International Social Research Nexus (ISRN)
ISSN (Online): 3105-0069

Review Article

The Invisible Grids-Gendered Access to Digital Infrastructure in Marginalized Urban Spaces

Akuma Ifeanyichukuw[1], Dr. A. P. Manimegalai[2*]

[1]Centre for Ethics, Yenepoya (Deemed to be University), Mangalore-575018, Karnataka, India.
[2]Department of Public Health, Yenepoya (Deemed to be University), Mangalore-575018, Karnataka, India.

***Correspondence**
Dr. A. P. Manimegalai
Email: mani.vijimani2009@gmail.com

Article History
Received: September 19, 2025
Accepted: October 22, 2025
Published: November 1, 2025

Citation
Ifeanyichukuw, I., & Manimegalai, A. P. (2025). The Invisible Grids-Gendered Access to Digital Infrastructure in Marginalized Urban Spaces. *International Social Research Nexus (ISRN)*, 1(3), 1-14. https://doi.org/10.63539/isrn.2025025

Abstract

Digital infrastructure, broadband connectivity, affordable smartphones, interoperable digital public infrastructure (DPI), and culturally appropriate digital literacy are rapidly becoming determinants of social, economic, and civic participation. Yet, when this infrastructure maps onto pre-existing social inequalities, it often reproduces and amplifies them. This paper develops a theoretical account of how gendered power relations intersect with spatial marginality to shape access to, use of, and benefits from digital infrastructure in marginalized urban and peri-urban spaces. Building on cross-regional qualitative and policy literature and empirical studies from South Asia and East Africa, we conceptualize the "invisible grids," the socio-technical arrangements, norms, market failures, and governance blind spots that render digital infrastructure unequal by design. We argue for a feminist digital-justice framework that centres intersectionality, spatiality, and infrastructural quality (not only device ownership) and that connects digital inclusion with safety, mobility, and labour justice. Policy recommendations emphasize gender-intentional DPI design, participatory infrastructure planning, targeted affordability and skills interventions, anti- surveillance safeguards, and cross-sectoral metrics to monitor outcomes. The paper provides actionable directions for policymakers, urban planners, and civil society actors seeking to move beyond hardware distribution toward structurally transformative digital inclusion in marginalized urban spaces.

Keywords

Feminist Justice, Digital Inclusion, Urban Marginality, Public, Intersectionality.

1. Introduction

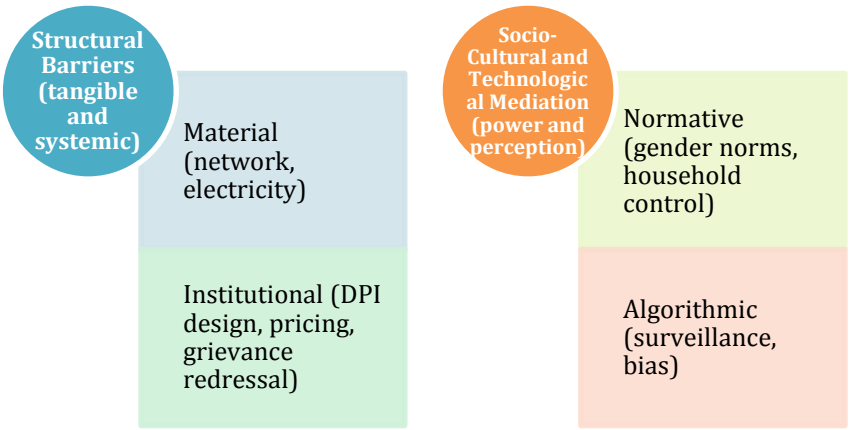
Digital technologies are no longer peripheral conveniences; they are foundational platforms mediating access to education, employment, health services, public benefits, and political participation (Dutton, 2004; Newman et al., 2012). Yet the benefits of digitalization are distributed unevenly. Gendered differentials in device ownership, connectivity, digital skills, and safe usage persist across low- and middle-income countries (LMICs), and they are particularly severe in marginalized urban contexts, informal settlements, peri-urban fringes, and low-income neighborhoods where people face layered vulnerabilities (Sharp, 2022). The International Telecommunication Union (ITU, 2021) reports that despite substantial gains in global internet use, large segments of the world remain offline and substantial within-country inequalities persist. Women and gender minorities experience distinct barriers to digital participation linked to structural inequalities including poverty, discriminatory gender norms, constrained mobility, and heightened exposure to both

online and offline harms (Agunwa, 2024). Also, market expansions in mobile devices and DPI, for example India's Unified Payments Interface (UPI), have produced widespread adoption but also exposed gendered gaps in uptake that reflect affordability, trust, design, and normative constraints (Tanvi & Pandey, 2025). Marginalized urban spaces, informal settlements, slums, peri-urban neighborhoods are distinctive (Carrilho & Trindade, 2022) because infrastructural deficits (intermittent electricity, poor network reach, absence of safe public spaces) and social topographies (landlord-tenant relations, gatekeepers, time poverty) converge to restrict women's digital autonomy.

Sharp (2022) reframes digital exclusion as an infrastructural and spatial justice problem. In this paper, the term "invisible grids" is used to denote the combination of material (network and electricity), institutional (DPI design, pricing and grievance redressal), normative (gender norms and household control), and algorithmic (surveillance and bias) structures that collectively determine who benefits from digitalization. This framing foregrounds that digital inclusion is not merely a distributional problem of devices but a spatialized justice issue requiring cross-sectoral policy responses, linking digital policy with urban planning, gender equity, and data governance.

This paper's goals are threefold. First, to synthesize measurement and theoretical advances in digital inclusion to highlight why traditional access metrics are insufficient. Second, to analyses the six interlocking dimensions of gendered infrastructural exclusion in marginalized urban spaces, drawing on cross-regional evidence and empirical studies. Third, to propose a feminist infrastructural justice framework and concrete policy levers for DPI design, urban planning, and monitoring. The argument is evidence-informed yet normative: digital infrastructures can be designed and governed to expand safe, meaningful participation for women and gender minorities, but only if interventions address the invisible grids that otherwise reproduce inequality (see Figure 1).

Figure 1: Invisible Grids



Categories of gendered barriers (invisible grids) to digital inclusion, distinguishing structural constraints (material and institutional) from socio-cultural and technological mediations (normative and algorithmic).

2. Theoretical Framing: Feminist Infrastructural Justice

This paper synthesizes gendered insights into a Feminist Infrastructural Justice (FIJ) framework, which advances three interrelated analytical axes. First, intersectionality (Pal, 2011; Bhatta et al., 2025) emphasizes that, gender does not operate in isolation but intersects with class, caste/ethnicity, disability, age, and migration status to shape differentiated opportunity structures for digital participation; neglecting these intersections risks reinforcing existing social hierarchies. Second, spatiality (Bernt & Colini, 2013; Woltjer, 2014) highlights the importance of place, showing how urban margins, including informal settlements, peri-urban fringes, and clustered low-income neighborhoods, concentrate infrastructural deficits such as intermittent electricity, inadequate public space, and poor network upgrades, alongside governance voids that systematically constrain meaningful digital access (Williams, 2020). Third, techno-political mediation; In this article, the authors define techno-political mediation as the process through which technical systems, design choices, and governance arrangements collectively shape social power, access, and equity outcomes. It highlights that

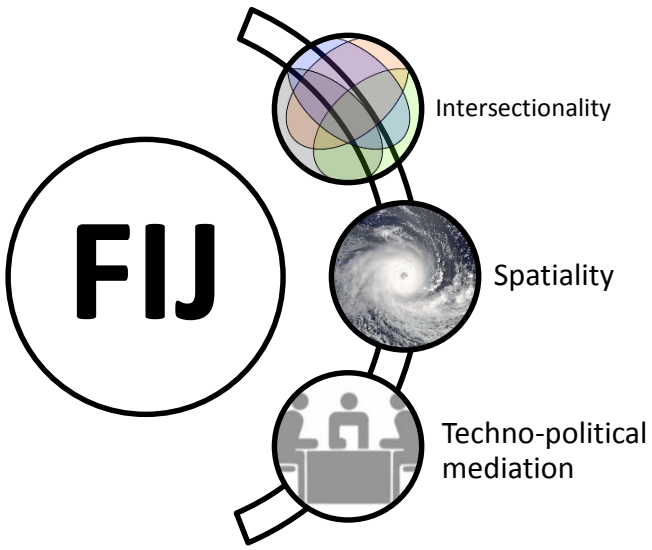
what appear to be neutral or purely technical decisions such as algorithmic settings, data-sharing protocols, procurement standards, or user-interface defaults are in fact politically charged mediations that influence who benefits, who is excluded, and whose interests are prioritized.

In other words, techno-political mediation stress upon the inseparability of technology and politics, showing that infrastructures and digital systems actively reproduce or challenge existing structural biases depending on how they are designed, deployed, and governed (Erigha et al., 2023; Karimi, 2024).

Collectively, the FIJ framework (Figure 2) shifts policy focus from the narrow distribution of hardware to the reconfiguration of infrastructures and governance: investing in spatially targeted quality connectivity and charging infrastructure, embedding gender impact assessments and algorithmic audits in DPI procurement, and centering participatory design processes that engage marginalized women as co-creators. This orientation calls for integrated, intersectional metrics and cross-sectoral collaboration across urban planning, telecom regulation, social protection, and civil society to ensure that digital participation becomes safe, autonomous, and consequential.

For example, In Dhaka's Korail informal settlement and other similar settings in LMICs, the intersection of gender, spatial marginality, and socio-cultural hierarchies vividly demonstrates how infrastructural exclusions manifest in everyday digital access. Frequent power outages and unstable network signals disrupt women's ability to charge devices or maintain consistent online connectivity, exemplifying the spatial dimension of infrastructural inequality. Simultaneously, entrenched caste and ethnic divisions often shape access to community digital hubs, with certain groups facing informal exclusion from shared resources. Layered onto these constraints is the invisible grid of male household control, where husbands or elders frequently decide who owns or uses mobile phones, monitor online activity, and regulate data expenditure. These converging factors render women's engagement with digital platforms conditional and fragmented, revealing that exclusion is not simply technological but socio-political. Feminist infrastructural justice frameworks can more effectively guide inclusive design and policymaking that respond to the rhythms, risks, and relational dynamics of marginalized urban life when grounded in intersectionality and spatiality in such lived realities.

Figure 2: Feminist Infrastructural Justice (FIJ) Framework



Feminist infrastructural justice as a framework centers (a) intersectionality (gender × class × caste/ethnicity × disability), (b) spatiality (neighborhood infrastructure and mobility), and (c) techno-political mediation (algorithmic governance, DPI design), and assesses access not merely as ownership but as meaningful, safe, and autonomous digital participation.

2.1.From a Digital Divide to a Digital-Inclusion Paradigm

Early work on the digital divide characterized it as a relatively simple binary, those who had access to digital technologies and those who did not, a framing that dominated policy and research agendas in the late twentieth and early twenty-first centuries (Hargittai, 2011; Van Dijk, 2012). Over time, however, scholarship has moved beyond this "have/have-not" view toward a richer, multidimensional conception of digital inclusion that emphasizes not only physical access but the quality and meaningfulness of use: reliable bandwidth and low latency, sufficient data allowances rather than punitive caps, device capability, affordable and predictable recurring costs (including charging where grid power is intermittent), and the autonomy to use devices privately and without surveillance. This expanded perspective also stresses digital skills, operational, strategic, and critical, and the downstream outcomes that matter to people's lives, such as educational attainment, health access, economic opportunity, and civic participation (Sharp, 2022; Fisk et al., 2024; Madiseh, 2024). Contemporary measurement critiques argue that routine indicators like subscription counts or nominal coverage maps obscure these qualitative differences: two areas with similar "coverage" statistics can yield very different lived experiences of connectivity once factors such as network quality, device usability, charging barriers, gendered control within households, and exposure to online harms are taken into account (Mori, 2011; Sharp, 2022; Oluda & Josephs, 2023). Consequently, policy and evaluation must shift from counting connections to measuring the conditions under which connections become meaningful, safe, and empowering.

2.2. Feminist Interventions: Gender as Infrastructure

Feminist scholarship reframes infrastructure not as neutral hardware but as a gendered assemblage, an interlocking set of material, social, and political arrangements in which technologies are embedded within households, labour regimes, mobility patterns, and normative orders that systematically constrain the capacities of women, girls, and gender minorities to exercise digital rights (Dutta, 2016; Agunwa, 2024). This gendering operates across scales, from the household level (who owns and controls a device), to the community (who governs shared connectivity and charging points), to municipal planning (where towers, public Wi-Fi and safe access points are located) and national policy (how DPI and data governance are structured), and it produces both material inequalities (uneven access, poor quality, high recurring costs) and non-material harms (surveillance, intimate partner monitoring, online harassment, and algorithmic invisibility). Feminist critiques therefore call for three linked normative moves: center bodily safety and the prevention of harm in access debates; recognize and redress power over data and surveillance as a distinct gendered injustice; and priorities participatory, user-centred design processes that reflect the expressed needs, risk environments, and priorities of women and gender minorities (Van Zoonen, 1992; Henwood, 2000; Fotopoulou, 2016).

2.3.Spatial Justice and Infrastructure

Cities are spatially unequal; informal settlements and peri-urban fringes disproportionately suffer from intermittent electricity, low-quality network coverage, scarce public services, and deficient public space (Woltjer, 2014), and these deficits are compounded because the spatial deployment of digital infrastructure, cell towers, fiber backhaul, public Wi-Fi kiosks, and charging hubs follows political-economic incentives that often bypass marginalized neighborhoods. This uneven infrastructural layering deepens gendered disadvantage where women's mobility is constrained by unpaid care responsibilities, safety fears, and limited legitimate presence in public space, producing cumulative barriers to meaningful digital participation (Ollivier et al., 2025). At the same time, Digital Public Infrastructure (DPI), large-scale, interoperable platforms for identity, payments and public services, holds real potential to democratize access to essential services, but only if design and rollout are gender-intentional; recent work on DPI in India shows that women's uptake is shaped not merely by technical availability but by perceived utility, affordability, trust and safety, and by prevailing normative constraints, meaning that DPI can function either as an accelerator of inclusion or as a vector of exclusion depending on defaults for privacy, language, on boarding simplicity, and outreach strategies.

3. The Invisible Grids: Six Interlocking Dimensions of Gendered Infrastructural Exclusion

Six interdependent dimensions that form the "invisible grids" determining gendered digital exclusion in marginalized urban spaces were analyzed.

3.1.Ownership and Intra-Household Control

Rising mobile penetration often conceals entrenched intra-household inequalities: evidence from multiple low- and middle- income contexts shows that men are significantly more likely to own smartphones and to exercise control over their

use, while women's device access is frequently mediated, supervised, or conditional, practices that curtail private, exploratory, and economically productive uses (GSMA, 2022; ITU, 2021; Sharp, 2022). Empirical work further indicates that where devices are available they are commonly deployed for voice calls and social communication rather than for transformative activities such as e-learning, online job searches, or interaction with e-governance platforms (ITU, 2021; Tanvi & Pandey, 2025), and ethnographic accounts document how domestic surveillance and gatekeeping inhibit women's capacity to use digital devices. Gatekeeping, in this context, refers to the control or restriction of access to information, technology, or opportunities by individuals or groups who hold social or domestic power. It involves the deliberate or implicit regulation of who can use certain resources, how they are used, and under what conditions. When applied to the household sphere, gatekeeping captures how family members, often men or elders, monitor, limit, or permit women's access to digital devices, online spaces, and information flows, thereby constraining their autonomy, self-expression, and civic participation (Agunwa, 2024).

In essence, gatekeeping functions as a social mechanism of control that maintains existing gender hierarchies by filtering or blocking women's pathways to digital empowerment. Consequently, policies focused solely on subsidizing hardware risk limited impact on empowerment; instead, distributional approaches must be paired with interventions that address power and privacy (community dialogue and male-engagement programs), provide confidential access options (women-only hours and women-managed hubs), and strengthen legal and regulatory protections for digital privacy to enable meaningful and equitable use (Ollivier et al., 2022).

3.2. Affordability and Data Quality

Affordability in digital access extends far beyond the one-time cost of devices to encompass recurring expenses for data and voice services as well as indirect costs such as charging fees and transport to access points, with intermittent electricity in informal settlements further inflating the effective price of connectivity by making reliable charging both costly and uncertain (Sharp, 2022). Low-quality networks, often restricted to 2G or 3G, exacerbate these constraints by rendering activities such as video-based learning, secure communications, tele-health consultations, and seamless digital payment transactions difficult or impossible, thereby limiting the meaningful use of connectivity. The policy landscape surrounding Digital Public Infrastructure (DPI), including India's Unified Payments Interface (UPI), illustrates both opportunities and risks: ongoing evaluations highlight affordability, perceived utility, trust, and safety as decisive factors shaping women's adoption of digital payment services (Tanvi & Pandey, 2025). Thus, policy responses should move beyond subsidizing devices alone to directly address recurring costs, for instance, through targeted data vouchers for women, while regulatory frameworks should oblige operators to guarantee minimum quality of service in low-ARPU neighborhoods and encourage investment in community Wi-Fi to ensure equitable access.

3.3.Digital Skills and Meaningful Usage

Digital skills are multidimensional, encompassing operational competencies such as learning to use devices and applications, strategic capacities for leveraging digital tools to access livelihoods and services, and critical literacies that enable privacy protection, safe navigation of online spaces, and the recognition of misinformation. Measurement frameworks now emphasize that both the quality of access and the depth of digital skills are central to genuine inclusion (Sharp, 2022), yet interventions that restrict themselves to basic or generic training without attention to context, such as the timing and location of sessions, the availability of childcare, the use of female trainers, and sensitivity to language and literacy barriers, tend to yield low participation among women in marginalized urban spaces. Evidence from citizen science and community champion models suggests that pairing device access with sustained mentorship and contextually relevant curricula fosters greater uptake and sustained use (Klein et al., 2025). As a result, skills programs must be deliberately designed with gender-responsive elements, linking content to women's everyday priorities such as market access or maternal health information, and embedding them within broader livelihood and social protection initiatives to generate incentives and ensure long-term impact.

3.4.Safety, Surveillance, and Gendered Harassment

Safety in digital participation operates across both offline and online domains, as women face layered risks ranging from intimate partner or family surveillance to online harassment, stalking, doxing, and the non-consensual circulation of intimate imagery, all of which erode trust and limit their willingness to engage in digital public life (Agunwa, 2024). Evidence from citizen-science initiatives in Tanzania demonstrates the dual edge of smartphones: while they can empower communities to document and map gender-based violence, inadequate safeguards expose participants to retaliation and

secondary harms (Klein et al., 2025). These risks are compounded by algorithmic systems that reproduce and amplify bias, facial recognition tools that misidentify women of color, language models that misclassify or erase minority voices, and recommendation systems that amplify abusive content, creating new vectors of exclusion and harm (Floridi et al., 2018). Addressing these threats require embedding privacy-by-design in digital public infrastructure, legislating against non-consensual image sharing, mandating rapid takedown and survivor support mechanisms on platforms, and ensuring gender-responsive safeguards such as community legal aid and confidential reporting. Crucially, technology procurement processes must include gendered risk assessments and algorithmic audits to anticipate harms and mitigate their disproportionate impact on women and other marginalized users.

3.5.Platform and DPI Design (Gender Intentionality)

Digital Public Infrastructure (DPI), including national identity systems, payment platforms, and public service portals, has the potential to scale rapidly and transform access to essential services, but its impact on women depends heavily on whether design choices are gender-intentional. Evidence from 3ie's research highlights that women's uptake of DPI is shaped not simply by availability but by affordability, perceived relevance, trust, and the ease and safety of use, with adoption often constrained by defaults that assume literacy, overlook multilingual accessibility, or set privacy parameters that do not reflect women's contexts (Tanvi & Pandey, 2025). User experience elements such as onboarding flows, interface language, and confidentiality features play decisive roles in shaping whether women in marginalized communities view DPI as usable and trustworthy. Emerging policy experiments, such as India's UPI "For Her" initiatives, indicate that tailored outreach and affordability measures can improve uptake, but the broader evidence base on effective strategies remains nascent. To avoid reinforcing existing exclusions, policy frameworks should mandate gender impact assessments for all DPI projects, embed co- design processes with women from marginalized neighborhoods, and ensure multilingual, low-literacy user interfaces with privacy-protective defaults as a baseline for inclusive digital governance (Verloo & Roggeband, 1996; Götzmann & Bainton, 2021; Tanvi & Pandey, 2025).

Additionally, a clear manifestation of techno-political mediation can be observed in the design defaults embedded within digital public infrastructure (DPI) and service platforms. For instance, mandatory real-name registration or literacy-dependent onboarding interfaces, while often justified as measures to enhance accountability and streamline user verification, inadvertently reproduce structural exclusions. These design choices reflect implicit political judgments about who is a "legitimate" or "trustworthy" user, privileging digitally literate and formally documented populations while marginalizing women, informal workers, and linguistic minorities. Similarly, user-interface defaults that assume uninterrupted connectivity or English-language proficiency reinforce existing hierarchies of access. In this sense, what may appear as neutral technical configurations, identity protocols, form fields, and authentication layers are in fact politically charged mediations that determine whose participation is rendered visible, whose agency is constrained, and whose digital citizenship is institutionally legitimized. Recognizing these mediations as sites of political decision-making emphasizes the need for inclusive co-design processes that foreground intersectional gendered experiences in platform development.

3.6.Governance, Measurement, and Accountability

Governance and accountability in digital inclusion are undermined by the persistence of standard indicators, such as network coverage and subscription counts, that obscure inequalities by failing to capture dimensions of quality, agency, and outcomes. Sharp (2022) argues for more disaggregated and sophisticated metrics that integrate quality of access, affordability indices, and internet skills scales to provide policymakers with actionable insights, while the World Bank's gender-responsive toolkits on mobility demonstrate the value of gender-disaggregated and participatory assessment frameworks that can be adapted for monitoring digital infrastructures (Ollivier et al., 2022). These approaches underscore the need for composite, context-sensitive indicators that reveal how women in marginalized urban spaces actually experience digital systems, encompassing device ownership and control, affordability of data and charging, network quality, digital skills, reported safety incidents, and downstream impacts on education, employment, and civic participation. Embedding such a gendered Digital Inclusion Index into DPI dashboards and urban development monitoring systems, with civil society participation in both design and oversight, would create the transparency and accountability mechanisms necessary to shift digital governance from nominal access metrics toward genuine infrastructural justice.

4. Spatial Dynamics: Marginalized Urban Spaces as Distinctive Sites of Digital Injustice

Marginalized urban contexts (slums, informal settlements, peri-urban fringes) have distinct infrastructural logics that produce compounded digital exclusion (Dangschat, 2009; Bernt & Colini, 2013). Key spatial considerations:

4.1.Infrastructure Scarcity and Compounding Deficits

Infrastructure scarcity in marginalized urban settlements generates compounding deficits that constrain digital inclusion: unreliable electricity, low-ARPU (average revenue per user) environments, and the absence of safe public spaces for charging or community Wi-Fi collectively result in intermittent connectivity and curtailed use. Informal settlements frequently lack dependable street lighting, secure walking paths, clean public toilets, formal land titles, and reliable public transport, and these deficits directly shape the usability of digital technologies, intermittent power reduces the capacity to keep devices charged, unsafe or poorly lit public areas deter women from accessing kiosks or hotspots, and weak physical connectivity diminishes operator incentives to invest in network upgrades. The World Bank's gender-responsive urban mobility toolkit documents how interventions such as improved lighting and safe transit stops enhance women's access and safety in cities (Ollivier et al., 2022), underscoring the need for parallel investments in digital infrastructure. Establishing safe charging hubs in community centers, equipping transit nodes with secure Wi-Fi, and integrating gender-sensitive spatial planning into infrastructure rollouts are, therefore, essential complements to connectivity policy, ensuring that infrastructural justice addresses both digital and physical urban deficits simultaneously.

4.2.Mobility, Time Poverty, and Digital Opportunity Cost

Women's digital participation is heavily shaped by mobility constraints and "time poverty," as disproportionate unpaid care work, safety risks, and restrictive social norms limit both the time and freedom available to attend trainings or access public telecentres during conventional hours. These intersecting burdens mean that even when infrastructure exists, women are less able to benefit from it, highlighting the need for digital programs that incorporate flexible scheduling, proximate and safe locations, and childcare support. Evidence from the World Bank's gender-responsive mobility guidance shows how interventions such as relocating access points to trusted community institutions, primary health centers, schools, and women's collectives or improving safety in transit and public space design can expand opportunities for women to engage with digital technologies (Ollivier et al., 2022). Embedding these considerations into urban planning and digital inclusion initiatives reduces normative friction, lowers opportunity costs, and enhances women's ability to participate meaningfully in digital ecosystems.

4.3.Social Topography, Informal Governance, and Gatekeeping

Digital access in marginalized urban spaces is often mediated by informal governance structures, where landlords, male household heads, and community leaders control shared infrastructure such as communal Wi-Fi points, charging stations, or household devices, thereby reproducing gendered hierarchies and constraining women's autonomy. Ethnographic research reveals that these gatekeepers often determine when and how women can access digital resources, whether by restricting mobility to public kiosks or by supervising device use, thereby effectively embedding patriarchal norms into the everyday functioning of the infrastructure (Agunwa, 2024). Consequently, interventions that overlook these dynamics risk reinforcing exclusion; instead, programs must strategically engage with informal power holders while simultaneously reforming governance models to empower women, for example, through women-led committees managing community hubs or participatory accountability mechanisms that redistribute control. Such approaches acknowledge the "social topography" of infrastructure and ensure that digital inclusion efforts directly address the gendered politics of access and use.

5. Towards a Feminist Digital-Justice Framework (Principles Plus Operational Levers)

We propose a framework with five principles and associated operational levers. Each principle responds directly to the invisible grids analysis (see figure three).

5.1. Principle 1 - Meaningful Access (Beyond Devices)

Meaningful access to digital infrastructure extends far beyond mere device ownership, requiring reliable and high-quality connectivity, affordable data, accessible charging infrastructure, and, critically, the ability to use platforms privately and autonomously. Without these conditions, women's engagement remains constrained despite nominal access, as recurring costs, poor service quality, and surveillance limit transformative use. Policy and programmatic levers to close this gap include targeted data vouchers for low-income women, ideally linked to empowerment training or female-led enter-

prises; publicly funded community charging hubs managed by women's committees to ensure safe and equitable oversight; and the provision of public Wi-Fi at trusted community locations such as health centers and schools. In parallel, telecom regulation should embed gender-sensitive quality metrics and mandate minimum service standards in low-income urban zones to counteract market neglect (Sharp, 2022; Tanvi & Pandey, 2025). Together, these interventions operationalize the principle of meaningful access by aligning affordability, infrastructural adequacy, and user autonomy with gender-equitable outcomes.

5.2.Principle 2 - Safety and Anti-Surveillance Protections

Digital participation is fundamentally conditional on safety, as surveillance by intimate partners, community gatekeepers, or platforms, alongside risks of online harassment and non-consensual image sharing, remain central deterrents to women's meaningful engagement. Feminist analyses underscore that without robust safeguards, digital inclusion efforts risk reproducing harm rather than empowerment (Agunwa, 2024), while citizen-science evidence highlights the retaliation risks faced by women who use digital tools for community protection work when safeguards are absent (Klein et al., 2025). To address these challenges, safety measures must be embedded into the design of both DPI and platforms through privacy-by-default settings, anonymous modes for sensitive services such as health and GBV reporting, and platform obligations for gender-sensitive moderation, rapid takedown, and survivor-support hotlines. Complementary legal frameworks should criminalize and enforce protections against online harassment and non-consensual image sharing, while community-based interventions such as digital-safety training strengthen resilience at the grassroots level. Taken together, these measures align safety with inclusion, ensuring that women's digital participation is both possible and protective.

5.3. Principle 3 - Participatory, Gender-Intentional Design of DPI & Platforms

Digital Public Infrastructure (DPI), such as payments, identity systems, and welfare portals, can only be transformative when they are designed with intentional engagement of women and marginalized groups, ensuring that platforms are usable, affordable, and trusted. Research on gender intentionality highlights that uptake depends not only on technical availability but on design processes that reflect women's lived contexts, including language, literacy, and trust-building mechanisms (Tanvi & Pandey, 2025). To operationalize this, DPI projects should mandate gender impact assessments at procurement and implementation stages, establish co-design labs that involve women from informal settlements in mapping user journeys and testing interfaces, and integrate female-led onboarding programs that simplify registration and transaction flows while embedding local trust agents into rollout. Partnerships with community-based NGOs are equally critical to facilitate outreach, troubleshoot adoption barriers, and ensure accountability. By embedding participatory, gender-intentional design into both the architecture and governance of DPI, policies can shift from top-down distribution models toward inclusive infrastructures that genuinely expand women's digital citizenship and autonomy.

5.4.Principle 4 - Integrated Mobility-Digital Planning

Digital access and physical mobility are deeply co-constituted, as women's ability to benefit from connectivity is constrained not only by affordability and infrastructure but also by their capacity to move safely and reliably through urban space. Gender- responsive mobility interventions, such as safer bus stops, adequate street lighting, low-floor buses, and secure public toilets, expand the temporal and spatial opportunities for women to engage with digital technologies, and integrating these with digital planning creates multiplier effects (Ollivier et al., 2025). Operational levers include installing safe Wi-Fi and charging infrastructure at transit hubs, health centers, and schools; aligning digital literacy training with women's mobility patterns by scheduling sessions during market hours or school pick-up times; and leveraging existing transport grievance systems as channels for reporting digital safety concerns. Drawing on the World Bank's gender-responsive mobility toolkit, such integrated planning ensures that investments in physical infrastructure directly support digital participation, reducing opportunity costs and enhancing women's capacity to engage with digital ecosystems on safe and equitable terms.

In practice, integrated mobility-digital planning has yielded measurable outcomes where multispectral coordination was achieved. For instance, DigiTel in Tel-Aviv, Israel has demonstrated that providing a residents' citizen engagement platform service can increase digital service use among women (Fink, 2020). Similarly, India's "Digital Sakhi" initiative aligned community digital training with rural women's market schedules, resulting in a 40% rise in financial app use within one year (Dei, 2025; Jha, 2025). These examples show that success depends not only on technological deployment

but also on careful mapping of women's daily mobility rhythms and safety perceptions. Monitoring frameworks can include indicators such as the number of gender-sensitive transport nodes with digital infrastructure, frequency of women's online engagement post-intervention, and incident reports related to transit-linked digital harassment. Embedding these indicators within urban mobility master plans allows policymakers to empirically assess how spatial access and digital inclusion interact, ensuring that both mobility and connectivity investments translate into tangible gains in women's autonomy, civic engagement, and economic participation.

5.5. Principle 5 - Measurement, Accountability, and Policy Coherence

Measurement and accountability are central to advancing digital inclusion, as what is measured ultimately guides resource allocation and policy priorities; yet standard metrics such as coverage or subscriptions fail to capture critical dimensions of quality, usage complexity, safety, and empowerment outcomes. Scholars argue for composite approaches that integrate affordability, skills, safety, and outcomes into digital inclusion indices, disaggregated by gender, caste/ethnicity, disability, and geography, to provide a more accurate picture of inequality (Sharp, 2022). Similarly, the World Bank's gender-responsive frameworks demonstrate how participatory and gender-disaggregated monitoring can strengthen accountability in infrastructure planning (Ollivier et al., 2022). Operationally, this requires establishing gendered Digital Inclusion Indices that measure not only device control and data affordability but also charging access, network quality, digital skills, and reported safety incidents; mandating DPI dashboards to include gender-disaggregated KPIs and procurement impact assessments; and creating multi-stakeholder oversight bodies that include women from marginalized neighborhoods to audit DPI rollouts and algorithmic systems. Embedding these practices in governance frameworks ensures that measurement evolves from counting connections to monitoring empowerment, making policy more coherent, equitable, and accountable.

6. Implementation Pathways and Policy Proposals

Implementation pathways for advancing feminist digital inclusion require coordinated action across affordability, infrastructure, governance, and community capacity. Gender-targeted affordability policies such as data vouchers linked to verified training participation or women's micro-enterprise registration, alongside zero-rating of essential public service portals with safeguards for privacy and competition, address recurring cost barriers (Sharp, 2022; Tanvi & Pandey, 2025). Community digital infrastructure bundles that combine safe charging hubs, public Wi-Fi, women-only digital literacy hours, and grievance kiosks managed by women's collectives can mitigate gatekeeping dynamics while ensuring confidentiality, building on participatory models from World Bank mobility interventions (Ollivier et al., 2022). At the systemic level, gender-intentional DPI procurement rules should mandate gender impact assessments, human-centred design KPIs, and accessible documentation, reflecting 3ie's evidence that intentionality in design improves women's adoption (Tanvi & Pandey, 2025).

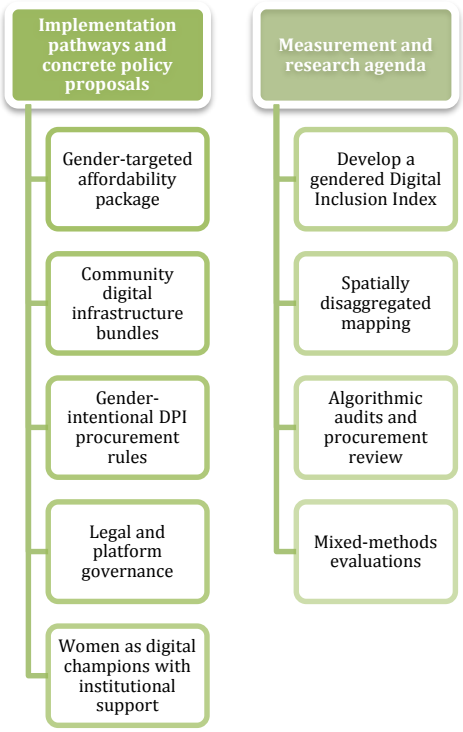
Parallel reforms in legal and platform governance must strengthen data protection frameworks, legislate against digital GBV, and mandate gender-sensitive moderation, backed by dedicated resources for enforcement and survivor support (Agunwa, 2024). Furthermore, capacity building through community champions is essential: recruiting and remunerating local women as digital champions, paired with device distribution, sustained mentorship, livelihood linkages, and institutional protections, can foster empowerment while addressing risks of burnout and retaliation identified in citizen-science studies (Klein et al., 2025). Together, these pathways operationalize a feminist infrastructural justice agenda that integrates affordability, safety, participatory governance, and sustainability. Several initiatives globally illustrate the effectiveness of feminist digital inclusion pathways. For example, the Kenya Women's Digital Literacy Programme (UNESCO, 2025) integrated subsidized data bundles with entrepreneurship training, resulting in over 60,000 women gaining sustained online market access (Khatun et al., 2023; UNESCO, 2025).

In India, the Internet Saathi program by Google and Tata Trusts trained rural women as digital educators, expanding digital literacy to over 30 million women across 300,000 villages (Chakravarti, 2021; Paul et al., 2017). Similarly, Rwanda's Digital Ambassadors Program embedded gender-sensitive design by training women as local digital champions, significantly narrowing the urban-rural digital gap (Adewusi et al., 2020). Latin America's Ella Aprende, Ella Emprende initiative further demonstrated that pairing digital skills with small business mentorship positively impacts women's participation (Romero, 2023). These examples confirm that integrating affordability measures, localized training, and women-led governance structures can yield measurable and scalable outcomes in advancing equitable digital participation.

7. Measurement and Research Agenda

A forward-looking measurement and research agenda must move beyond simplistic indicators of coverage and subscriptions to develop composite, gender-sensitive tools that capture the full spectrum of digital inclusion. A proposed Composite Digital Inclusion Index would integrate device ownership and control, affordability of data and charging (effective connectivity costs), network quality (latency and bandwidth), multidimensional digital skills (operational, strategic, and critical), safety indicators (reported GBV or online harassment prevalence), and outcome measures in employment, education, and civic participation, aligning with Sharp's (2022) call for multidimensional metrics. To guide investment and planning, spatially disaggregated datasets should map network coverage, charging points, and public Wi-Fi against gendered mobility flows and service usage, adapting approaches from the World Bank's gender-responsive mobility mapping (Ollivier et al., 2022). Methodologically, mixed-methods evaluation designs are needed to assess not only adoption but also agency and safety outcomes, combining experimental and quasi-experimental approaches with ethnographic inquiry, as illustrated by the Tanzanian citizen science study (Klein et al., 2025). Furthermore, algorithmic audits and surveillance risk assessments should become standard for DPI and government procurement of AI systems, applying ethical principles such as those advanced by Floridi et al. (2018) to ensure transparency, fairness, and accountability. This integrated agenda provides both operational monitoring tools for policymakers and a scholarly framework for advancing feminist digital inclusion research.

Figure 3: From Policy to Practice - Pathways for Feminist Digital Inclusion



Pragmatic pathways must integrate policy, regulation, and programmatic action, paired with improved measurement and rigorous evaluation to ensure meaningful and equitable impact.

8. Conclusions

Digital infrastructure is an arena of contested social goods. If left to neutral market logics and gender-blind technical design, digitalization can intensify pre-existing inequities. The "invisible grids" framing highlights how network coverage, pricing, household power, mobility barriers, platform design, and surveillance practices interlock to produce gendered exclusions in marginalized urban spaces. A feminist infrastructural justice agenda insists on meaningful access, safety, participatory design, integrated mobility-digital planning, and improved measurement. Implemented coherently, these steps can transform digital programs from tokenistic device dis-

tribution to structural pathways for gender justice in cities. Policymakers, donors, and civil society should therefore prioritize gender-intentional DPI design, combine physical mobility reforms with digital interventions, and develop robust gender-disaggregated metrics to monitor outcomes. Research must accompany implementation with mixed-methods evaluation and attention to surveillance and algorithmic harms. Only by recognizing the infrastructural and spatial character of digital exclusion can we move toward inclusive, just, and safe digital cities.

8.1. Limitations and Critical Reflections

Several critical cautions temper the optimism around feminist digital inclusion. Technology alone is not a panacea: evidence from the Tanzania citizen-science study (Klein et al., 2025) shows that distributing smartphones without parallel investments in institutional support, social protection, and gender norm change yields limited translation into durable empowerment, as structural constraints continue to restrict women's life chances. Similarly, overreliance on centralized Digital Public Infrastructure (DPI) risks concentrating power, creating single points of failure, and amplifying surveillance harms; feminist approaches, therefore, call for pluralistic, interoperable, privacy-preserving, and locally governed systems. Contextual heterogeneity further highlights that interventions effective in one setting, such as India's UPI ecosystem, may not translate seamlessly to African informal settlements, where infrastructural and normative environments differ, making iterative, co-designed, and locally adapted strategies essential. Moreover, citizen-science models and device distribution, while valuable, also carry risks of retaliation and data misuse if safeguards are weak. Although this study's analytical scope was shaped by contextual constraints such as limited primary field engagement and reliance on secondary documentation, these limitations also provided a vantage point to interrogate broader structural patterns in digital inclusion. Nevertheless, the analysis recognizes the enduring risk of techno-solutionism where digital inclusion efforts risk becoming symbolic gestures rather than transformative interventions. Many initiatives that prioritize device distribution or surface-level participation, without addressing underlying socio-economic, spatial, and gendered power asymmetries, often reproduce the very inequities they aim to redress. This can lead to tokenism (symbolic gestures), wherein women's presence in digital spaces is quantitatively visible but qualitatively limited by continued dependence, surveillance, or infrastructural exclusion. The Feminist Infrastructural Justice (FIJ) framework, therefore, aims to move beyond performative inclusion by embedding digital interventions within wider agendas of social protection, infrastructural equity, and participatory governance. Through this structural orientation, digital initiatives can evolve from short-term technical fixes into sustained processes of redistributing access, agency, and accountability across gendered systems of power.

8.2. Policy Actions for Stakeholders

Some of the policy actions that could be adopted in order to advance feminist digital inclusion effectively, are to embed digital initiatives within broader social protection and education frameworks to ensure sustained empowerment; institutionalize gender safeguards in DPI through mandatory gender impact assessments, privacy-by-design standards, and community oversight mechanisms; promote decentralized and interoperable systems that reflect local governance and data stewardship norms; foster cross-sectoral coalitions among civil society, women's networks, and local leaders to challenge restrictive gender norms; implement robust safeguards such as anti-retaliation clauses and ethical data protocols in citizen-science and device distribution programs; and strengthen institutional capacity through training, monitoring, and accountability mechanisms aligned with feminist infrastructural justice principles. Together, these actions could ensure that digital inclusion becomes a transformative and context-responsive process rather than a technocratic exercise.

Declarations

Author Contributions

Akuma Ifeanyichukwu was primarily responsible for conceptualizing the study, developing the theoretical framework, integrating interdisciplinary perspectives, and drafting the manuscript. Dr. A.P. Manimegalai contributed to the literature review, provided critical inputs on public health dimensions, validated the analytical framework, and reviewed and refined the policy recommendations. Both authors read and approved the final version of the manuscript.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Acknowledgement

The authors gratefully acknowledge the institutional support provided by the Centre for Ethics and the Department of Public Health at Yenepoya (Deemed to be University), Mangalore, India, which created an environment that enabled scholarly exchange and interdisciplinary collaboration.

Conflict of Interest

The authors declare no conflict of interest.

References

Adeleke, R. 2021. "Digital divide in Nigeria: The role of regional differentials." *African Journal of Science, Technology, Innovation and Development* 13, Issue 3: 333-346. Available at: https://doi.org/10.1080/20421338.2020.1748335.

Adewusi, B. A., AdekunlE, B. I., Mustapha, S. D., & Uzoka, A. C. (2020). Advances in Inclusive Innovation Strategy and Gender Equity Through Digital Platform Enablement in Africa. *IRE Journals*, Volume 3 Issue 8, https://www.researchgate.net/profile/Bolaji.

Agunwa, N. (2024). *Feminism and the Digital Era*. Feminist Africa, 5(2), 113-126.

Awino I, Fofie IM, Steeves HL. Gender and Digital Communication in Sub-Saharan Africa: A Feminist Political Economy of Enduring Inequities. InWomen in Mass Communication 2022 Dec 30 (pp. 125-140). *Routledge*.

Bernt, M., & Colini, L. (2013). *Exclusion, marginalization and peripheralization: Conceptual concerns in the study of urban inequalities* (No. 49). Working paper. https://www.econstor.eu/bitstream/10419/228579/1/irs-wp49.pdf.

Bhatta, T. R., Lekhak, N., Roy, M., & Fuller, K. (2025). The Intersections of Gender and Caste: Cumulative Dis/Advantage and Later-Life Health in Nepal. In Population Aging in Societal Context (pp. 116-139). *Routledge*.

Bhattacharya, S. (2024, December 11). *Bridging the Gender Digital Divide: Africa's Imperatives. Orfonline.org; Observer Research Foundation (ORF)*. https://www.orfonline.org/research/bridging-the-gender-digital-divide-africa-s-imperatives.

Carrilho, J., & Trindade, J. (2022). Sustainability in peri-urban informal settlements: a review. *Sustainability*, 14(13), 7591.

Chakravarti, A. (2021, March 8). *Google Internet Saathi programme turns messiah for unemployed women in rural areas*. India Today. https://www.indiatoday.in/technology/features/story/google-internet-saathi-programme-turns-messiah-for-unemployed-women-in-rural-areas-1776789-2021-03-08.

Dangschat, J. S. (2009). Space matters—marginalization and its places. International Journal of Urban and Regional Research, 33(3), 835-840. *International Journal of Urban and Regional Research*. https://doi.org/10.1111/j.1468-2427.2009.00924.x.

Dei, P. R. (2025). Empowering Rural Women through Digitalization: Case Studies of Digital India in Odisha. *TIJER*, ISSN 2349-9249, Volume 12, Issue 6. https://tijer.org/tijer/papers/TIJER2506259.pdf.

Dutta, U. (2016). Adivasi Media in India: Relevance in Representing Marginalized Voices. *Intercultural Communication Studies*, 25(3).

Dutton, W. H. (2004). *Social transformation in an information society: Rethinking access to you and the world* (Vol. 13). Paris: UNESCO.

Erigha, E. D., Obuse, E., Okare, B. P., Uzoka, A. C., Owoade, S., & Ayanbode, N. (2023). *GDPR-Compliant Consent Management Architecture for Global Mobile Applications Using Modular Cloud Microservice Design*. https://shisrrj.com/paper/SHISRRJ122593.pdf.

Fink, J. (2020, September). D*igital City Testbed Center: Using campuses as smart city testbeds in the binational Cascadia region*. In 2020 IEEE International Conference on Smart Computing (SMARTCOMP) (pp. 362-367). *IEEE*.

Fisk, R. P., Gallan, A. S., Joubert, A. M., Beekhuyzen, J., Cheung, L., & Russell-Bennett, R. (2023). Healing the digital divide with digital inclusion: enabling human capabilities. *Journal of Service Research*, 26(4), 542-559.

Floridi, L., Cowls, J., Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V., ... & Vayena, E. (2018). AI4People—An ethical framework for a good AI society: Opportunities, risks, principles, and recommendations. *Minds and machines*, 28(4), 689-707.

Fotopoulou, A. (2016). *Digital and networked by default? Women's organisations and the social imaginary of networked feminism*. New media & society, 18(6), 989-1005.

Global System for Mobile Communications Association (2022). *The Mobile Gender Gap Report 2022*. https://media.gsma.com/assets/2022/annual_report.pdf Accessed 3-04-2025.

Götzmann, N., & Bainton, N. (2021). *Embedding gender-responsive approaches in impact assessment and management. Impact Assessment and Project Appraisal*, 39(3), 171-182.

Hargittai, E. (2011). Minding the digital gap: Why understanding digital inequality matters. In Media perspectives for the 21st century (pp. 231-240). *Routledge*.

Henwood, F. (2000). From the woman question in technology to the technology question in feminism: Rethinking gender equality in IT education. *European Journal of Women's Studies*, 7(2), 209-227. https://library.fes.de/libalt/journals/swetsfulltext/7953335.pdf.

Jha, A. (2025). *Digital Infrastructures for Cultural Revival and Collective Empowerment in Sakhi Bahinpa. Communications of the Association for Information Systems*, 57(1), 32.

Karimi, A. (2024). Optimal governance of data in the ecosystem of connected vehicles with assistance of maturity mode (Doctoral dissertation, Loughborough University). https://repository.lboro.ac.uk/articles/thesis/Optimal_governance_of_data_in_the_ecosystem_of_connected_vehicles_with_assis tance_of_maturity_mode/29652137?file=5658514.

Khatun, F., Nawrin, N., & Kabir, F. A. Neelormi., S.(2023). *Financing for Women's Empowerment in the Context of Post-COVID Recovery and LDC Graduation of Bangladesh*, 4.

Klein C, Kostkova P, Kasunga H. & Chapman J., (2025). Smartphones, citizen science, and the fight against gender-based violence in rural Tanzania. *Front. Glob. Women's Health* 6:1490918 https://doi.org/10.3389/fgwh.2025.1490918.

Madiseh, F. R. (2024). *From digital divide to digital inclusion: Challenges, perspectives and trends in the development of digital competences*. Technology in Language Teaching & Learning, 6(4), 102345-102345.

Mori, C. K. (2011). '*Digital inclusion': are we all talking about the same thing?. In ICTs and sustainable solutions for the digital divide: Theory and perspectives* (pp. 45-64). IGI Global Scientific Publishing. https://www.unapcict.org/sites/default/files/2019- 01.

Newman, L., Biedrzycki, K., & Baum, F. (2012). Digital technology use among disadvantaged Australians: implications for equitable consumer participation in digitally-mediated communication and information exchange with health services. *Australian Health Review*, 36(2), 125-129.

Ojo, T. A., & Ndzendze, B. (2024). Women and the 4IR in Africa. In African Women in the Fourth Industrial Revolution (pp. 8-35). *Routledge*.

Ollivier, G., Nikore, M., & Natasha, S. (2022). *Toolkit for enabling gender responsive urban mobility and public spaces India; Volume I: The 'What-To-Do'Note for Policymakers*. World Bank, Washington, DC.

Ollivier, G.P., Nikore, M., Natasha, S., Vasudevan, V., Shah, S., Singhal, A., Banerji, A., & Varghese, A. (2025). *India - Toolkit for Enabling Gender Responsive Urban Mobility and Public Spaces : Volume 2 - The 'How-To' Guide - Practical Tools for Implementing Agencies (English)*. Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/099659510192229938 Accessed 16/09/2025.

Oluda, O. F., & Josephs, C. (2023). *The Causes of Digital Divide in Nigeria: The Context of the Nigerian Law Reform Commission*. https://lup.lub.lu.se/luur/;ownload?func=downloadFile&recordOId=9123699&fileOId=9123921.

Pal, G. C. (2011). *Disability, intersectionality and deprivation: An excluded agenda*. Psychology and Developing Societies, 23(2), 159-176.

Paul, P. K., Aithal, P. S., & Bhuimali, A. (2017). *Internet Saathi: A step towards promoting rural Indian women*. In Proceedings of the international conference on interdisciplinary research in humanitarian technology, August 28–29, 2017, Pathankot (pp. 150-156).

Romero, G. (2023, August 26). Success Stories: Emprende Pro Mujer reaches more than 1,100 women in Southeast Mexico. Pro Mujer | Invest in a Woman, Transform a Family. https://promujer.org/2023/08/25/success-stories-emprende-pro-mujer-reaches-more-than-1100-women-in-southeast-mexico/ Accessed 09/10/2025 .

Sharp, M. (2022). *Revisiting digital inclusion: A survey of theory, measurement and recent research*. Digital Pathways at Oxford,1.https://www.bsg.ox.ac.uk/sites/default/files/2022-04/

Tanvi, & Pandey, D. (2025). *What works to increase women's adoption of digital payment services in India* | 3ie. 3ieimpact.org; International Initiative for Impact Evaluation (3ie). CCAFS/2014/Prashanth Vishwanath. https://www.3ieimpact.org/blogs/what-works-increase-womens-adoption- digital-payment-services-india Accessed 16/09/2025.

The International Telecommunication Union. (2021). *Measuring Digital Development: Facts and Figures 2021. International Telecommunication Union*. https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2021.pdf Accessed 3-04- 2025.

UNESCO, (2025). Empowering Women and Girls through DigiKen. Unesco.org. UN Women https://www.unesco.org/en/articles/empowering-women-and-girls-through-digiken.

United Nations Fund for Population Activities-UNFPA in India. (2023, March 22). *The stage has been set for gender equity in Digital India. UNFPA India*; News. https://india.unfpa.org/en/news/stage-has-been-set-gender-equity-digital-india As Published in The Mint on 22.3.2023.

Van Dijk, J. A. (2012). *The evolution of the digital divide-the digital divide turns to inequality of skills and usage*. In Digital enlightenment yearbook 2012 (pp. 57-75). IOS Press.

Van Zoonen, L. (1992). *Feminist theory and information technology*. Media, Culture & Society, 14(1), 9-29.

Verloo, M., & Roggeband, C. (1996). *Gender impact assessment: The development of a new instrument in the Netherlands*. Impact Assessment, 14(1), 3-20.

Williams, R. (2020). *Surmounting Boundaries: Closing The Governance Gap Governance Arrangements In Public Sector Ict Shared Services* (Doctoral dissertation, Open Access Te Herenga Waka-Victoria University of Wellington).

Woltjer, J. (2014). A global review on peri-urban development and planning. Jurnal Perencanaan Wilayah dan Kota, 25(1), 1-16.