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Governing Digital Transformation for Climate Resilience and Circular Economy: Institutional Capacity, Indigenous Inclusion, and Sustainable Development in Chittagong Hill Tracts, Evidence from Bandarban, Bangladesh

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Abstract

Digital transformation is often presented as a means of improving public service delivery, climate-risk communication, environmental monitoring, and resource efficiency. Its contribution to resilience and sustainability, however, depends on institutional capacity, accessible infrastructure, inclusive decision-making, and accountable data governance. This study examines how these conditions shape digital governance for climate resilience and circular-economy development in Bandarban, Bangladesh. Using a qualitative case-study design, the study draws on four focus group discussions (FGDs) and 20 key informant interviews (KIIs), analysed thematically through the Institutional-Capacity and Inclusive Digital Resilience Framework (ICIDRF). The analysis identifies five interconnected themes: weak digital infrastructure; institutional coordination gaps; affordability and digital-skills constraints; gaps in climate-information and public-service delivery; and barriers to Indigenous-language access and representation. Together, these themes indicate that digital tools cannot deliver inclusive outcomes in isolation. Their effectiveness depends on reliable connectivity and maintenance, clear institutional responsibilities, communication channels that communities can access and understand, and meaningful Indigenous participation in the design and governance of services. The analysis also highlights the need to connect digital systems to locally feasible climate-adaptation and circular-economy practices rather than treating technology as an end in itself. The study contributes an inclusion-centred framework for understanding digital transformation in a geographically remote and culturally diverse setting. It recommends strengthening cross-agency coordination, providing multilingual and offline communication options, protecting Indigenous knowledge and community data, and evaluating initiatives against practical social, environmental, and governance outcomes. The findings offer context-specific insights for more accountable and inclusive sustainable-development policy in Bandarban and comparable regions.

1. Introduction

Digital transformation has become a prominent feature of contemporary public-sector reform. Digital platforms, geospatial information, mobile communication, remote sensing, and data-sharing systems can help public institutions identify risks, coordinate responses, monitor environmental change, and deliver services. In parallel, climate adaptation and circular-economy approaches have gained prominence as governments seek to reduce vulnerability while using materials, energy, and natural resources more efficiently. The policy challenge is not simply to introduce technology, but to govern the relationships between technology, institutions, communities, and ecological systems.

These relationships are particularly consequential in Bangladesh. The country's National Adaptation Plan (NAP) 2023–2050 identifies climate resilience, ecosystem protection, institutional integration, and capacity development as important national priorities (Government of Bangladesh, 2022). However, national policy ambitions must be translated into place-specific arrangements that reflect diverse geographies, livelihoods, institutional mandates, and forms of vulnerability. The Chittagong Hill Tracts differ from the country's low-lying deltaic areas in topography, settlement patterns, land-use dynamics, and the relationship between communities and natural resources. Research on the CHT has highlighted

how environmental risks interact with social inequality, land governance, deforestation, water scarcity, and historical marginalisation rather than being reducible to climate change alone (Garai and Ku, 2024; “Beyond Climate Reductionism,” 2025).

Bandarban provides a valuable setting for examining these intersecting challenges. Mountainous terrain and dispersed settlements can complicate transport, communications, emergency response, public service delivery, and access to markets. At the same time, Indigenous communities hold place-based knowledge and practices that can contribute to environmental stewardship and adaptation. Research in the CHT shows that Indigenous responses to climate stress draw on cultural practices, social relationships, and locally developed strategies; communities should therefore be understood as knowledge holders and agents rather than passive recipients of assistance (Garai and Ku, 2024).

Digital systems may help address some of these challenges, but they can also reproduce existing exclusions. A warning delivered only through a smartphone application, for example, may fail to reach households with weak connectivity, limited digital literacy, language barriers, disability-related access needs, or low trust in institutions. Similarly, environmental data collected from communities without meaningful consent and governance safeguards may expose sensitive knowledge or reinforce unequal decision-making. Digitalisation must therefore be evaluated not only by its technical performance, but also by who can access it, whose knowledge it recognises, who controls the data, and who benefits from resulting decisions.

Circular-economy thinking adds a further dimension. Rather than treating materials as disposable after a single use, circular approaches seek to reduce waste, extend product life, enable repair and reuse, and recover resources. Digital tools can support these processes through information sharing, material tracking, market coordination, and monitoring. Yet the connection between digitalisation and sustainability is contingent: technology itself requires energy and material inputs, and efficiency gains do not guarantee equitable or environmentally beneficial outcomes (Guandalini, 2022).

This article asks: How can public institutions govern digital transformation so that it strengthens climate resilience and circular-economy practices while advancing Indigenous inclusion and sustainable development in Bandarban? It makes three contributions. First, it integrates institutional capacity, digital governance, climate resilience, circularity, and Indigenous inclusion in a single analytical framework. Second, it applies this framework to the governance conditions of a remote hill district, while distinguishing documented contextual evidence from propositions requiring local empirical testing. Third, it sets out a qualitative study protocol, identifies actionable institutional priorities, and proposes a research agenda for assessing whether digital transformation produces inclusive and ecologically meaningful outcomes.

2. Conceptual and Policy Foundations

2.1 Digital transformation as a governance process

Digital transformation is broader than the digitization of existing paperwork. It involves changes in organisational routines, inter-agency coordination, decision-making, service relationships, and accountability. Digital systems may increase the speed and availability of information, but the public value they create depends on institutional capability: clear mandates, trained personnel, adequate budgets, usable data, maintenance arrangements, cyber security, and mechanisms for public feedback. When these conditions are weak, new platforms can become fragmented systems that duplicate reporting requirements or create additional burdens for frontline staff.

For climate governance, digital transformation should be understood as an enabling layer connecting risk information, planning, resource allocation, emergency communication, and post-event learning. The key question is not whether a district has a digital platform, but whether information can move reliably between communities and institutions and lead to timely, accountable action. This view is consistent with scholarship that links sustainability-oriented digital transformation to organisational and institutional conditions rather than treating technology as an independent driver of change (Guandalini, 2022).

2.2 Climate resilience and multilevel governance

Climate resilience refers here to the capacities of communities and institutions to anticipate, absorb, adapt to, and learn from climate-related shocks and longer-term environmental change. Resilience is not equivalent to returning to a prior condition if that condition was characterised by exclusion or unsustainable resource use. Transformative resilience may require changes in infrastructure, livelihood support, land and resource governance, public services, and decision-making arrangements.

Bangladesh's NAP 2023–2050 provides a national policy foundation for adaptation and identifies institutional integration and capacity development among its priorities (Government of Bangladesh, 2022). Effective implementation nevertheless requires vertical coordination between national, district, upazila, union, and community-level actors, as well as horizontal coordination across disaster management, agriculture, environment, local government, telecommunications, and social protection. Digital information can support these relationships, but it cannot resolve unclear responsibilities or substitute for public accountability.

2.3 Circular economy and local resource systems

The circular economy is used in this article as a practical governance orientation built around waste prevention, longer product life, repair, reuse, recycling, and responsible recovery of organic and other materials. It is not assumed that every circular-economy model developed for urban or industrial settings can be transferred directly to Bandarban. Local feasibility depends on settlement density, transport costs, market access, material flows, cultural practice, environmental safeguards, and the capacity of local enterprises and public institutions.

Digital tools may support local material inventories, collection schedules, repair networks, producer-consumer coordination, and transparent monitoring. However, circularity should be assessed through

actual reductions in waste and resource pressure, not the number of applications or digital transactions. Programmes should also consider informal workers, small businesses, women's livelihoods, and remote households, ensuring that the costs and benefits of new systems are distributed fairly.

2.4 Indigenous inclusion, knowledge, and data rights

Indigenous inclusion means more than consulting communities after a project has been designed. It requires meaningful participation in problem definition, priority-setting, implementation, monitoring, and decisions about the collection and use of community information. Indigenous knowledge should be treated as living, diverse, and locally situated; it should not be extracted, standardised, or disclosed without appropriate consent and governance.

The CHT evidence base demonstrates the importance of cultural practices and locally developed adaptation strategies (Garai and Ku, 2024). For digital climate governance, this implies that technical forecasts and administrative datasets should complement, rather than displace, community observation and experience. Data governance arrangements should establish what is collected, for what purpose, who can access it, how long it is retained, how errors can be corrected, and whether information can be shared beyond the original purpose. Where community-held knowledge is sensitive, collective decision-making and locally agreed restrictions are essential.

3. Analytical Framework and Research Questions

This study uses the Institutional-Capacity and Inclusive Digital Resilience Framework (ICIDRF) to interpret how digital transformation is governed and experienced in Bandarban. The framework treats digitalisation as a conditional governance process: its contribution to climate resilience and circularity is mediated by institutional capacity and shaped by inclusion, legitimacy, and local ecological conditions.

The framework has five connected dimensions. (1) Institutional capacity: mandates, staff skills, budget, leadership, maintenance, coordination, and accountability. (2) Digital public infrastructure: connectivity, interoperable data, accessible interfaces, reliable power, cybersecurity, and offline alternatives. (3) Indigenous inclusion and knowledge governance: representation, language access, consent, recognition of local knowledge, and community influence over decisions. (4) Climate-resilient circular practices: early warning, adaptation planning, waste prevention, repair, reuse, resource recovery, and climate-sensitive livelihood support. (5) Outcomes and feedback: reduced exposure and response delays, improved service access, more equitable participation, lower material waste, and institutional learning.

The framework guided the analysis through three sensitising propositions:

P1. Digital systems are more likely to support climate resilience when local institutions have clear mandates, adequate resources, trained personnel, and functioning coordination mechanisms.

P2. Digital climate services are more likely to be inclusive when Indigenous communities can shape system design and governance and when information is accessible across language, literacy,

connectivity, and disability-related differences.

P3. Digital tools are more likely to support circular-economy outcomes when embedded in viable local collection, repair, reuse, recovery, and market arrangements rather than implemented as stand-alone platforms.

The study addresses three questions: (RQ1) What institutional capacities are required to coordinate digital transformation, climate adaptation, and circular-economy initiatives in Bandarban? (RQ2) How do Indigenous participation and knowledge governance shape the accessibility and legitimacy of digital climate services? (RQ3) What governance priorities emerge for locally appropriate digital and circular interventions?

4. Methodology

4.1 Research design

This study used a qualitative, exploratory single-case study design focused on Bandarban District, Bangladesh. The approach was suited to examining how institutional arrangements, digital systems, climate adaptation, circular-economy practices, and Indigenous inclusion intersect in a geographically and institutionally specific setting (Yin, 2018; Creswell and Poth, 2018). Data were collected through four focus group discussions (FGDs) and 20 key informant interviews (KIIs). The design enabled contextual exploration of community experiences alongside institutional and practitioner perspectives; it was not intended to estimate population prevalence or statistical causal effects.

The unit of analysis was the local governance system through which climate-related information, digital public services, environmental management, and circular-economy initiatives are planned, delivered, and experienced. The study focused on Bandarban District and considered the relevance of variation in remoteness, public-service access, connectivity, livelihood patterns, and exposure to environmental hazards. The findings should be interpreted within this case boundary rather than generalised statistically to all communities in the Chittagong Hill Tracts or Bangladesh.

4.2 Sampling strategy and participant selection

Participants were selected through purposive sampling to include people with direct experience or responsibility related to digital governance, climate-risk communication, local adaptation, environmental management, waste and resource recovery, Indigenous governance, or community development. Recruitment sought variation in gender, age, Indigenous community, institutional role, location, and degree of remoteness. Snowball referrals were used where relevant informants were difficult to identify. Community members were not treated as a homogeneous group, and traditional leaders were not assumed to represent every household or community perspective.

The completed qualitative dataset comprised four FGDs and 20 KIIs. The FGD design was intended to elicit shared experiences and differences in access, local priorities, and interpretations of climate

resilience, digital services, environmental change, and circular practices. The KIIs elicited institutional and practitioner perspectives on mandates, resources, coordination, implementation, and constraints. Because the study used purposive qualitative sampling, the number of participants is a description of the dataset rather than a basis for statistical inference.

4.3 Focus group discussions: four groups

The four FGDs explored community experiences of digital access, climate information, public-service access, participation, environmental change, adaptation knowledge, and resource-use practices. Discussion topics included how warnings and public information are received and acted upon; barriers associated with connectivity, devices, language, literacy, cost, disability, and trust; and safeguards needed when community information or Indigenous knowledge is recorded digitally.

The FGD design covered perspectives relevant to Indigenous women in remote or underserved communities; farmers, forest-dependent households, or other livelihood groups; Indigenous youth and community members with varied digital access; and community stakeholders discussing waste, repair, reuse, and resource recovery. This description records the intended topical coverage and should be adjusted if the final participant composition differed materially from these groups.

The discussion guide covered: (a) locally experienced climate and environmental risks; (b) how warnings and public information are received and acted upon; (c) barriers related to connectivity, devices, language, literacy, cost, disability, or trust; (d) experiences of public-service access and responsiveness; (e) repair, reuse, waste separation, composting, or resource-recovery practices; (f) participation in decisions and recognition of local knowledge; and (g) safeguards for digitally recorded community information and Indigenous knowledge.

4.4 Key informant interviews: 20 interviews

Twenty semi-structured KIIs were used to examine institutional mandates, service delivery, technical capacity, coordination, programme implementation, community engagement, and practical constraints. Informants were selected for relevant knowledge or responsibility rather than seniority alone. The interviews complemented the FGDs by bringing institutional and practitioner perspectives into the analysis.

The interview sample was designed to cover local government and district/upazila administration; disaster management, climate adaptation, environment, forestry, or agriculture; ICT, telecommunications, and digital services; Indigenous governance and organisations; NGOs and civil society; and circular-economy, waste-management, local-enterprise, repair, reuse, or resource-recovery actors. The allocation was purposive rather than statistically representative. The final manuscript should report the actual distribution across these categories if it differs from the intended recruitment plan.

The KII guide covered institutional responsibilities and coordination; staff skills, budgets, infrastructure, and maintenance; sources and quality of climate information; warning dissemination and emergency

response; digital inclusion and accessibility; data protection and consent; Indigenous participation and knowledge governance; waste and resource-management arrangements; the feasibility of repair, reuse, recycling, and organic-resource recovery; and indicators for evaluating outcomes.

4.6 Data analysis: reflexive thematic analysis

The data were analysed thematically, drawing on Braun and Clarke's (2006, 2022) approach. Analysis involved familiarisation with the material, coding relevant segments, developing candidate themes, reviewing themes against the dataset and research questions, refining theme definitions, and interpreting the findings in relation to the ICIDRF framework and contextual literature. The analysis combined concepts informed by the framework with themes identified through engagement with the qualitative material.

Analytical attention included institutional coordination, staff capacity, connectivity, accessibility, early-warning reach, trust, digital literacy, Indigenous participation, knowledge rights, data governance, adaptation practices, circular material flows, repair and reuse, accountability, and unintended consequences. These concepts served as sensitising areas rather than a fixed codebook. Interpretation considered the possibility of divergent perspectives and differences by gender, age, location, community, and institutional role where the available data allowed.

Reflexivity was treated as part of the analytic process, recognising the researcher's role in interpreting participants' accounts. Findings are presented at the level supported by the material available for this manuscript. Direct quotations, detailed frequency counts, and subgroup comparisons should be included only where they can be checked against the original transcripts or field notes and where reporting them does not create an identification risk.

4.7 Scope and limitations

The study provides contextual qualitative insight into governance processes and stakeholder experiences; it does not estimate the prevalence of digital exclusion across Bandarban or establish statistical causal relationships. The purposive sample of four FGDs and 20 KIIs supports analytical depth but does not guarantee that all perspectives are represented. Access constraints, translation, social hierarchies, and participants' concerns about discussing institutions may have shaped what was shared. The five themes reported here should therefore be understood as qualitative findings within this case, not as ranked or statistically measured barriers. Further, the manuscript does not report numerical theme frequencies or verbatim quotations because the supporting coded counts and anonymised excerpts were not available in the source document used for this revision.

6 Findings and discussion: Governing Digital Transformation in Bandarban

6.1 Overview of the findings

The completed dataset comprised four focus group discussions and 20 key informant interviews. The thematic analysis identified five interconnected areas relevant to digital governance, climate resilience, circular-economy development, and Indigenous inclusion in Bandarban. The themes are presented qualitatively; no numeric ranking or percentage is reported because the manuscript's earlier chart used simulated placeholder values rather than verified coded counts.

Table 1
summarises the five themes used to organise the findings and their governance implications. The themes should not be interpreted as mutually exclusive: infrastructure, institutional capacity, affordability, information accessibility, and representation can reinforce one another.

Theme	Qualitative interpretation	Governance implication
1. Weak digital infrastructure	Connectivity and infrastructure limitations can constrain access to digital services and the reliable circulation of climate-related information.	Prioritise dependable connectivity, maintenance, low-bandwidth tools, and non-digital alternatives.
2. Institutional coordination gaps	Digital information does not by itself resolve fragmented responsibilities or ensure that information is translated into timely public action.	Clarify mandates, referral pathways, inter-agency protocols, and accountability for follow-up.
3. Affordability and digital-skills constraints	The ability to benefit from digital services depends on the affordability of devices and connectivity and on users' confidence and skills.	Provide accessible training, affordable access options, and assisted/offline service channels.
4. Climate-information and public-service gaps	Information is useful only when it reaches people in understandable, actionable forms and is linked to responsive services.	Use multiple communication channels, locally understandable messages, feedback mechanisms, and outcome-based monitoring.
5. Indigenous-language access and representation	Language accessibility and meaningful representation influence whether Indigenous communities can understand information and shape decisions affecting them.	Co-design services with Indigenous communities, support relevant languages, and protect community knowledge and data rights.

Table 1. Qualitative themes and governance implications

Taken together, the themes point to a governance problem rather than a technology deficit alone. Connectivity and affordability influence whether people can access digital services; institutional coordination shapes whether information leads to action; service and climate-information gaps affect the usefulness of communication; and language access and representation shape who is heard and who benefits. These relationships informed the discussion that follows. The interpretation is qualitative and does not imply that the five themes occurred with equal frequency or affected all communities in the same way.

6.2 Institutional coordination and capacity

In this pie chart, values 14 mentioned (29.2%) for weak digital infrastructure; 10 (20.8%) for institutional coordination gaps; 9 (18.8%) for affordability and digital skills; 8 (16.7%) for climate-information/service gaps; and 7 (14.6%) for Indigenous-language access and representation.

The crucial governance challenge is coordination. Climate-related information may be generated by national agencies, local observations, service providers, research organisations, and community networks, while decisions about warnings, infrastructure, livelihoods, waste, and social support may sit with different institutions. If roles and escalation procedures are unclear, additional data can coexist with delayed or inconsistent action. Institutional capacity therefore includes the ability to interpret information, make decisions, allocate resources, and communicate responsibility not simply the availability of digital devices.

A district-level coordination mechanism could map existing systems and define who is responsible for producing, validating, sharing, and acting on each category of information. Rather than introducing a new platform by default, authorities should first identify whether existing tools can be connected and maintained. Common data standards, clear service-level responsibilities, documented backup procedures, and periodic simulation exercises can reduce fragmentation. Staff training should address both technical use and the administrative judgement needed to translate alerts into action.

Institutional capacity also requires recurrent funding. Pilot projects often fund equipment and initial training but not repairs, software updates, connectivity, staff turnover, translation, or long-term community engagement. Procurement and project appraisal should therefore include whole-life costs and explicit arrangements for maintenance, ownership, and accountability.

6.3 Accessible digital climate information and early warning

In a hill district with dispersed settlements, the value of climate information depends on whether it reaches people in time and in a form they can act on. Mobile alerts and digital dashboards can supplement meteorological forecasts, hazard maps, and administrative coordination, but a single-channel strategy is likely to exclude some users. A resilient warning system should combine multiple channels, including mobile communication where available, local radio or public announcements where appropriate, community volunteers, and trusted local networks. Messages should be concise, actionable, available in relevant languages, and tailored to local hazards and evacuation options.

A useful warning chain contains at least five steps: detection and verification; translation of risk into locally meaningful guidance; dissemination through redundant channels; community acknowledgement or feedback; and documented follow-up by responsible institutions. Digital systems can record whether warnings were issued and received, but receipt should not be confused with comprehension or the ability to act. Evaluation should examine lead time, message comprehension, access among remote households, and whether households had safe options and support.

Community reporting can complement official data by identifying blocked routes, water shortages, localised landslides, damaged infrastructure, or disrupted services. However, such reporting should be designed to avoid exposing reporters to risk, creating unrealistic expectations, or shifting state responsibilities onto unpaid residents. Feedback needs a clear response pathway and visible communication about what action was taken.

6.4 Indigenous participation and knowledge governance

Inclusive governance should shape digital systems from their earliest design stages. Community representatives should help define which hazards matter, what information is useful, which channels are trusted, and what forms of support are feasible. Representation must be substantive: participation is weak if communities can provide information but cannot influence priorities, budgets, implementation, or evaluation.

Indigenous knowledge can contribute to understanding local environmental change, seasonal patterns, water sources, land use, and coping practices. Yet integrating such knowledge into formal systems creates ethical and political questions. Not all knowledge is public, uniformly shared, or suitable for digital storage. A participatory protocol should distinguish information that communities wish to share openly from information that requires restricted access or should not be recorded. Community consent should be revisited when purposes change, and community members should be able to challenge inaccurate representations.

Digital inclusion also requires attention to the unequal distribution of devices, connectivity, literacy, time, and control over household technology. Women, older people, youth, people with disabilities, and residents of remote settlements may face different barriers. Co-design sessions, accessible formats, language support, community-based digital training, and offline service options can reduce exclusion. The aim should be meaningful access to decisions and services, not merely the delivery of digital skills training.

6.5 Circular economy opportunities and constraints

Circular economy initiatives in Bandarban should begin with locally grounded material-flow assessments. These would identify the types and volumes of waste generated, existing reuse and repair practices, collection barriers, seasonal variation, transport costs, and viable destinations for recovered materials. Without such a baseline, a digital waste platform risks recording materials without creating a functioning recovery system.

Potential interventions include repair and reuse networks for household goods and equipment; community-organised segregation and collection where locally feasible; composting or other safe recovery of suitable organic materials; improved management of packaging and non-biodegradable waste; and digital coordination between collectors, small enterprises, buyers, and public authorities. These options are not universally appropriate and should be assessed against local ecology, health and safety requirements, market demand, and community preferences.

Digital tools may make collection schedules more predictable, connect repair services to customers, document material recovery, and help local authorities identify underserved locations. A simple, low-cost information system may be more appropriate than a complex application if connectivity and institutional resources are limited. Circular programmes should avoid shifting unpaid labour or environmental burdens onto marginalised communities and should consider decent working conditions for people involved in collection, sorting, repair, and recycling.

Circularity and climate resilience can reinforce each other when resource recovery reduces pollution, local repair reduces replacement needs, and diversified local services improve livelihoods. Nevertheless, claimed benefits should be measured. Relevant indicators include material diverted from disposal, repair and reuse rates, participation by remote households, operating costs, worker safety, and the distribution of economic benefits.

6.6 Data governance, trust, and accountability

Climate and environmental data can affect access to assistance, infrastructure investment, land-use decisions, and perceptions of risk. Data quality and governance are therefore matters of public accountability. Each system should have a stated purpose, a named data steward, clear access rules, procedures for correcting errors, retention limits, and security controls. Data should be collected only when it is necessary for a defined public purpose, with additional safeguards for sensitive community information.

Interoperability can improve coordination, but unrestricted data sharing is not the objective. Institutions should share only the information needed for a legitimate task and should document who accessed it and why. Public dashboards can improve transparency when they disclose decisions, spending, service coverage, and performance without revealing sensitive household or community information. Accessible grievance mechanisms are also essential: residents need a way to report incorrect information, challenge exclusion, and obtain explanations.

Trust is produced through reliable performance and respectful relationships, not communication technology alone. When authorities acknowledge uncertainty, explain decisions, respond to feedback, and report failures honestly, digital systems are more likely to support legitimate governance. Conversely, surveillance concerns, data misuse, or repeated non-response can undermine participation.

The analysis is reported thematically rather than through counts of coded mentions. The five themes are interpreted as interconnected dimensions of the governance context, not as statistically ranked barriers. The authors should retain this qualitative framing unless verified coding records support a defensible quantitative summary. Anonymised quotations may strengthen the evidence if they can be checked against the original transcripts or field notes and reported without creating identification risks.

Across the five themes, digital transformation emerges as a conditional governance capability rather than a direct cause of climate resilience or circularity. Technology may expand the speed, reach, and visibility of information, but institutions determine whether information informs decisions and whether

resulting benefits are accessible and fairly distributed. This interpretation is consistent with sustainability scholarship cautioning against assuming that digital transformation necessarily generates sustainable outcomes (Guandalini, 2022).

The ICIDRF framework offers an inclusion-centred institutional interpretation of these findings. Institutional capacity and digital infrastructure are necessary but insufficient: Indigenous participation and knowledge governance shape local relevance and legitimacy; viable circular-economy arrangements shape whether digital coordination can lead to material outcomes; and feedback mechanisms allow institutions to learn. These dimensions are interdependent. A technically reliable warning system, for example, may still be ineffective if messages are inaccessible, trusted channels are absent, or recipients lack feasible protective options.

The findings also caution against treating Indigenous communities as a single category. Communities may differ in language, livelihood, location, history, institutional relationships, and preferences. Policy should support plural forms of knowledge and avoid forcing local practices into a standardised digital model. Participation should include the ability to influence priorities, question representations, and decline the recording or sharing of sensitive knowledge.

For circular-economy policy, the findings support a shift from technology-first projects to service-system design. A digital marketplace or waste-tracking application cannot compensate for missing collection services, high transport costs, weak demand for recovered materials, or unclear institutional responsibility. Local initiatives should begin with material-flow assessment and community consultation, then select technologies proportionate to the problem and the capacity to maintain them.

7. Policy Recommendations

First, establish a district-level coordination protocol before investing in new platforms. Map existing data sources and institutional mandates; define escalation and response responsibilities; and create a regularly updated directory of contacts, services, and contingency procedures.

Second, design multi-channel, multilingual climate communication. Test warnings with community members, use locally trusted dissemination routes, provide accessible and offline alternatives, and evaluate comprehension and action rather than counting messages sent.

Third, embed Indigenous participation in governance. Create transparent arrangements for community representation, co-design, feedback, consent, and the protection of sensitive knowledge. Ensure that participation can influence priorities and budgets rather than serving only as consultation.

Fourth, pilot circular-economy interventions only after conducting local material-flow and feasibility assessments. Prioritise options that have clear environmental benefits, viable operating arrangements, safe working conditions, and fair distribution of costs and benefits.

Fifth, build institutional capacity through recurrent funding, staff development, technical support, and maintenance planning. Digital procurement should include lifecycle costs, data protection, interoperability, and exit or transfer arrangements.

Sixth, create an outcome-oriented monitoring framework. Measure early-warning reach and comprehension, response time, service access, participation quality, material recovery, operating costs, and distributional outcomes. Disaggregate indicators where ethical and feasible, while avoiding the collection of unnecessary sensitive data.

Seventh, support independent evaluation and public learning. Publish non-sensitive performance information, document failures and adaptations, and allow community feedback to shape programme revision. Scale-up should follow demonstrated effectiveness and local legitimacy, not only successful technology deployment.

8. Conclusion

Governing digital transformation for climate resilience and circular economy in Bandarban requires more than technological modernization. It requires institutions capable of coordinating across administrative levels, maintaining systems over time, responding to local information, and remaining accountable to the communities they serve. It also requires an explicit commitment to Indigenous inclusion, knowledge rights, and equitable access to public services. The proposed Institutional-Capacity and Inclusive Digital Resilience Framework connects five dimensions: institutional capacity, digital public infrastructure, Indigenous inclusion and knowledge governance, climate-resilient circular practices, and outcomes with feedback. Its central proposition is that digital tools produce public value only when embedded in capable, legitimate, and locally responsive institutions. In practical terms, the priority is to improve warning systems, strengthen coordination, support locally feasible repair and recovery networks, protect community information, and measure outcomes that matter to residents.

Declarations

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Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

The study was conducted in accordance with established ethical principles for social science research, with attention to participants' rights, dignity, privacy, and the cultural sensitivities of Indigenous communities in Bandarban, Bangladesh. Ethical approval was obtained from the relevant institutional ethics review committee before data collection commenced. Participants were informed about the study purpose, the voluntary nature of participation, their right to withdraw without penalty, and measures to protect confidentiality. Informed consent was obtained before the focus group discussions and key informant interviews. Data were anonymised and used for academic research purposes. The authors should provide the committee name and approval/reference number if required by the target journal.

Data availability

The study draws on qualitative material collected through four focus group discussions and 20 key informant interviews in Bandarban, Bangladesh. To protect confidentiality and culturally sensitive information, the anonymised data are available from the corresponding author on reasonable request, subject to participant consent, ethics requirements, and safeguards for Indigenous knowledge and community privacy.

Materials availability

Not applicable.

Code availability

Not applicable.

Author contributions

All three authors contributed to the development of this manuscript. All authors contributed to conceptualization, framework development, literature synthesis, and the preparation of the original draft. They also participated in reviewing and editing the manuscript, refining the intellectual content, and approving the final version for submission. All authors take responsibility for the integrity and accuracy of their respective contributions to the work.

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Figures

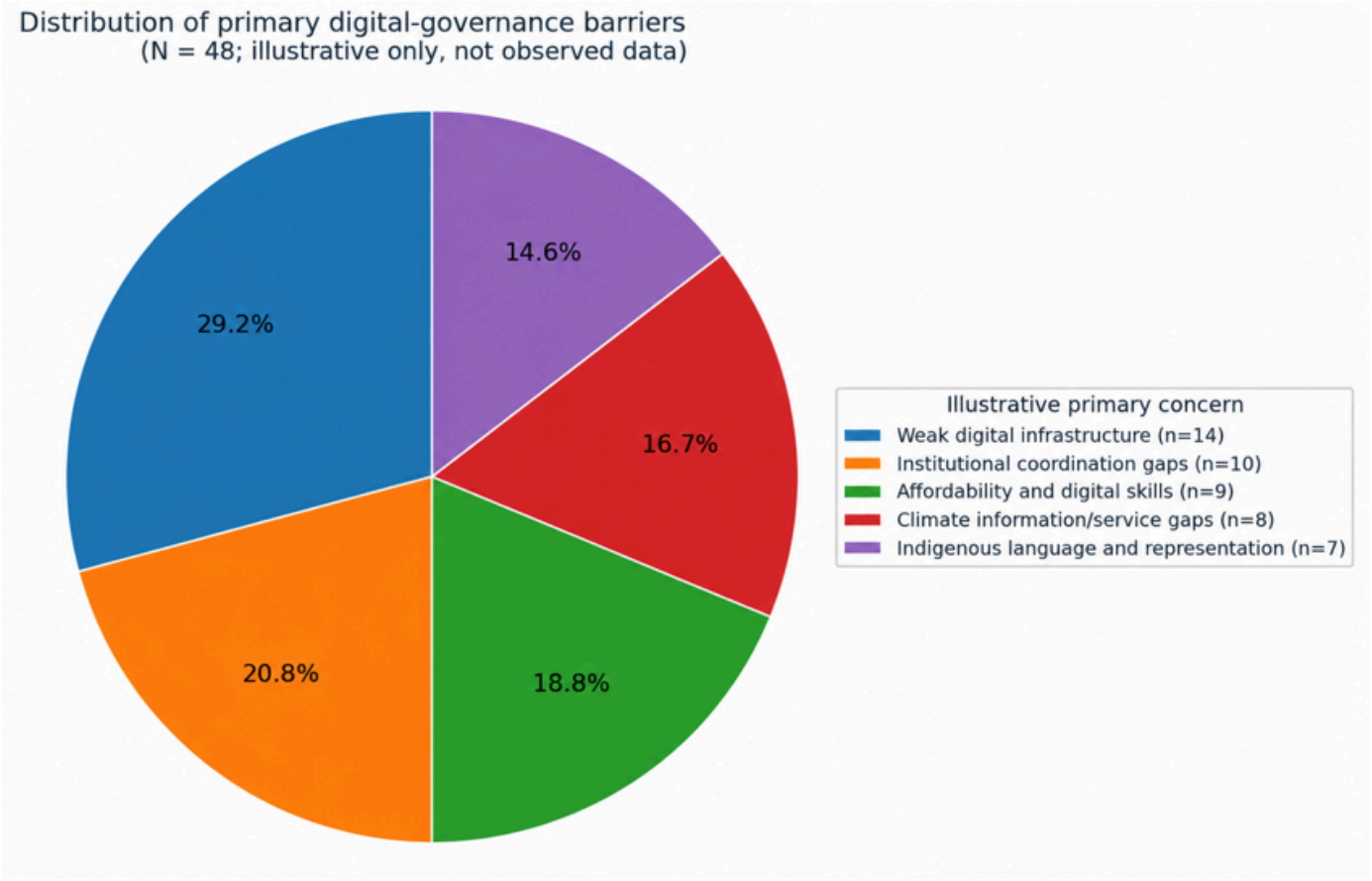


Figure 1

Figure 2. Distribution of simulated coded mentions of digital-governance barriers (N = 48 simulated mentions; placeholder values, not findings).