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Technology, Society, and Sustainable Development: A Critical Integrative Review

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Abstract

Digital technologies increasingly influence the institutional, economic, social, and environmental pathways through which sustainable development is pursued. Existing research, however, remains dispersed across technological domains and Sustainable Development Goals (SDGs), with limited integration of distributional, environmental, and governance conditions in developing-country settings. This study conducts a qualitative critical integrative review of peer-reviewed and institutional literature published primarily between 2016 and 2026. Sources were identified purposively through academic databases, publisher platforms, and repositories of international organisations and assessed using explicit relevance criteria. The synthesis applies sociotechnical systems theory and the capability approach to examine digital technologies, artificial intelligence, and digital public infrastructure across social, economic, environmental, and governance dimensions. Three recurrent positions are identified in the literature: technology-optimist, technology-risk, and governance-conditioned perspectives. The reviewed evidence indicates that digital technologies can extend access to education, health services, financial services, public administration, and environmental monitoring, while benefits remain uneven where connectivity, affordability, skills, institutional capacity, and data governance are inadequate. Digitalisation also entails material and energy costs associated with data infrastructure, computation, hardware production, and electronic waste. The synthesis supports a conditional interpretation of technology's contribution to sustainable development: developmental effects depend on inclusive access, digital capability, environmental responsibility, accountable governance, institutional capacity, and international cooperation. The proposed framework remains an interpretive proposition requiring subsequent empirical evaluation.

Keywords: technology, society, sustainable development, digitalisation, digital divide, artificial intelligence, governance.



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INTRODUCTION

Digital networks, artificial intelligence (AI), mobile technologies, cloud computing, automation, the Internet of Things (IoT), and digital public infrastructure increasingly influence communication, education, employment, commerce, and access to public services. The 2030 Agenda for Sustainable Development identifies technology, data, and innovation as important means of implementation for the Sustainable Development Goals (SDGs) (United Nations, 2015). Subsequent academic and institutional research has examined the potential contribution of AI, blockchain, IoT, big data, and remote sensing across the seventeen SDGs (Hariyani, Hariyani, & Mishra, 2025; Vinuesa et al., 2020).

Three limitations remain prominent in this literature. First, research frequently concentrates on individual technologies or single SDGs, which restricts analysis of interactions among technological, social, economic, and environmental dimensions; this fragmentation is also identified in the PRISMA review of 473 studies reported by Hariyani, Hariyani, and Mishra (2025). Second, structural conditions that are especially consequential in developing countries, including constrained digital infrastructure, persistent digital divides, and limited regulatory capacity, receive less systematic attention than technological opportunity. Third, benefits and risks are commonly examined as separate analytical domains even though both arise from the institutional and social conditions under which technologies are designed, distributed, and governed.

This study addresses these limitations through a theory-informed critical integrative review. The analysis is guided by three research questions: (1) how emerging technologies contribute to sustainable

development; (2) which social and environmental risks accompany technological expansion, particularly in developing-country settings; and (3) which governance conditions influence whether technological change produces inclusive and environmentally sustainable outcomes. The analytical proposition examined throughout the review is that developmental effects are conditional on access, institutional capacity, governance arrangements, human capability, and environmental safeguards. This proposition is treated as an interpretive synthesis of the reviewed literature rather than as a causal claim established through primary empirical testing.

The contribution is analytical rather than bibliometric. Systematic reviews such as Hariyani, Hariyani, and Mishra (2025) and Lythreatis, Singh, and El-Kassar (2022) map and classify defined bodies of evidence through explicit search and screening procedures. The present integrative review instead combines literatures on digital opportunity, digital inequality, AI ethics, environmental impacts, and data governance within a common analytical framework. Sociotechnical systems theory is used to examine the interaction between technical systems and institutional arrangements, while the capability approach is used to distinguish formal access to technology from the substantive capacity to derive valued outcomes from it. The study contributes by integrating these lenses across economic, social, environmental, and governance dimensions, comparing three recurrent perspectives in the literature, and deriving seven conditions for assessing when technological deployment is compatible with sustainable development, with particular attention to developing-country settings.

RESEARCH METHODS

The study uses a qualitative critical integrative literature review. This design permits synthesis of heterogeneous evidence, including peer-reviewed research and authoritative institutional reports on technology, digitalisation, social transformation, and sustainable development, for the purpose of developing and examining a conceptual argument. The review is not a systematic review: no pre-registered protocol or PRISMA flow procedure was applied. Methodological transparency is instead provided through explicit description of source identification, eligibility criteria, thematic synthesis, and qualitative appraisal.

Identification

Sources were identified through Google Scholar, publisher platforms, and the repositories of the United Nations, UNESCO, UNCTAD, UNEP, the World Bank, the International Telecommunication Union (ITU), the OECD, and UNITAR. Scopus-indexed journals were prioritised where relevant. Searches combined terms including "digital technology," "artificial intelligence," "sustainable development," "digital divide," "e-waste," "data governance," and "capability approach." The search was purposive rather than exhaustive, and individual retrieval and exclusion counts were not systematically recorded. The resulting evidence base should consequently be interpreted as a theoretically directed sample of relevant literature rather than a comprehensive census of publications.

Screening and eligibility

Sources published between 2016 and 2026 were prioritised to capture research produced during the SDG implementation period and the recent expansion of generative AI. Earlier publications were retained when they provided theoretical foundations that continue to inform contemporary analysis, including Sen (1999), Robeyns (2005), Zheng (2009), and Oosterlaken (2011). Inclusion required a direct connection between digital or AI technologies and at least one social, economic, environmental, or governance dimension of sustainable development. Purely technical computer-science studies without a development or policy dimension were excluded.

Synthesis and appraisal

The synthesis was organised around four interconnected themes: technological opportunity, social inclusion, environmental consequences, and governance. Sociotechnical systems reasoning was used to examine how technical capabilities interact with institutions, organisations, and users, while the capability approach was used to assess whether access to technological resources is converted into substantive opportunities and outcomes. Evidence was appraised qualitatively according to source type, geographical scope, and the definitions underlying quantitative estimates. Claims were qualified where evidence was geographically narrow, conceptually heterogeneous, or based primarily on institutional

synthesis rather than outcome evaluation. The review does not estimate causal effects; its purpose is to integrate the available evidence and formulate a testable framework describing the conditions under which technology may contribute to sustainable development.

RESULTS AND DISCUSSION

Technology and the Sustainable Development Goals

Table 1 summarises the relationship between major technology families discussed in the reviewed literature and selected SDGs, together with recurrent constraints associated with their application. The synthesis draws on Hariyani et al. (2025), Vinuesa et al. (2020), UNESCO (2023), UNEP (n.d.), UNCTAD (2024), and World Bank (2024).

Table 1. Technology-SDG Linkages and Key Challenges

SDG	Potential technological contribution	Major challenge
SDG 1 — No Poverty	Digital financial services; social-protection platforms	Exclusion of digitally disconnected groups
SDG 3 — Health	Telemedicine; AI-assisted diagnosis; digital health records	Privacy, data quality, and unequal access
SDG 4 — Education	Digital learning platforms; open educational resources	Digital and pedagogical inequalities
SDG 6 — Water	Smart monitoring and leak/quality detection systems	Institutional and financing capacity
SDG 7 — Energy	Smart grids; renewable-energy optimisation	Infrastructure and investment requirements
SDG 9 — Infrastructure	Digital infrastructure and innovation ecosystems	Unequal technological capacity between countries
SDG 11 — Cities	Smart transport and urban monitoring	Surveillance risk and exclusion of non-users
SDG 12 — Consumption	Digital supply-chain traceability	Growing electronic-waste burden
SDG 13 — Climate	Climate modelling; emissions and disaster monitoring	Energy footprint of the monitoring systems themselves
SDG 16 — Institutions	Digital government; transparency platforms	Privacy, misinformation, and cyber risk
SDG 17 — Partnerships	Knowledge sharing and technology transfer	Unequal digital capacity between countries

Table 1. Technology and selected Sustainable Development Goals. Source: Authors' synthesis based on Hariyani, Hariyani, and Mishra (2025), Vinuesa et al. (2020), UNESCO (2023), UNEP (n.d.), UNCTAD (2024), and World Bank (2024).

The synthesis indicates that technology operates as a cross-cutting means of implementation rather than as an independent development objective. Across the mapped SDGs, major constraints are predominantly institutional, distributional, or environmental rather than purely technical. This pattern is consistent with both sociotechnical systems reasoning and the capability approach, which locate developmental outcomes in the interaction between technical resources and the conditions that enable their effective use. The mapping is interpretive and is intended to identify recurrent relationships in the reviewed literature rather than to represent a systematic coding of all available studies.

Sectoral Applications: Economy, Education, and Health

In the economic domain, the World Bank's Digital Dividends framework identifies complementary institutions, skills, and competition policy as conditions that shape whether digital technologies broaden economic opportunity and improve service delivery (World Bank, 2016). Subsequent evidence similarly indicates that digitalisation can expand access to information, markets, and services while concentrating gains among firms and individuals with stronger capital, skills, and connectivity when complementary conditions are weak (World Bank, 2016, 2024). The expansion of

cloud infrastructure, computational capacity, and data-intensive business models also contributes to disparities between countries and firms that produce digital technologies and those positioned mainly as technology consumers (UNCTAD, 2024).

In education, UNESCO (2023) evaluates educational technology in relation to relevance, equity, scalability, and sustainability rather than assuming a uniform positive effect on learning. Reported outcomes depend on teacher capacity, infrastructure, curriculum, learner circumstances, and the quality of human interaction. These conditions are also relevant to generative AI, where potential benefits such as personalised support coexist with concerns regarding academic integrity, bias, and dependence on automated systems. From a capability perspective, access to digital learning tools constitutes a resource; educational benefit depends on the skills, guidance, and institutional support required to use that resource effectively.

In health, telemedicine and AI-assisted diagnostic systems can extend professional services to geographically dispersed populations and improve information management, supporting objectives associated with SDG 3 (Haleem et al., 2021). Their use also introduces substantial requirements for data quality, privacy protection, professional oversight, and equitable access. Incomplete or biased data can reproduce existing disparities when algorithmic systems are integrated into clinical or administrative decisions. The reviewed evidence consequently supports treating health-sector performance as a joint function of technical capability and governance quality rather than as an outcome of technological availability alone.

The Digital Divide and Social Inequality

The digital divide is more accurately represented as a multidimensional form of inequality than as a single access gap. Lythreath, Singh, and El-Kassar (2022) distinguish physical access to connectivity and devices from disparities in skills and meaningful use, while more recent discussion extends the analysis to unequal outcomes associated with platforms, data, and algorithmic systems. This framing is consistent with earlier distinctions among material access, skills, and patterns of use (van Dijk, 2020) and with work on differential outcomes of internet use (Ragnedda, 2017). The empirical strength of these dimensions is not equivalent. Physical access is routinely measured through national and international statistics, skills and meaningful use have a substantial research base, and algorithmic inequality remains comparatively less developed empirically. ITU (2025) estimates that 2.2 billion people remained offline, capturing the access dimension, while Jamil's (2021) Pakistan-focused analysis illustrates how affordability, electricity reliability, and gender norms can constrain meaningful use even where basic infrastructure exists.

The capability approach clarifies why infrastructure expansion alone is insufficient as a measure of digital inclusion. Connectivity and devices provide resources, but their conversion into substantive capability depends on affordability, digital literacy, locally relevant content and interfaces, and protection against platform- and algorithm-related harms. Digital-inclusion policy is therefore more accurately evaluated through measures of meaningful use and realised opportunity than through infrastructure availability alone.

Environmental Sustainability and the Footprint of Digitalisation

Environmental assessment requires simultaneous consideration of the benefits enabled by digital technologies and the environmental costs of their production and operation. Digital systems can support energy management, precision agriculture, and remote monitoring of deforestation, biodiversity, and climate indicators (Vinuesa et al., 2020). UNEP (n.d.) distinguishes the use of digital technologies for environmental objectives from the separate requirement that digitalisation itself be environmentally sustainable. This distinction is important because environmental benefits at the application level do not necessarily imply a favourable life-cycle environmental balance.

Available quantitative evidence documents substantial resource and energy requirements associated with digitalisation, although estimates vary with system boundaries and accounting methods. UNCTAD (2024) reports that digital devices, data centres, and ICT networks together account for an estimated 6-12% of global electricity use, while data centres consumed approximately 460 terawatt-hours in 2022. The growing computational intensity of AI may increase this demand (Kaack et al., 2022). The breadth of the electricity-use range reflects differences in whether estimates include hardware production as well as operational consumption and should therefore be interpreted as an order-

of-magnitude indicator. The Global E-waste Monitor 2024 reports 62 million tonnes of electronic waste generated in 2022, an 82% increase from 2010, with documented environmentally sound collection and recycling covering 22.3% of the total (Baldé et al., 2024). Zhuk (2023) further identifies data-centre energy use, hardware-related resource extraction, and AI-associated electronic waste as environmental costs that are often omitted from assessments of AI-enabled sustainability benefits. AI-specific environmental impacts remain less precisely quantified than aggregate ICT impacts.

These findings support a life-cycle approach to evaluating the sustainability contribution of digital and AI applications. Environmental benefits generated through monitoring, optimisation, or decision support should be assessed alongside the energy, material, and waste burdens of the infrastructure required to produce those benefits. A point-of-use assessment alone can consequently overstate the net environmental contribution of digital systems.

Governance, Data, and Institutions

Governance conditions are central to the relationship between technological capability and sustainable development. Jobin, Ienca, and Vayena's (2019) global analysis of AI ethics guidelines identifies broad normative convergence around transparency, fairness, non-maleficence, and accountability, but substantially less convergence regarding implementation. The OECD (2022) similarly identifies persistent tensions between data flows and privacy protection, innovation and precaution, and national regulatory autonomy and cross-border digital services. Jamil's (2021) study of digital inclusion in Pakistan illustrates how expanded connectivity may exceed institutional capacity for regulation and data protection in a developing-country setting. Because this evidence derives from a single national case, its broader applicability remains limited. Goh and Vinuesa (2021) likewise identify AI regulation as a relevant condition for alignment between AI applications and the SDGs.

Cybersecurity, digital government, and international cooperation extend the governance requirements associated with sustainable digitalisation. Increasing digitisation of health, financial, and administrative systems raises the social and economic consequences of cyber incidents and increases the importance of institutional resilience. At the international level, the United Nations Global Digital Compact and SDG 17 emphasise cooperation, technology transfer, and shared governance for cross-border issues including connectivity, AI standards, and electronic-waste flows (United Nations, 2024). UNCTAD (2024) further indicates that the environmental and economic burdens of digitalisation are unevenly distributed, with developing countries often occupying weaker positions in high-value digital production while facing substantial resource-extraction and waste-management pressures.

Towards a Human-Centred, Sustainable Technology Framework

Cross-domain comparison identifies a consistent conditional pattern, although the strength of supporting evidence varies. Economic and educational studies emphasise complementary institutions, skills, infrastructure, and competition or curriculum conditions (World Bank, 2016; UNESCO, 2023). Health-sector evidence highlights data quality and professional accountability (Haleem et al., 2021), while digital-inclusion research identifies affordability, electricity reliability, skills, and gender-related constraints (Jamil, 2021). Environmental studies require life-cycle accounting (UNEP, n.d.), and AI-governance research emphasises enforceable regulation and accountability (Jobin et al., 2019; OECD, 2022). Evidence is strongest where multiple independent literatures identify similar constraints and weaker where conclusions rely on geographically narrow cases or conceptually emerging dimensions, particularly algorithmic inequality. Quantitative environmental findings are comparatively extensive but remain sensitive to definitions and system boundaries.

Integration of these findings through the sociotechnical and capability perspectives yields seven interdependent principles for human-centred and sustainable technological development, summarised in Table 2.

Table 2. Core Principles of Human-Centred and Sustainable Technological Development

Principle	Main requirement	Theoretical basis
Inclusion	Affordable, universal, meaningfully usable access	Capability approach (Sen, 1999)
Digital capability	Skills, literacy, locally relevant content	Conversion factors (Zheng, 2009; Oosterlaken, 2011)
Sociotechnical fit	Alignment with institutions, culture, existing systems	Sociotechnical systems theory (Hariyani et al., 2025)
Environmental responsibility	Life-cycle assessment of energy and materials	UNEP (n.d.); Baldé et al. (2024); Kaack et al. (2022)
Data governance	Privacy, transparency, and accountability	OECD (2022); Jobin et al. (2019)
Institutional capacity	Effective, enforceable regulation	Jamil (2021); OECD (2022)
International cooperation	Finance, knowledge, and technology transfer	United Nations (2024); UNCTAD (2024)

Table 2. Principles for human-centred, sustainable technological governance. Source: Authors' synthesis of the sources cited in the table.

The proposed framework treats the seven principles as interdependent conditions rather than as independent policy items. Each principle represents a conversion factor or sociotechnical condition that influences whether technical capacity produces substantive developmental capability. Inclusive infrastructure without data-governance safeguards, for example, may expand access while increasing exposure to privacy or accountability risks; environmental monitoring systems may generate useful information while imposing substantial energy and material costs. The framework therefore conceptualises sustainable technological development as conditional on the joint adequacy of access, capability, institutional fit, environmental responsibility, data governance, institutional capacity, and international cooperation. This proposition has not been tested through primary empirical research, and the supporting evidence varies across dimensions.

Critical Discussion

The reviewed literature can be organised into three broad analytical perspectives: technology optimism, technology risk, and governance-conditioned development. Comparison of these perspectives clarifies the assumptions underlying different evaluations of technological change. Because the present study is an interpretive review, the comparison assesses explanatory consistency with the assembled evidence rather than establishing empirical superiority among the perspectives.

The technology-optimist perspective treats innovation as a major mechanism for addressing development challenges. Its empirical basis includes the wide range of SDG-relevant applications documented in research on digital technologies and sustainable development (Hariyani et al., 2025; Vinuesa et al., 2020). This perspective is strongest in identifying potential applications and productivity or service gains. Its explanatory limitation is that distributional and environmental costs may be treated as secondary even when they are structurally associated with the production, deployment, and use of the same technologies.

The technology-risk perspective emphasises inequality, surveillance, environmental burden, and governance failure. Substantial support for these concerns is provided by research on the digital divide (Lythreath et al., 2022), electronic waste (Baldé et al., 2024), and AI ethics (Jobin et al., 2019). This perspective identifies important constraints and externalities but offers less direct guidance on the institutional conditions under which documented technological benefits can be retained while risks are reduced.

The governance-conditioned perspective interprets technological benefits and costs as outcomes of the same sociotechnical system. Under this interpretation, governance, institutional capacity, accessibility, and environmental safeguards influence the balance between beneficial and adverse outcomes. This perspective is consistent with the cross-sector pattern identified in the review, where major constraints are frequently institutional or distributional rather than purely technical. Alternative interpretations remain plausible: expanding connectivity may support a more optimistic assessment

(ITU, 2025), while weak enforcement of ethical and regulatory standards may support a more risk-centred interpretation. The conditionality framework should consequently be treated as a theoretically integrated synthesis whose empirical support differs across dimensions, not as a conclusively superior account.

A conceptual tension also exists between the individual-level emphasis of the capability approach and the structural analysis required by digital-divide and environmental research. Focusing primarily on individual skills and conversion factors may understate the influence of market concentration, national infrastructure investment, regulatory capacity, and international terms of technology production and trade. A governance-centred synthesis therefore requires both levels of analysis: the capability approach clarifies whether technological resources expand substantive human opportunities, while sociotechnical and structural perspectives identify the institutional and political-economic conditions that shape those opportunities.

CONCLUSION

The review addresses three limitations in research on technology and sustainable development: fragmentation across individual technologies and SDGs, limited treatment of developing-country structural conditions, and the analytical separation of technological benefits from associated social and environmental risks. The combined sociotechnical and capability perspectives indicate that digital technologies can contribute to economic, social, and environmental objectives, but the magnitude and distribution of those contributions depend on enabling conditions. The synthesis identifies inclusive access, digital capability, sociotechnical fit, environmental responsibility, accountable data governance, institutional capacity, and international cooperation as interdependent conditions shaping developmental outcomes. Weakness in these conditions can reduce benefits or intensify inequality, governance deficits, and environmental burdens.

Policy implications follow from the conditional nature of these findings and should be interpreted as evidence-informed propositions rather than tested prescriptions. Connectivity policy and digital-capability development should be designed as complementary interventions because infrastructure alone does not ensure meaningful use. Ministries responsible for digital infrastructure, education, and health, together with telecommunications regulators, can combine universal-service measures with affordability policies, digital-literacy programmes, and institutional support. Relevant monitoring indicators include population internet use, gender disparities in internet use, and the affordability of entry-level connectivity relative to income.

Environmental governance should incorporate the life-cycle impacts of digital and AI infrastructure, including energy sourcing, hardware production, material consumption, and electronic-waste management. Potential regulatory instruments include life-cycle disclosure for data centres, extended producer responsibility for electronic equipment, and formal collection and recycling targets. Assessment should include measurable indicators of energy and material intensity as well as documented collection and recycling rates. Such measures would permit environmental benefits from digitalisation to be evaluated alongside the resource burdens required to produce them.

Data-protection authorities and sectoral regulators, particularly in health and finance, require governance instruments that translate broad AI principles into monitorable obligations. Algorithmic impact assessment, independent audit, incident reporting, transparency requirements, and defined accountability for automated decisions are examples of mechanisms consistent with the governance concerns identified in the literature. Their purpose is to constrain risks to privacy, fairness, transparency, and institutional accountability without assuming that technical efficiency alone constitutes a public benefit.

International cooperation on technology transfer, financing, and capacity development should be evaluated according to its contribution to durable local capability. Programmes that include skills development, technical maintenance, institutional strengthening, and knowledge transfer are more consistent with the capability framework than arrangements limited to the transfer of finished technological products. This orientation also addresses the unequal distribution of production capacity and environmental burdens identified in the digital-economy literature.

Several methodological limitations constrain interpretation of the findings. The review is integrative rather than systematic, uses a purposive search strategy, and was not conducted under a pre-specified protocol. Records identified, screened, and excluded were not counted systematically, and

relevant studies may therefore have been omitted. Source selection and thematic interpretation also involve author judgement. A registered systematic or scoping review using explicit reporting procedures would provide a complementary assessment of the prevalence and consistency of the three perspectives identified here.

The evidentiary base is uneven across dimensions. AI ethics and digital-divide research are more developed than country-specific evidence on governance conditions in many developing-country settings, limiting generalisability across institutional and socioeconomic contexts. Quantitative estimates of ICT-related electricity consumption and environmental impacts also vary according to definitions, measurement approaches, and system boundaries. These differences restrict direct comparison among estimates and require cautious interpretation of aggregate numerical claims.

Future research should subject the conditionality framework to empirical evaluation. Comparative case studies could examine countries with similar connectivity but different regulatory and institutional capacity, while cross-national panel or quasi-experimental designs could operationalise the seven principles using indicators of meaningful connectivity, affordability, gender disparities, digital skills, formal e-waste collection, and the strength of data-protection and AI-governance regimes. Sector-specific studies of telemedicine and digital learning could test whether skills, governance safeguards, institutional capacity, and environmental conditions moderate observed outcomes. Systematic reviews of the three analytical perspectives would also clarify the extent to which the broader literature supports the conditionality framework.

Technology's contribution to sustainable development cannot be evaluated solely through the availability or sophistication of technological systems. Developmental value depends on the capabilities, institutions, safeguards, and resources that enable societies to convert technological potential into equitable and environmentally sustainable outcomes. The framework developed in this review therefore treats technology as a sociotechnical instrument whose effects are shaped by conditions of design, access, governance, institutional capacity, and maintenance.

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