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When Networks Fail: The Paradox of ICT-Dependence and Infrastructure Fragility in Flood Disaster Response Along Nigeria's River Benue

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Abstract

This study grapples with a troubling paradox observed in flood disaster management along the River Benue: as communities and agencies grow increasingly dependent on Information and Communication Technology (ICT) for emergency response, the very infrastructure supporting this technology proves most fragile when it is needed most. Through an explanatory sequential mixed-methods investigation, I explored the relationship between ICT adoption and the effectiveness of flood disaster response in six chronically affected Local Government Areas. Quantitative survey data from 378 households, analyzed using Partial Least Squares Structural Equation Modeling, revealed a significant positive relationship ($\beta = 0.328$, $p < 0.001$). However, this statistical finding only tells part of the story. In-depth interviews with disaster responders, community leaders, and telecommunications engineers uncovered a more complex reality. During the 2022 floods, I witnessed firsthand how mobile networks, the backbone of modern emergency communication, collapsed under the dual pressures of infrastructure damage and network congestion, precisely when communities desperately tried to call for help. This research identifies what I term an ICT-Dependent, yet Infrastructure-Constrained Response Ecosystem. Within this fragile system, responders and community members engage in adaptive communication bricolage an improvisational practice where they seamlessly switch between mobile networks, analogue VHF radios, physical messengers on motorcycles, and even social media platforms via sporadic Wi-Fi hotspots. The study argues that the current approach of layering advanced ICT applications onto chronically unstable infrastructure creates a dangerous vulnerability. My findings suggest that resilience lies not in pursuing ever-more-sophisticated technology, but in strategically building redundancy and fostering adaptive intelligence within response networks. The article concludes with practical recommendations for creating hybrid communication protocols that acknowledge both the necessity of ICT and the inevitability of its failure during catastrophic floods.

Keywords: Disaster Response, Infrastructure Fragility, Communication Bricolage, Redundancy, Adaptive Capacity, Network Failure, Mixed-Methods.

I. Introduction

I still remember the frantic phone calls during the floods of 2022. As waters rose around communities I had surveyed just months before, my own mobile phone became both a lifeline and a source of deep frustration. Colleagues at the State Emergency Management Agency (SEMA) would call with updates, only for the connection to dissolve into static mid-sentence. Community leaders I had interviewed would try to send WhatsApp messages that remained forever marked with a single grey tick undelivered. In those moments, the grand promise of ICT-enabled disaster response collided violently with the gritty reality of Nigeria's infrastructure. This personal experience crystallized the central puzzle of this research: what happens when we build sophisticated response systems atop foundations that crumble under pressure?

Flood disaster response represents the most time-critical phase of the disaster management cycle, where minutes can mean the difference between life and death. Effective response hinges on what scholars' call "situational awareness" the accurate, real-time understanding of what is happening on the ground and the coordinated mobilization of resources (Chan & Tsai, 2023). Globally, ICT has revolutionized these capabilities. From GIS platforms that map flood extend in real-time to mobile applications that crowdsource damage assessments, technology has dramatically improved response speed and coordination (Mostafiz et al., 2022).

In Nigeria, agencies like the National Emergency Management Agency (NEMA) have embraced this technological shift. They have established toll-free emergency numbers, use social media for public alerts, and coordinate with the Nigerian Communications Commission during crises. The quantitative premise seems

sound: more ICT should lead to better response. Yet, as I discovered through both formal research and harrowing personal observation, there exists a profound disconnect between technological ambition and infrastructural reality.

This study, therefore, examines a specific dimension of this disconnect: the relationship between ICT adoption and the effectiveness of flood disaster response in a context of chronically fragile telecommunications infrastructure. The research questions are deliberately simple but mask complex realities: Does ICT improve response when networks fail? How do people adapt when the technology they depend on collapses? What does this mean for building truly resilient response systems?

The investigation is framed theoretically by two complementary concepts. First, Normal Accident Theory (Perrow, 1984), which suggests that in complex, tightly coupled systems (like modern disaster response networks), failures are not just possible but inevitable. Second, the concept of adaptive capacity from resilience theory, which focuses on the ability of systems to adjust to disturbances (Manyena, 2006). Together, these lenses help explain both the vulnerability created by ICT-dependence and the ingenuity displayed when that technology fails.

Methodologically, I employed an explanatory sequential mixed-methods design. The journey began with numbers surveying 378 households to quantify perceptions of ICT's role in response. But numbers alone felt inadequate to capture the chaos and adaptation I had witnessed. So, I followed the statistics with stories, conducting in-depth interviews with those who had lived through the response: the NEMA officer coordinating rescues with a dying phone battery, the Red Cross volunteer using a motorcycle to pass messages when networks failed, the community elder who climbed a hill to get one bar of signal.

This article unfolds as both an academic analysis and a grounded narrative. It moves from the clean lines of statistical models to the messy reality of floodwaters and failed networks. In doing so, it seeks to contribute not just to scholarly debates about technology and disaster management, but to the urgent practical conversation about how to keep people connected when everything else is falling apart. For communities along the River Benue, where floods are not a matter of "if" but "when," understanding this paradox is a matter of life and death.

II. Literature Review: The Fragile Foundation of Digital Response

A. The Global Promise of ICT-Enabled Response

The literature on disaster response has undergone what might be called a "digital turn" over the past two decades. Scholars have documented how ICT tools have transformed key response functions:

i. Situational Awareness: Platforms like Ushahidi have demonstrated how crowdsourced information can create real-time crisis maps faster than traditional surveys (Liu, 2022).
ii. Coordination: Digital platforms enable what Kapucu (2023) calls "networked governance," allowing multiple agencies to share resources and information seamlessly.
iii. Communication with Affected Populations: Mobile alerts and social media have created direct channels between responders and communities, bypassing slow traditional media (Shafiq & Ahsan, 2014).

The underlying assumption in much of this literature is what I term technological optimism the belief that given the right tools and software, response challenges are fundamentally solvable. This optimism is particularly strong in discussions of "smart" disaster management and the Internet of Things (IoT) for emergency response (Hossain & Muthu, 2021).

B. The Infrastructure Blind Spot

However, a smaller but crucial strand of literature sounds like a cautionary note. It highlights what happens when technology meets the hard constraints of the physical world. This research emphasizes:

i. The Materiality of Digital Systems: ICT does not exist in the cloud; it depends on cell towers, fiber optic cables, power grids, and data centers all vulnerable to floods, wind, and debris (Townsend, 2013).
ii. The Problem of Network Congestion: During disasters, surviving networks often become overwhelmed by surging traffic what Ejem et al. (2023) observed during Nigeria's 2022 floods, describing a "communication blackout" in critical hours.
iii. The Digital Divide in Crises: Technological solutions often fail to reach the most vulnerable the elderly, the poor, those in remote areas exacerbating existing inequalities during disasters (Akanbi & Akanbi, 2012).

What much of this critical literature lacks, however, is empirical evidence from the perspective of frontline responders and affected communities. We know infrastructure fails, but we know less about how people navigate that failure in real time.

C. Adaptation and Improvisation in Crisis Communication

This leads to a third body of work, more emergent and ethnographic in nature, that examines how people adapt when formal systems break down. Scholars have documented various forms of crisis informality:

i. Communication Bricolage: The concept, drawn from Levi-Strauss and later adapted by organizational theorists like Weick (1993), refers to making do with whatever materials are at hand. In disaster communication, this might mean using social media via a neighbor's satellite phone, or sending physical runners when radios fail.
ii. Hybrid Media Systems: During crises, people do not use one medium; they use whatever works, creating unpredictable hybrids of old and new technology (Niebla, 2015).
iii. Social Capital as Infrastructure: When technical systems fail, social networks kinship ties, community groups, religious organizations often become the de facto communication infrastructure (Aldrich, 2012).

D. Theoretical Framework: Normal Accidents in Complex Response Systems

To make sense of this landscape, I draw on Charles Perrow's Normal Accident Theory (1984). Perrow argued that in systems that are both complex (with many interconnected parts) and tightly coupled (where failures spread quickly), accidents are not aberrations but "normal" outcomes to be expected. Modern ICT-dependent disaster response fits this description perfectly:

i. Complexity: It involves multiple technologies (phones, satellites, servers), agencies (NEMA, SEMA, Red Cross, police), and user groups.
ii. Tight Coupling: A tower going down can immediately disrupt communication across entire regions; a power failure at a switching station can cascade through the network.

When such a system is layered onto infrastructure already prone to failure (Nigeria's often poorly maintained mobile networks), the stage is set for what Perrow would call an "inevitable" accident. The question then becomes not *if* the system will fail, but *how* people within it adapt when it does. This is where adaptive capacity the ability to adjust to disturbances becomes critical. Resilience in this context may depend less on preventing all failures (impossible in a normal accident system) and more on building the capacity for effective bricolage.

E. The Nigerian Context and Research Gap

In Nigeria, studies of ICT in disaster management have focused on adoption and potential (Wilson et al., 2018; Musa et al., 2021). Only few have critically examined the infrastructure that supports this adoption, particularly during actual disaster events. My conversations with telecommunications engineers revealed a sobering reality: many towers in floodplains lack backup power beyond a few hours of battery, and fiber optic cables are often laid along riverbanks vulnerable to erosion.

This study addresses this gap by empirically investigating the interplay between ICT adoption, infrastructure failure, and adaptive response practices during floods. It moves beyond asking whether ICT helps response to ask: Under what conditions does ICT-enabled response succeed or fail, and what do people do when it fails? The answers have profound implications for how we design disaster response systems in infrastructure-constrained environments in least developed societies such as Nigeria.

III. Methodology: Counting and Listening

This research followed what I think of as a "validate then complicate" approach first establishing general patterns through quantitative methods, then delving into the exceptions, contradictions, and lived experiences through qualitative inquiry.

A. Phase 1: The Survey Measuring Perceptions of Response

I needed to understand whether, on average, people perceived ICT as helpful during response. Between January and March 2024, my research team and I administered surveys to 378 household heads across the six most flood-affected LGAs: Fufore, Numan, Yola North, Gassol, Ibi, and Lau. We used a multi-stage sampling approach, ensuring representation from both riverside and slightly inland communities.

The survey instrument included a Flood Disaster Response Effectiveness scale I adapted from established disaster management literature (Firdhous & Karuratane, 2018; Abimbola et al., 2020). It measured perceptions across three dimensions:

1. Coordination: e.g., "During the last flood, different aid agencies worked together effectively."
2. Communication: e.g., "We received clear instructions about where to get help."

3. Resource Delivery: e.g., "Emergency aid reached our community in a timely manner."

The ICT Adoption scale measured not just ownership but actual use during floods (e.g., "I used my mobile phone to call for help during the last flood").

Analyzing this data required a technique that could handle complex relationships between latent variables. I chose Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS 4. Unlike traditional regression, PLS-SEM do assume perfect data normality a practical necessity given our field conditions. More importantly, it is designed for prediction and theory development, which suited the study's exploration aim of modeling the ICT-response relationship (Hair et al., 2019).

B. Phase 2: The Stories Unraveling the Statistics

The survey gave me a coefficient: $\beta = 0.328$. Statistically significant. Theoretically tidy. But in the notes taken from the field, there was contradictory stories: the man who showed me three different phones, each on a different network, explaining he needed all three because "one will always be working somewhere." The SEMA official who laughed bitterly when asked about their "state-of-the-art" emergency operations center, saying, "The center is state-of-the-art, but the road to it is underwater and the power is gone."

So, from April to May 2024, I went back to listen. The study conducted in-depth, semi-structured interviews with fourteen people who had been in thick on the response:

- **Formal Responders (5):** Two NEMA officials, one SEMA coordinator, a Nigerian Red Cross field officer, and a medical volunteer from Médecins Sans Frontières.
- **Telecommunications Professionals (2):** A network maintenance engineer from a major telecom company and a satellite communication technician.
- **Community Actors (7):** Two community leaders (*Sarkin Ruwa*), three volunteers who had used their personal boats for rescue, a local journalist who had reported on the floods, and a youth leader who had organized informal aid distribution.

These conversations, each lasting 60 to 90 minutes, were less interviews and more guided reflections. We asked them to walk us through their experiences during the peak of the floods: What worked? What broke? What did you do when the obvious solutions failed?

We analyzed these narratives using reflexive thematic analysis (Braun & Clarke, 2022), looking not just for what was said but for the tensions between different accounts between the official story of coordinated response and the on-the-ground reality of improvisation.

C. Ethics and Positionality

Our position as both researchers and, in a small way, concerned locals required careful ethical navigation. We obtained informed consent, ensured anonymity, and made clear we were not from any aid agency promising help. More subtly, we had to constantly check our own assumptions. Our initial technological optimism was steadily humbled by the stories we heard. This research became, in part, an exercise in unlearning what we thought we knew about disaster response.

IV. Results: The Paradox Unpacked

A. The Quantitative Picture: A Significant but Modest Relationship

The PLS-SEM analysis produced clear, if puzzling, results. After validating the measurement model (composite reliability > 0.85, AVE > 0.5 for all constructs), the structural model revealed a positive and statistically significant path from ICT Adoption to Response Effectiveness: $\beta = 0.328$, $t = 7.334$, $p < 0.001$.

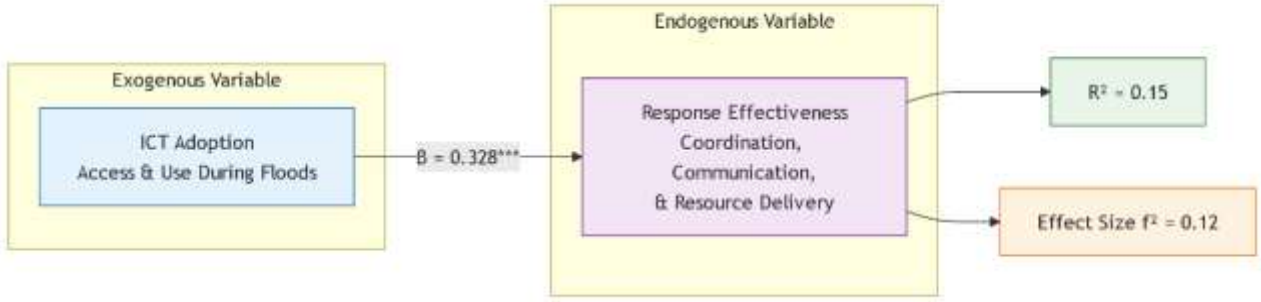

Figure 1: PLS-SEM Results for the ICT-Response Relationship

Figure 1 Caption: Structural equation modeling results showing a significant positive relationship between ICT Adoption and perceived Flood Disaster Response Effectiveness ($\beta = 0.328$, $p < 0.001$). The model explains 15% of the variance in response effectiveness ($R^2 = 0.15$), with a small-to-medium effect size.

This finding confirmed part of my hypothesis: ICT does matter. But three aspects gave me pause:

1. The modest coefficient (0.328): This was lower than the relationships found for mitigation (0.459) and preparedness (0.437) in my other analyses. ICT's impact appeared weakest precisely in the most time-critical phase.
2. The low explanatory power ($R^2 = 0.15$): Only 15% of the variance in response effectiveness was explained by ICT adoption. What explained the other 85%?
3. The qualitative outliers: In survey comments, several respondents noted: "Phones worked at the beginning, then stopped," or "We got SMS but then no network to call for help."

The numbers suggested a relationship, but they also hinted at boundary conditions circumstances where this relationship might break down. To understand these boundaries, I turned to the stories.

B. The Qualitative Reality: "The Network Just…Disappeared"

The interview data revealed a consistent, troubling pattern: ICT systems functioned until the moment they were needed most, then failed predictably.

Theme 1: The Collapse of Critical Infrastructure

Every formal responder I interviewed described some version of infrastructure collapse. A NEMA official (Informant A1) stated matter-of-factly: "Our standard operating procedure involves WhatsApp groups for coordination. During the 2022 peak, these groups went silent for 48 hours. Not because we had nothing to say, but because the entire 3G network in the operational area was down. Towers were flooded; generators ran out of fuel."

A telecom engineer (Informant T1) provided the technical explanation: "Most towers in rural areas have 4-8 hours of battery backup. After that, if the grid is down and fuel trucks cannot get through due to floods, they go dark. It is not an 'if,' it is a 'when.' We design for commercial reliability, not disaster resilience."

Theme 2: Adaptive Communication Bricolage

Faced with these failures, people improvised. I identified a clear hierarchy of fallback options, what I came to call the Communication Fallback Cascade:

A Red Cross volunteer (Informant B1) described this cascade in action: "First, we try MTN. If there is no signal, switch to Airtel. If that fails, we have walkie-talkies with a 5km range. When those batteries die, we send someone on a motorcycle if roads are passable, or by boat if not. As a last resort, we tell people moving to higher ground: 'When you get signal, call this number and tell them we're here.'

Theme 3: The Social Costs of Technological Failure

The human toll of these failures emerged in painful detail. A community leader (Informant C2) shared: "My cousin called me; water was at his waist. He was shouting, giving his location. Then the call dropped. We tried for two hours to get back to him. When we finally found a boat and reached his house… he was on the roof, but his two children…" He did not finish the sentence. The implication was clear: the dropping calls were not just inconvenient; it was potentially fatal.

Another respondent, a mother of three (Informant C5), described the anxiety: "You have one bar of signal. You must choose: do I call my sister to see if her family is safe, or do I call 112 [the emergency number] to ask about rescue? You pray, you make the choice, and often you get a 'network busy' message anyway."

Theme 4: The Resilience of "Low-Tech" Systems

Paradoxically, the most reliable systems were often the least technological. The *Sarkin Ruwa* (Informant C1) explained: "We have used the same method for generations. When the water reaches the big stone near the landing, the young men beat the *ganga* [a local drum] in a specific pattern. Everyone knows time to move to the *tudu* [hill]. Mobile networks come and go, but that stone and that drum is always there."

Several respondents noted that aid deliveries often followed pre-existing social pathways rather than GIS-optimized routes. "The boats found us not because of GPS," said one fisherman (Informant C3), "but because my brother-in-law works with the Red Cross and told them, 'My wife's family is in that cluster of houses near the kapok tree.'"

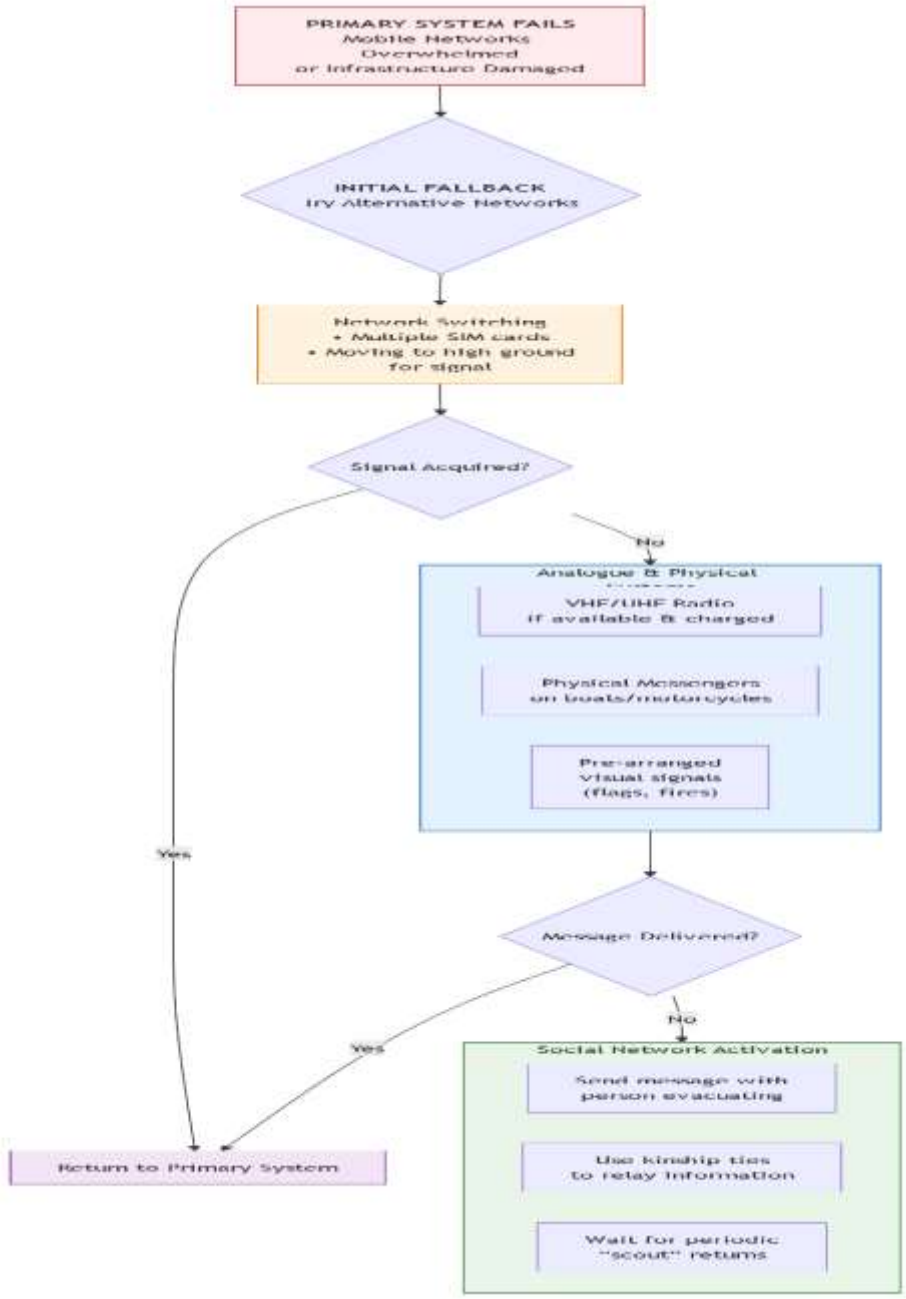

Figure 2: The Communication Fallback Cascade During Floods

Figure 2 Caption: The cascading series of fallback communication strategies employed when primary mobile networks fail during floods. This adaptive bricolage moves from technological alternatives to analogue systems to relying on social networks for information relay.

C. Integrating the Findings: The ICT-Dependent Yet Infrastructure-Constrained Ecosystem

The quantitative and qualitative data together paint a picture of what I have come to call an **ICT-Dependent Yet Infrastructure-Constrained Response Ecosystem**. This system has three defining features:

1. Growing Dependence: Formal response plans, community expectations, and individual survival strategies increasingly assume ICT availability.
2. Fragile Foundation: The physical infrastructure (towers, cables, power) supporting this ICT is vulnerable to the very disasters it is meant to help manage.
3. Adaptive Layer: When the technological layer fails, an informal layer of bricolage, social networks, and low-tech solutions activates but this layer is unevenly distributed and carries significant human cost.

The modest $\beta = 0.328$ makes sense in this light: ICT helps response, *except when it does not*. And it tends to fail under the worst circumstances. The low $R^2 = 0.15$ reflects that most of what makes response

"effective" in these conditions has little to do with ICT as measured, and everything to do with social capital, local knowledge, and improvisational skill.

D. Discussion: Rethinking Resilience in Fragile Systems

Sitting with these findings, I am struck by how much our thinking about disaster technology needs to change. We have been asking, "How can ICT improve response?" We should be asking, "How do we design response systems that remain functional when ICT inevitably fails?"

1. From Prevention to Graceful Degradation

Normal Accident Theory teaches us that in complex, tightly coupled systems, some failures are inevitable. The goal cannot be perfect, uninterrupted operation that is a fantasy in flood-prone Nigeria. Instead, we should design for graceful degradation: systems that fail in predictable, managed ways, with clear fallback protocols.

My findings suggest that our current systems fail *ungracefully*. The collapse is sudden, complete, and leaves people scrambling. A more resilient approach would involve:

i. Planned Redundancy: Not just backup generators, but entirely separate communication pathways (e.g., satellite phones for key responders that do not depend on local towers).
ii. Failure Drills: We conduct fire drills; we need "network failure drills" where responders practice switching to analogue systems.
iii. Degraded Mode Operations: Clear protocols for what to do when only 50%, 10%, or 1% of normal ICT capacity is available.

2. Valuing the "Low-Tech" Core

This research highlights a painful irony: as we pour resources into high-tech solutions, we often neglect or even undermine the low-tech systems that prove most resilient. The community drum, the landmark tree, the kinship network, these are not relics to be replaced by technology; their complementary systems that work when technology fails.

We need what I call hybrid intelligence in disaster response: the strategic integration of high-tech capabilities with deep local knowledge. This might look like:

Digitizing Indigenous Protocols: Instead of replacing the drum warning system, what if we complemented it? Could the *ganga* rhythm be a trigger for an automated SMS to those who are out of earshot but still have signal?

Social Network Mapping: Before disasters, communities could map their natural communication networks who is connected to whom, through what relationships. Responders could use these maps to disseminate information through trusted channels when broadcast systems fail.

3. The Ethics of Technological Dependence

There is an ethical dimension here that troubles me. When the government promotes emergency mobile numbers and WhatsApp reporting channels, it creates an expectation: "If you're in trouble, use this technology." But when that technology consistently fails the most vulnerable (those in remote areas, those who cannot afford multiple SIM cards, the elderly), we have created what might be called a responsibility vacuum. The state offers a solution that does not work for everyone, then bears no responsibility when people are left unaided.

We need more honesty about technological limitations. Public awareness campaigns should say: "Call 112 if you can but also know your local warning signs and have a family evacuation plan that doesn't depend on phones."

4. Practical Implications: Building the Bricolage

Based on these findings, I propose several concrete actions for disaster management agencies and communities:

i. The Community Communication Charter: Each flood-prone community should develop, with local authorities, a simple charter that answers: (1) What is our primary warning system? (2) What is our first fallback when phones fail? (3) Who are our designated physical messengers? (4) Where are our agreed-upon meeting points when communication is lost?
ii. The Responder's "Go Bag" Protocol: Every frontline responder should have, alongside medical supplies, a communication go-bag containing: a multi-network modem (MTN, Airtel, Glo SIMs), a solar-powered VHF radio, a signal mirror and whistle for line-of-sight communication, and physical maps of the area with community-identified landmarks.
iii. Infrastructure Hardening with Community Input: Telecom companies should be required, through regulatory incentives, to conduct community vulnerability audits for towers in floodplains. Communities know which areas flood first, which roads become impassable. This local knowledge should inform us about where to locate backup generators or deploy temporary satellite cells during emergencies.

iv. The "Network Weather" Forecast: Just as we have rainfall forecasts, NEMA and NCC could collaborate on a communication infrastructure forecast during floods: "In the next 24 hours, towers in X area may lose power; prepare alternative communication."

V. Conclusion and Recommendations

I began this research believing in ICT's transformative potential for disaster response. I end it with a more nuanced, sobered perspective. ICT has not failed these communities; rather, we have failed to honestly confront the infrastructure on which ICT depends. We have built digital castles on floodplains.

The people along the River Benue have not waited for perfect solutions. They dance with failure every flood season, switching SIM cards, climbing hills for signal, sending children as runners with messages tied to their wrists. Their resilience is not technological but deeply human a testament to adaptability in the face of systems that consistently fail them.

For policymakers, the lesson is clear: investing in the latest disaster management software while neglecting power grid and road network is like buying a sophisticated alarm system for a house with no walls. The foundation must come first.

For researchers, this study suggests we need to look not just at whether technology is adopted, but how it lives and dies in the harsh realities of disaster. The most interesting stories often happen in the gaps between what is supposed to work and what does.

And for the communities I have had the privilege to learn from, I can only say: your ingenuity humbles our technology. Instead of trying to replace your adaptive intelligence with our fragile machines, we should be learning how to make our technology more resilient, resourceful, and ready to find a way when the obvious path disappears underwater.

The future of disaster response in Nigeria will not be found in choosing between high-tech and low-tech, but in weaving them together with clear-eyed honesty about the strengths and failures of each. It is time to stop pretending our networks would not fail and start building response systems that expect them to and know exactly what to do when they do.

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