], *Governance* (centralized, strategic execution) [74], and *Cybersecurity* (perfect GCI score) [11], [47].

Tunisia occupies a middle ground, with notable strengths in *Innovation* (growing SME ecosystem, mobile payments) [84], [85]. Yet, it is still facing challenges related to institutional stability in cybersecurity and data protection regulations [71].

The key point is that successful DT is multi-dimensional for Libya and similar nations. Immediate priorities have to include standardizing DT governance roles, investing in high-speed internet and local cloud infrastructure, strengthening legal frameworks for data protection and cybersecurity, and persuading private sector adoption to build a solid resilient digital economy.

Figure 2 and Table 2 assess national digital transformation across six core pillars. The axes represent Infrastructure, Governance, Human Capital, Innovation, Cybersecurity, and Inclusion. Scores are scaled from 0 to 100 and each country's profile instantly reveals its strategic position: a larger, more balanced shape indicates advanced, holistic development, while a smaller, irregular shape exposes critical gaps and inconsistent progress.

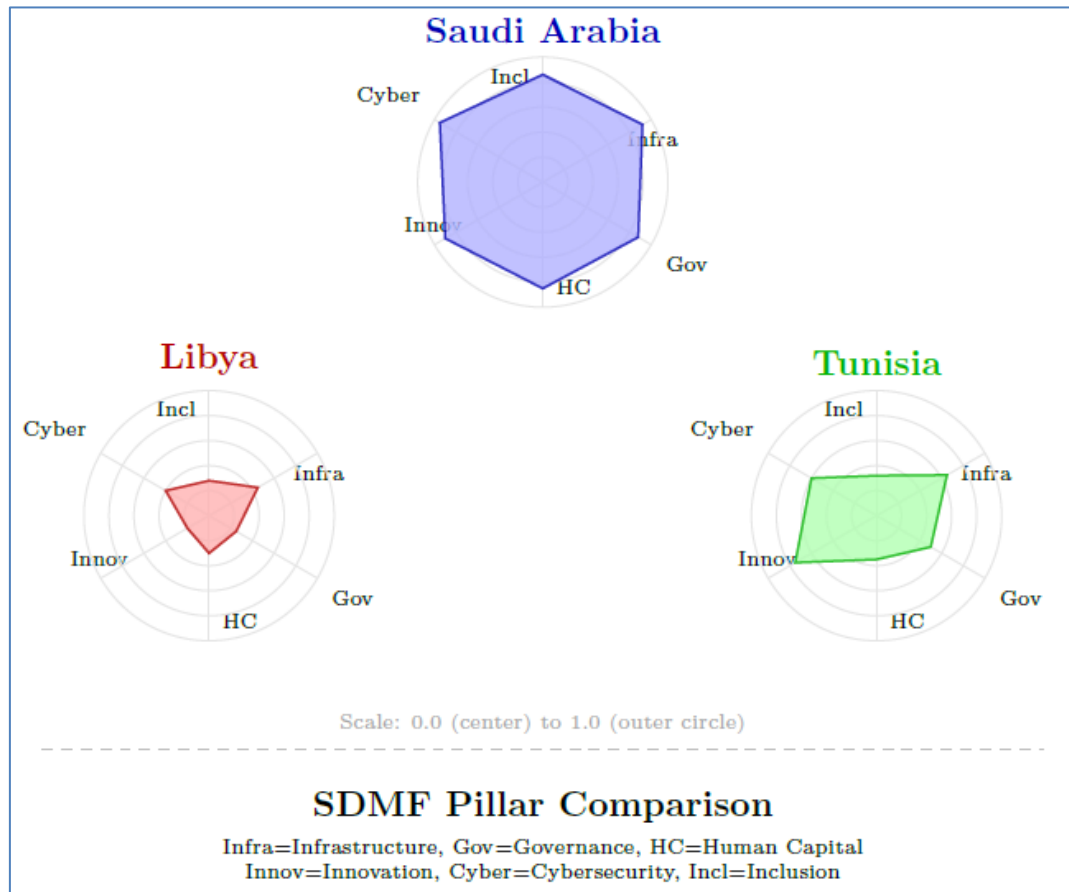


Figure 2: DT comparison of regional peers using SDMF

Table 2: SDMF Pillar Scores Comparison (/100)

Pillar	Libya	Tunisia	Saudi Arabia
Infrastructure	45	65	92
Governance	25	50	88
Human Capital	30	35	85
Innovation	20	75	90
Cybersecurity	40	60	95
Inclusion	28	32	86
Total	31	53	89
Pillar	Libya	Tunisia	Saudi Arabia
Infrastructure	45	65	92
Governance	25	50	88
Human Capital	30	35	85
Innovation	20	75	90
Cybersecurity	40	60	95
Inclusion	28	32	86
Total	31	53	89

5. CONCLUSION AND FUTURE WORK

This study has examined transitioning countries, Libya in particular, digital transformation trajectory through, the inherent constraints of a fragile, post-conflict institutional environment and the systemic inter-dependencies required for sustainable innovation. The findings underscore that digital transformation in fragile and transitional states is fundamentally a sequencing challenge, requiring the establishment of an authoritative coordination anchor prior to large-scale technological investment. Comparative experience indicates that without such institutional anchoring, digital initiatives risk producing isolated successes without systemic impact, reinforcing a governance–innovation decoupling that limits long-term transformation. Furthermore, the analysis confirms that Libya's digital landscape, while exhibiting nascent potential through sectoral initiatives in finance and private ICT services, is fundamentally characterized by strategic fragmentation and a critical governance deficit. The application of the Six-Pillar Digital Transformation Maturity Framework (SDMF) to Libya, Tunisia, and Saudi Arabia reveals a core finding for African innovation scholarship: **high technical investment without concomitant institutional scaffolding yields limited digital maturity**. Libya's relative infrastructure strength is systematically neutralized by its governance collapse, creating a pronounced governance-innovation decoupling that stifles the development of a cohesive national innovation ecosystem.

The study makes two primary contributions to African Science, Technology, and Innovation (STI) literature. **Theoretically**, it advances the SDMF as a diagnostic tool tailored for fragile state contexts, moving beyond DT models that presume stable governance. Empirically, the comparative institutional analysis provides evidence that in transitioning African states, institutional alignment, specifically the formalization of digital leadership and regulatory coherence, is the paramount catalyst for transforming infrastructure into inclusive growth.

To bridge this gap, evidence-based policy interventions must prioritize institutional development alongside technical upgrades. The following strategic pathway is proposed:

1. **Establish an Institutional Anchor:** Create a **Libya Digital Transformation Authority (LDTA)**. This central body would be mandated to unify standards, oversee the SDMF as a national assessment tool, and coordinate public-private initiatives, directly addressing the current fragmentation.
2. **Launch a Focused Institutional Pilot (2026–2028):** Implement a fast-track strategy targeting foundational governance. Key priorities must include enacting a comprehensive cybercrime and data protection law, deploying a national digital identity system, and formalizing critical organizational roles (Chief Information Officer and Governance, Risk, and Compliance officers) within lead ministries.
3. **Align Human Capital with Institutional Needs:** Develop targeted capacity-building programs under the LDTA to cultivate local expertise in digital governance, cybersecurity, and innovation management, ensuring that institutional reforms are sustainably led and maintained domestically.

Future research should investigate the longitudinal impact of such institutional interventions on innovation outcomes in fragile states and explore models for South-South cooperation in digital governance. For Libya and similar African states, the path to a resilient digital future lies not in bypassing institutional voids but in deliberately constructing the governance frameworks that enable technology to serve as a genuine engine for inclusive development.

Author Contributions: Ibrahim Ejdayid Ajbarah Mansour: Conceptualization, methodology, analysis, writing the original and the final draft editing

Funding: This research received no external funding.

Acknowledgments: The first author acknowledges the use of large language model-based tools to assist with language refinement, structural organization, and formatting of the manuscript. The tools were used solely to improve clarity and presentation. All scientific content, interpretations, and conclusions remain the sole responsibility of the author.

Conflicts of Interest: The authors declare that there is no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- [1] K. Schwab, *The Fourth Industrial Revolution: what it means, how to respond*. Geneva, Switzerland: World Economic Forum, 2016.
- [2] G. Nhamo, C. Nhemachena, and S. Nhamo, "Using ICT Indicators to Measure Readiness of Countries to Implement Industry 4.0 and the SDGs," *Environmental Economics and Policy Studies*, vol. 22, no. 2, pp. 315–337, 2020, doi: 10.1007/s10018-019-00259-1.
- [3] World Bank, "GovTech Tunisia: Life Events and Citizen Barometers." 2024. [Online]. Available: <https://www.worldbank.org/en/programs/teri/brief/govtech-tunisia-life-events-and-citizen-barometers>
- [4] A. Guermit and Z. Laouedj, "The Duality of Digital Innovation and Sustainable Development in MENA Countries," in *Competitive Advantage, Strategy and Innovation in Africa*, Routledge, 2023, p. 27. doi: 10.4324/9781003306405-8.
- [5] Ndulu, Benno J. and Stuart, Elizabeth and Dercon, Stefan and Knaack, Peter, *Driving Digital Transformation: Lessons from Seven Developing Countries*. Oxford University Press, 2023. doi: 10.1093/oso/9780192872845.001.0001.
- [6] Fozan Fareed, Sidra Rehman, Ran Bi, Jeong Dae Lee, Yuan Gao Rollinson and Tongfang Yuan, "Departmental Papers," *Digital Transformation in the Gulf Cooperation Council Economies*, vol. 2025, no. 003, International Monetary Fund, p. A001, 2025. doi: 10.5089/9798400291449.087.A001.
- [7] A. A. Varzaru and C. G. Bocean, "Digital Transformation and Innovation: The Influence of Digital Technologies on Turnover from Innovation Activities and Types of Innovation," *Systems*, vol. 12, no. 9, 2024, doi: 10.3390/systems12090359.
- [8] Sansom Milton and Mohammad Alhamawi, "World Development Perspectives," *Peace-centred sustainable development: An analysis of SDG 16 in the Arab states*, vol. 34, Elsevier, p. 100587, 2024. doi: 10.1016/j.wdp.2024.100587.
- [9] UN Economics24, "E-Government Development Index (EGDI) 2024." 2024. [Online]. Available: <https://publicadministration.un.org/egovkb/en-us/Data/Country-Information/id/97-Libya>
- [10] UN Economics22, "E-Government Development Index (EGDI) 2022." 2022. [Online]. Available: <https://publicadministration.un.org/egovkb/en-us/Data/Country-Information/id/97-Libya/dataYear/2022>
- [11] ITU Dev, *Global Cybersecurity Index 2024*. 2024. [Online]. Available: https://www.itu.int/en/ITU-D/Cybersecurity/Documents/GCIv5/2401416_1b_Global-Cybersecurity-Index-E.pdf
- [12] OECD Policy, "The OECD Digital Government Policy Framework: SIX DIMENSIONS OF A DIGITAL GOVERNMENT." 2020. [Online]. Available: <http://dx.doi.org/10.1787/f64fed2a-en>
- [13] S.Africa, "Egypt-Japan University of Science and Technology (E-JUST) TICAD8 African Scholarships for STI (TICAD8 Scholarships)." Department of Higher Education and Training, 2024. Accessed: Feb. 02, 2026. [Online]. Available:

<https://www.internationalscholarships.dhet.gov.za/index.php/scholarships/undergraduate-scholarships/446-egypt-egypt-japan-university-of-science-and-technology-ticad8-african-scholarships-for-sti-ticad8-scholarships>

- [14] UN Economic, "Digital Government in the Decade of Action for Sustainable Development," E-Government Survey 2020, 2020.
- [15] A. Jr. Singun, "Unveiling the Barriers to Digital Transformation in Higher Education Institutions: A Systematic Literature Review," *Discover Education*, vol. 4, no. 1, p. 37, 2025, doi: 10.1007/s44217-025-00430-9.
- [16] Ibrahim E A Mansour and Abdelhamid Bouchachia, "Institutional Conditions for Digital Innovation and Transformation: A Contingent Framework for Smart Technology Adoption in Developing Nations," Preprints.org, 2026. doi: 10.20944/preprints202602.0295.v1.
- [17] M. Javaid, A. Haleem, R. P. Singh, and A. K. Sinha, "Digital economy to improve the culture of industry 4.0: A study on features, implementation and challenges," *Green Technologies and Sustainability*, vol. 2, no. 2, p. 100083, 2024, doi: <https://doi.org/10.1016/j.grets.2024.100083>.
- [18] Richard Heeks, "Digital inequality beyond the digital divide: conceptualizing adverse digital incorporation in the global South," *Information Technology for Development*, vol. 28, no. 4, Routledge, pp. 688–704, 2022. doi: 10.1080/02681102.2022.2068492.
- [19] UN Press, *Widening Digital Gap between Developed, Developing States Threatening to Exclude World's Poorest from Next Industrial Revolution, Speakers Tell Second Committee*. 2023. [Online]. Available: <https://press.un.org/en/2023/gaef3587.doc.htm>
- [20] M. S. Sumbal, A. Tariq, Q. Amber, K. Janovská, and A. Ferraris, "Tech revolution unleashed: Navigating the winds of digital transformation in the fast lane," *Journal of Innovation & Knowledge*, vol. 9, no. 4, 2024.
- [21] Košíková, Martina and Vašaničová, Petra, "Exploring the Link Between Digital Readiness and Sustainable Development: A Cluster Analysis of EU Countries," vol. 17, no. 5080, Sustainability, 2025. doi: 10.3390/su17115080.
- [22] Christofi, Michael and Lamprinakos, Grigorios and Nguyen, Duc Khuong and Tran, Phuong Tra, "Digital strategy design and digital transformation: a review and future research directions," vol. 42, no. 6, International Marketing Review, 2025. doi: 10.1108/IMR-10-2025-0538.
- [23] W. Jack and T. Suri, "Mobile Money: The Economics of M-Pesa," *NBER Working Paper Series*, 2011.
- [24] African Union, "THE DIGITAL TRANSFORMATION STRATEGY FOR AFRICA." Addis Ababa, Ethiopia, 2020. [Online]. Available: https://au.int/sites/default/files/documents/38507-doc-DTS_for_Africa_2020-2030_English.pdf
- [25] Martin Mbaya and John Ouma-Mugabe, "A systematic literature review and mapping of systemic barriers to digital learning innovation in Africa in the context of changing global value chains," *African Journal of Science, Technology, Innovation and Development*, vol. 16, no. 4, Routledge, 2024. doi: 10.1080/20421338.2023.2287803.
- [26] ITU, *Irembo eGovernment Portal*. 2017. [Online]. Available: <http://www.irembo.gov.rw/>
- [27] Elizabeth Bermeo and Fabrizio Santoro, "Bridging the divide: Rwanda's quest for equitable digital governance," 2025. [Online]. Available: <https://www.ictd.ac/blog/bridging-the-divide-rwandas-quest-for-equitable-digital-governance/>
- [28] Ghulam Shabir Arain, "Tunisia drives digitization agenda forward while navigating

risks,” 2025.

[29] Alex Boakye, “Estimating the impact of digital technologies on government operations, business operations and general welfare: The case of South Africa,” *African Journal of Science, Technology, Innovation and Development*, vol. 16, no. 2, Routledge, 2024. doi: 10.1080/20421338.2023.2296181.

[30] LPITC-Acad, “Strategic projects.” Misurata, Libya. [Online]. Available: <https://lati.ly/en/>

[31] LATI-Academy, “Libyan Academy for Telecom & Informatics.” Tripoli, Libya. [Online]. Available: <https://lptic.ly/projects/>

[32] S. Zaptia, “General Information Authority makes its National Strategy for Artificial Intelligence (2025-2030) publicly available,” *Libya Herald*, 2025.

[33] J. Alonso, “New IT Governance Regulation: A Strategic Blueprint for Libyan Banks,” *Euro-Libya Trade Centre*, 2024.

[34] CBL-Inclusion, “Governor of the Central Bank of Libya announces from Tripoli the launch of the National Financial Inclusion Strategy.” 2025. [Online]. Available: <https://cbl.gov.ly/en/governor-of-the-central-bank-of-libya-announces-from-tripoli-the-launch-of-the-national-financial-inclusion-strategy-and-a-number-of-transformative-projects-during-the-opening-of-the-electronic-payment/#:~:text=Naji%20Mohammed%20Issa%20C%20Governor%20of,without%20requiring%20a%20bank%20account.>

[35] CBL-18, “Publication No. 18 of 2025 regarding the Data Protection System and the Regulatory Bylaw for the Banking Sector.” 2025. [Online]. Available: <https://lawsociety.ly/legislation/منشور-رقم-18-لسنة-2025-م-بشأن-نظام-حماية-البي>

[36] AWAL, “AWAL leading Libyan Internet Provider.” Tripoli, Libya. [Online]. Available: <https://awal.ly/>

[37] LS, “Libyan Spider technology and cloud service provider.” Tripoli, Libya. [Online]. Available: <https://libyanspider.com/>

[38] Speedtest, “Speedtest Global Index ranking.” [Online]. Available: <https://www.speedtest.net/global-index>

[39] Digital Watch, “Tunisia’s National Digital Strategy 2021-2025.” 2020.

[40] J. Olaje, “Vision 2030 in Saudi Arabia: A Shift to Digital Governance.” 2025. [Online]. Available: <https://www.azeusconvene.com/en-sa/articles/vision-2030-and-digital-governance-in-saudi-arabia>

[41] S. Njaya, “Tunisia: Electronic Transactions Hit \$8.8 Billion in 2024.” 2024.

[42] G. B. Sahibdeep Singh, “Challenges of Applying Artificial Intelligence in Libyan Higher Education,” *Journal of Research in Vocational Education*, 2025.

[43] O. Elswad and C. Jensen, “Identity management for e-government Libya as a case study,” *Information Security for South Africa (ISSA)*, 2016.

[44] W. Olabiyi, “Evaluating the Effectiveness of Government Policies and Initiatives in Mitigating the Digital Divide in E- Learning in Libya,” 2024.

[45] T. M. H. Al-Gailani and S. M. Said, “Challenges of ICT Infrastructure in Post-Conflict Libya,” in *Proc. 2019 Int. Conf. Informatics, Technology and Engineering (InCITE)*, 2019, pp. 1–6.

[46] A. B. Martin Wynn and Y. Forti, “Digital Transformation in Libyan Municipalities: Governance Challenges and Coordination Issues,” *International Journal of Teaching and Case Studies*, 2021.

[47] F. Alharbi, “Twelve Years of Cyber Resilience: Analyzing Cyberattacks in Saudi Arabia (2012-2024),” in *TEM JOURNAL - Technology, Education, Management, Informatics*, 2025.

- [48] O. A.-T. Alberto-Tomas Delso-Vicente Luis Diaz-Marcos and M. G. de Blanes-Sebastián, "Factors influencing employee compliance with information security policies: a systematic literature review of behavioral and technological aspects in cybersecurity," *Future Business Journal*, 2025.
- [49] World Bank, *The Upside of Digital for the Middle East and North Africa: How Digital Technology Adoption Can Accelerate Growth and Create Jobs*. 2022.
- [50] J. Taylor, "Google Cloud accidentally deletes UniSuper's online account due to 'unprecedented misconfiguration,'" *The Guardian*, 2024.
- [51] E. Casprini and R. Palumbo, "Reaping the benefits of digital transformation through Public-Private Partnership: A service ecosystem view applied to healthcare," *Global Public Policy and Governance*, 2022.
- [52] Y.-W. Chang and J. Chen, "An empirical investigation of critical success factors in implementing digital transformation," *Journal of Technological Forecasting and Social Change*, vol. 217, 2025.
- [53] I. B. Mohammad Rakibul, *Industry Readiness and Adaptation of Fourth Industrial Revolution: Applying the Extended TOE Framework*. Wiley online library, 2024.
- [54] A. Waara, "Examining Digital Government Maturity Models: Evaluating the Inclusion of Citizens," *MDPI Administrative Sciences*, 2025.
- [55] el Mostafa Alshamy, "Stage-based maturity model approach for measuring enterprise governance of information technology and supply chain sustainability in Middle East and North Africa region," *International Business Logistics*, 2024.
- [56] OECD Gover17, *Benchmarking Digital Government Strategies in MENA Countries*. OECD Publishing, 2017.
- [57] A. A. Okan, "Exploring the Landscape of e-Government Maturity Models: Insights from Systematic Mapping Study and Comparative Analysis," *ACM Digital Government: Research and Practice*, vol. 5, no. 2, 2024.
- [58] H. F. Dmitry Plekhanov and T. H. Netland, "Digital transformation: A review and research agenda," *European Management Journal*, vol. 41, no. 6, 2023.
- [59] EU Commission, "European Commission: Directorate-General for Communications Networks, Content and Technology and Visionary Analytics, International benchmarking of the digital transformation – Executive summary," *Publications Office of the European Union*, 2024.
- [60] Omol, Edwin Juma and Mburu, Lucy Waruguru and Abuonji, Paul Anyango, "Digital Maturity Assessment Model (DMAM): assimilation of Design Science Research (DSR) and Capability Maturity Model Integration (CMMI)," vol. 4, no. 2, *Digital Transformation and Society*, pp. 128–152, 2024. doi: 10.1108/DTS-04-2024-0049.
- [61] D. Plekhanov, H. Franke, and T. H. Netland, "Systematic comparison of digital maturity assessment models," *Journal of Industrial Production Engineering*, 2023.
- [62] RMG team, *Pillars of Digital Transformation: Your Comprehensive Guide to Building a Sustainable Digital Enterprise*. World Economic Forum and FTI Consulting, 2025.
- [63] Marcin Franckiewicz, "Internet Access in Libya: A Comprehensive Overview." 2025.
- [64] Marcin Franckiewicz, "The Digital Desert Awakens: Inside Tunisia's Expanding Internet Frontier." 2025.
- [65] Africa Wireless, "Tunisia works on connecting schools." 2023. [Online]. Available: <https://www.africanwirelesscomms.com/news-details?itemid=6778>
- [66] Saudi (CST), "CST Issued the Saudi Internet Report 2024." 2025.
- [67] Mordor Intelligence, "Saudi Arabia Hyperscale Data Center Market Size & Share

- Analysis Source.” 2025. [Online]. Available: <https://www.mordorintelligence.com/industry-reports/saudi-arabia-hyperscale-data-center-market>
- [68] A. Al-Tira and F. Gerdes, “Libya’s Economy: A Digital Transformation as a Path to Stability?,” German Institute for International and Security Affairs (SWP), Comment 2021/C 51, 2025.
- [69] Eltumi Partners, “Data Protection under Libya’s e-Transactions Law.” 2023.
- [70] Octopus Cybercrime, “Libya Cybercrime policies/strategies by Octopus Cybercrime Community.” 2025.
- [71] DLA Piper, “Data protection laws in Tunisia.” 2025.
- [72] Saudi DGA, “Digital Government Authority (DGA).” 2025. [Online]. Available: <https://dga.gov.sa/en>
- [73] SDAIA, “Saudi Data and Artificial Intelligence Authority.” 2025. [Online]. Available: <https://sdaia.gov.sa/en>
- [74] Saudi unified DGA, “Saudi Digital Government Authority (DGA) Integrates and Closes 267 Digital Platforms.” 2025. [Online]. Available: <https://dga.gov.sa/en/news/digital-government-continues-whole-of-government-program>
- [75] A. B. Shwehdy, “Drivers and Barriers in Libya’s E-Government Implementation - A Case Study,” *26th Annual International Conference on Digital Government Research*, 2025.
- [76] Alwadi Co., “The State of Digital Transformation in Libya.” [Online]. Available: <https://alwadi.ly/the-state-of-digital-transformation-in-libya/>
- [77] EU4Skills, “Promoting Skills and Employability for Private Sector Development.” [Online]. Available: <https://alwadi.ly/the-state-of-digital-transformation-in-libya/>
- [78] E-nable, “EU-funded E-nable Project Concludes with Remarkable Achievements for Libya’s Economic Growth.” Tripoli, Libya. [Online]. Available: https://e-nable.ly/e_nable_final_ceremony_pr/
- [79] IOM Libya, “Labour Market Assessment Libya.” [Online]. Available: https://libya.iom.int/sites/g/files/tmzbd1931/files/documents/20210811_LMA%20Collated%20Report%20ENG.pdf
- [80] EU Training Foundation (ETF), “Policies for human capital development in Tunisia.” 2021.
- [81] Saudi Wa’ad, “The first edition of ‘Wa’ad’ achieved remarkable success.” 2024.
- [82] Saudi NSP, “National Skills Platform.” 2025.
- [83] Korhogo Agency, “Libya’s Economy and Digital Landscape.” 2025.
- [84] O. S. Philip Benton, “Evolution of Digital Banking in MEA.” 2025.
- [85] R. Mubika, “From Tourism to Tech: Tunisia’s Startup Ecosystem Finds Its Voice.” 2025.
- [86] Oxford Business G, “What is behind growth in Saudi Arabia’s ICT sector?” 2025.
- [87] S. Brains, “SDAIA and Vision 2030: How It’s Leading AI in Saudi Arabia’s Digital Transformation.” 2025.
- [88] NEOM, “The NEOM innovation hub.” 2025.
- [89] NISSA, “National Information Security and Safety Authority.” 2025. [Online]. Available: <https://nissa.gov.ly/en/>
- [90] ISC2 Chapter, “Navigating Cybersecurity in Tunisia: Trends and Challenges for 2025.” 2025.
- [91] Spark, “Clicks to Progress: Celebrating Libyan Youth’s Role in Digital Transformation.” 2024.

- [92] Libya Digital Dev, "Libya Digital Ecosystem Country Assessment (DECA)." 2022.
- [93] F. Raddoui, "Inclusive Innovation in Tunisia Main Challenges and Policies Implemented," *International Journal of Research and Innovation in Social Science (IJRISS)*, 2024.
- [94] Saudi NP, "Digital Inclusion." 2025. [Online]. Available: <https://my.gov.sa/en/content/digital-inclusion/#section-9>
- [95] S. Ekanem, "Top 10 African Countries with Best Digital Quality of Life," *Business Insider Africa*, 2025, [Online]. Available: <https://africa.businessinsider.com/local/lifestyle/top-10-african-countries-with-best-digital-quality-of-life/jrk72tj>
- [96] African Manager, "Tunisia ranks among top 5 African countries for Digital Quality of Life." 2024. [Online]. Available: <https://en.africanmanager.com/tunisia-ranks-among-top-5-african-countries/-for-digital-quality-of-life/>
- [97] A. Guermit and Z. Laouedj, "The Duality of Digital Innovation and Sustainable Development in MENA Countries," in *Competitive Advantage, Strategy and Innovation in Africa*, Routledge, 2023, p. 27. doi: 10.4324/9781003306405-8.
- [98] C. Barnet, N. Maïzi, and S. Selosse, "From hydrocarbon to low-carbon hydrogen: Energy and economic challenges facing the Middle East and North Africa region," *Renewable and Sustainable Energy Reviews*, vol. 217, p. 115768, 2025, doi: <https://doi.org/10.1016/j.rser.2025.115768>.
- [99] R. A. D. Sarto and E. S. i Lecha, "Regionalism and Alliances in the Middle East, 2011-2021: From a 'Flash in the Pan' of Regional Cooperation to Liquid Alliances," *Geopolitics*, vol. 29, no. 4, pp. 1447–1473, 2024, doi: 10.1080/14650045.2023.2268542.
- [100] H. M. Aljaroodi, M. T. P. Adam, T. Teubner, and R. Chiong, "Understanding the Importance of Cultural Appropriateness for User Interface Design: An Avatar Study," *ACM Trans. Comput.-Hum. Interact.*, vol. 29, no. 6, 2023, doi: 10.1145/3517138.
- [101] UN25, "UN E-Government Knowledgebase." [Online]. Available: <https://publicadministration.un.org/egovkb/Data-Center>
- [102] G. Kayal and J. Shin, "AI Watch: Global regulatory tracker - Saudi Arabia." 2024.
- [103] NISSA, "Libya State of Cybersecurity report 2024." 2024.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of JLABW and/or the editor(s). JLABW and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.
