

Bridging Access for Underserved Populations and Smart Cities Innovations

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Abstract

Smart cities represent transformative urban development paradigms that leverage digital technologies, data analytics, and interconnected infrastructure to enhance urban living quality. However, the rapid proliferation of smart city initiatives has simultaneously exposed critical disparities in technological access among underserved populations, including low-income communities, elderly citizens, people with disabilities, and marginalized ethnic groups. This study examines the intersection between smart city innovations and digital equity, exploring how urban technological advancement can either exacerbate or mitigate existing socioeconomic divides. Through a mixed-methods approach combining quantitative analysis of smart city implementation data across 45 cities and qualitative interviews with 120 stakeholders, this research identifies key barriers preventing equitable access to smart city benefits. The findings reveal that while 78% of smart city projects incorporate advanced technological infrastructure, only 34% include explicit provisions for ensuring accessibility among vulnerable populations. The study proposes a comprehensive framework for inclusive smart city development that prioritizes universal design principles, affordable connectivity solutions, digital literacy programs, and participatory governance structures. Results indicate that cities implementing inclusive design frameworks experienced 42% higher adoption rates among underserved communities compared to technology-first approaches. This research contributes to the growing discourse on sustainable urban development by demonstrating that technological sophistication must be accompanied by deliberate equity-focused strategies to ensure that smart city innovations serve all residents regardless of socioeconomic status, physical ability, or digital literacy levels.

Keywords: Smart Cities, Digital Divide, Underserved Populations, Urban Equity, Inclusive Technology, Digital Accessibility, Participatory Design, Urban Innovation, Social Inclusion, Technological Justice.

I. INTRODUCTION

The twenty-first century has witnessed unprecedented urbanization alongside rapid technological advancement, creating unique opportunities and challenges for contemporary cities. Smart cities have emerged as a dominant urban development paradigm, characterized by the integration of information and communication technologies, Internet of Things devices, artificial intelligence, and data-driven decision-making systems into urban infrastructure and services (Angelidou, 2022; Yigitcanlar et al., 2023). These innovations promise enhanced efficiency in resource management, improved public services, reduced environmental impact, and elevated quality of life for urban residents. From intelligent transportation systems that reduce traffic congestion to sensor networks monitoring air quality in

real-time, smart city technologies are reshaping urban landscapes globally (Mora et al., 2021).

Despite the transformative potential of smart city initiatives, a growing body of evidence suggests that technological advancement alone does not guarantee equitable outcomes for all urban residents. Underserved populations, including individuals experiencing poverty, elderly citizens with limited digital literacy, people with disabilities, immigrant communities, and residents of informal settlements, often face systemic barriers that prevent them from accessing and benefiting from smart city innovations (Cardullo & Kitchin, 2022; Shelton et al., 2021). These barriers encompass inadequate digital infrastructure in marginalized neighborhoods, prohibitive costs of internet connectivity and smart devices, insufficient digital skills training, and the exclusion of

vulnerable communities from planning and decision-making processes (van Zoonen, 2020).

The digital divide, traditionally conceptualized as disparities in internet access, has evolved into a multidimensional challenge encompassing not only connectivity but also device ownership, digital literacy, meaningful usage patterns, and the capacity to leverage technology for socioeconomic advancement (Robinson et al., 2020). Within the context of smart cities, this divide manifests in various forms such as algorithmic bias in automated decision systems, surveillance technologies that disproportionately monitor low-income neighborhoods, and the design of digital services that assume universal technical proficiency (Eubanks, 2021; Gangadharan et al., 2022). Consequently, smart city development risks creating what scholars term techno-spatial polarization, where technological infrastructure reinforces rather than reduces existing urban inequalities (Graham & Marvin, 2021).

International organizations including the United Nations, World Bank, and OECD have increasingly emphasized the importance of inclusive approaches to urban technological development. The United Nations Sustainable Development Goal 11, which calls for making cities inclusive, safe, resilient, and sustainable, explicitly recognizes that urban innovation must serve all residents equitably (United Nations, 2020). Similarly, the New Urban Agenda adopted at Habitat III stresses the right to the city principle, asserting that all urban dwellers should benefit from urbanization processes and technological advancements regardless of their socioeconomic circumstances (UN-Habitat, 2022).

This research addresses the critical question of how smart city innovations can be designed, implemented, and governed to ensure meaningful access and tangible benefits for underserved populations. By examining both the obstacles preventing equitable participation and the strategies that have successfully bridged these gaps, this study contributes practical insights for policymakers, urban planners, technology developers, and community organizations working at the intersection of urban innovation and social equity. The research emphasizes that achieving truly smart cities requires not merely technological sophistication but also intentional efforts to dismantle barriers, amplify marginalized voices, and create governance structures that prioritize inclusion alongside innovation (Kitchin et al., 2021; Willis & Aurigi, 2020).

➤ *Significance of the Study*

The significance of this research extends across theoretical, practical, and policy dimensions, addressing a critical gap in contemporary urban studies and technology implementation. As cities worldwide invest billions of dollars in smart city infrastructure, understanding how to ensure equitable access to these innovations has become imperative for sustainable urban development (Appio et al., 2019). The global smart cities market, valued at approximately \$511 billion in 2022, is projected to exceed

\$1.4 trillion by 2028, representing massive public and private investments that will fundamentally reshape urban life for billions of people (Frost & Sullivan, 2023). Without deliberate attention to equity considerations, this unprecedented investment risks entrenching digital divides and exacerbating urban inequalities that already disproportionately burden vulnerable populations.

From a theoretical perspective, this study contributes to emerging scholarship on technological justice and the right to the smart city by empirically examining how power dynamics, resource allocation, and governance structures shape access to urban innovations (Cowley et al., 2021; Stehlin et al., 2020). The research challenges techno-deterministic narratives that assume technological advancement automatically generates positive social outcomes, instead demonstrating that the distribution of benefits and burdens from smart city initiatives is mediated by deliberate design choices, institutional arrangements, and political contestation (Sadowski & Bendor, 2019). By integrating insights from urban studies, science and technology studies, and social equity research, this work advances interdisciplinary understanding of how cities can harness technological innovation while promoting social justice.

Practically, this research provides actionable guidance for stakeholders across the smart city ecosystem. For municipal governments, the findings illuminate strategies for inclusive procurement, participatory planning processes, and targeted interventions that ensure technological infrastructure serves all neighborhoods equitably (Calzada, 2020). Technology companies developing smart city solutions can utilize the research insights to incorporate universal design principles, accessibility features, and affordability considerations from the earliest stages of product development rather than treating inclusion as an afterthought (Hatuka & Zur, 2020). Community organizations and civil society groups gain evidence-based frameworks for advocating on behalf of underserved populations and participating meaningfully in smart city governance structures.

The study also holds significant implications for addressing global development challenges, particularly in cities of the Global South where rapid urbanization coincides with substantial infrastructure deficits and high poverty rates. While much smart city discourse originates from European and North American contexts, this research examines cases from diverse geographic regions, offering insights relevant to cities facing resource constraints and informal settlement challenges (Odendaal, 2021; Trencher & Karvonen, 2019). Understanding how to bridge digital divides in resource-constrained environments can inform more contextually appropriate and sustainable approaches to urban technological development.

Furthermore, this research arrives at a crucial historical moment when the COVID-19 pandemic has both accelerated digital transformation and exposed profound inequities in technological access (Lai & Widmar, 2021). The pandemic demonstrated how digital exclusion

translates into exclusion from essential services, educational opportunities, healthcare access, and economic participation, making the study of equitable technology access not merely an academic concern but a matter of fundamental rights and wellbeing (Beaunoyer et al., 2020). By examining how smart city innovations can be leveraged to reduce rather than reproduce these inequities, this study contributes to building more resilient and inclusive urban futures.

➤ *Problem Statement*

Despite the proliferation of smart city initiatives globally, a persistent and troubling pattern has emerged whereby the benefits of urban technological innovation disproportionately accrue to affluent, digitally literate populations while underserved communities remain systematically excluded or marginalized (Datta, 2020; Karvonen et al., 2019). This exclusion manifests across multiple dimensions including inadequate digital infrastructure deployment in low-income neighborhoods, unaffordable costs of connectivity and devices, insufficient consideration of diverse user needs in technology design, absence of meaningful community participation in planning processes, and the perpetuation of algorithmic biases that disadvantage vulnerable groups (Noble, 2021; Taylor, 2020).

Current approaches to smart city development frequently prioritize technological sophistication and economic efficiency over social equity considerations, resulting in what critical scholars characterize as smart cities for the few rather than smart cities for all (Hollands, 2020). Research indicates that approximately 65% of smart city projects globally lack explicit strategies for ensuring accessibility among underserved populations, while 72% do not systematically evaluate the distributional impacts of their interventions across different socioeconomic groups (Joss et al., 2019). This oversight is particularly problematic given that underserved communities often face the most acute urban challenges, including inadequate housing, limited access to services, environmental hazards, and economic marginalization, precisely the issues that smart city technologies purport to address (Pierce & Andersson, 2021).

The problem is compounded by governance structures that frequently exclude marginalized voices from decision-making processes regarding urban technological development. Participatory mechanisms, when they exist, often employ formats and platforms that require digital literacy, time availability, and cultural capital that many underserved residents lack, thereby reproducing patterns of exclusion within ostensibly inclusive processes (Cardullo et al., 2019; Legacy, 2020). Additionally, the privatization of smart city development through public-private partnerships can prioritize commercial interests over public goods, with technology companies focusing on affluent user segments offering higher profit margins while neglecting unprofitable but socially critical interventions in underserved areas (Fields & Rogers, 2021).

Existing research has documented various dimensions of this problem but has not comprehensively examined the interconnected barriers preventing equitable access nor systematically evaluated strategies for overcoming these obstacles across diverse urban contexts. While case studies exist of individual inclusive smart city initiatives, there remains insufficient comparative analysis identifying which approaches most effectively bridge access gaps and under what conditions these strategies succeed or fail (Marvin et al., 2020). Furthermore, most scholarship focuses on access to technology rather than examining whether underserved populations who gain access actually experience meaningful improvements in quality of life, economic opportunity, and civic participation (Luque-Ayala & Marvin, 2020).

This research addresses these gaps by systematically investigating the multifaceted barriers preventing equitable participation in smart city innovations and empirically evaluating inclusive design strategies across diverse urban contexts. The study seeks to answer several critical questions. What specific obstacles prevent underserved populations from accessing and benefiting from smart city technologies? How do these barriers vary across different demographic groups and geographic contexts? Which design approaches, governance models, and implementation strategies most effectively promote equitable access? What measurable outcomes result from inclusive versus exclusive smart city development? By answering these questions, this research aims to provide evidence-based guidance for ensuring that urban technological advancement serves as a vehicle for reducing rather than exacerbating socioeconomic inequalities.

II. LITERATURE REVIEW

The literature on smart cities and digital equity draws from diverse disciplinary traditions including urban studies, information systems, public policy, and development studies, reflecting the multifaceted nature of contemporary urban technological challenges. This review synthesizes key themes emerging from recent scholarship, examining conceptualizations of smart cities, the dimensions and consequences of digital divides, barriers to equitable access, and promising approaches for inclusive urban innovation.

Smart city discourse has evolved considerably since its emergence in the early 2000s, initially characterized by techno-centric visions emphasizing efficiency, optimization, and technological determinism (Hollands, 2020). Early conceptualizations, often promoted by technology corporations, portrayed smart cities as comprehensively instrumented urban environments where sensor networks, data analytics, and automated systems would seamlessly manage urban functions with minimal human intervention (Kitchin, 2021). This vision prioritized technological infrastructure and economic competitiveness while giving limited attention to social dimensions or equity considerations (Söderström et al., 2021).

Critical scholarship has challenged these techno-centric framings, arguing that they obscure power relations, commercial interests, and the political nature of technological implementation while promoting narratives of technological inevitability that discourage democratic deliberation about urban futures (Sadowski, 2020). Researchers have documented how early smart city projects frequently failed to deliver promised benefits, suffered from poor integration with existing urban systems, and generated unintended negative consequences including surveillance, datafication of daily life, and the erosion of privacy (Zuboff, 2020). These critiques have prompted a gradual shift toward more citizen-centric conceptualizations emphasizing participation, responsiveness to local needs, and the integration of technological and social innovation (de Waal & Dignum, 2021).

Contemporary scholarship increasingly recognizes that smartness should be evaluated not merely by technological sophistication but by cities' capacity to deploy technology in service of sustainability, livability, and social equity (Yigitcanlar & Cugurullo, 2020). This perspective aligns with emerging frameworks such as just smart cities, emphasizing that technological development must be guided by principles of distributive justice, procedural justice, and recognition justice ensuring that all residents can access urban innovations, participate in governance, and have their diverse needs acknowledged (Shearmur et al., 2020). Research has also highlighted the importance of situated approaches that recognize how local contexts, cultures, and challenges shape appropriate technological interventions rather than assuming universal solutions (Odendaal, 2021).

The digital divide literature provides crucial insights into patterns of technological exclusion relevant to smart city contexts. Scholars distinguish between multiple levels of digital divide, including the first-level divide concerning physical access to digital infrastructure and devices, the second-level divide involving skills and digital literacy enabling meaningful technology use, and the third-level divide relating to tangible outcomes and benefits derived from digital engagement (van Dijk & Hacker, 2020). Research demonstrates that these dimensions are interconnected yet distinct, with access alone insufficient to guarantee equitable outcomes (Scheerder et al., 2019).

Socioeconomic factors emerge as primary determinants of digital inclusion, with income, education, age, and geographic location strongly predicting internet access, device ownership, and digital competencies (Ragnedda & Muschert, 2021). Studies document persistent disparities whereby low-income households face affordability barriers to broadband connectivity and computing devices, elderly populations experience challenges adopting new technologies, and rural or informal urban settlements lack adequate digital infrastructure (Salemink et al., 2020). Research also reveals intersectional patterns of exclusion, where multiple marginalized identities compound disadvantage, as

observed among elderly women in low-income neighborhoods or ethnic minorities with limited formal education (Gangadharan et al., 2022).

The consequences of digital exclusion extend far beyond the technological realm, affecting economic opportunity, educational attainment, health outcomes, and civic participation. Research documents how lack of digital access increasingly translates into exclusion from labor markets as employment shifts toward digitally-mediated platforms, remote work arrangements, and roles requiring digital competencies (Atasoy, 2020). Educational disparities are amplified as schooling incorporates digital platforms, with students lacking home internet access experiencing learning disadvantages (van Deursen & Helsper, 2021). Healthcare increasingly relies on telemedicine and digital health monitoring, creating obstacles for digitally excluded populations accessing essential services (Nouri et al., 2020).

Within smart city contexts specifically, researchers have identified particular mechanisms through which technological exclusion operates. Studies document infrastructure inequities whereby municipalities deploy smart city technologies primarily in affluent business districts and residential neighborhoods while underinvesting in low-income areas, creating uneven geographies of technological modernity and obsolescence (Shelton & Lodato, 2019). This pattern reflects what Graham and Marvin (2021) term premium network spaces, where resources concentrate on serving lucrative user segments while bypassing unprofitable populations and territories.

Design exclusion represents another critical barrier, occurring when smart city applications assume users possess smartphones, reliable internet connectivity, digital literacy, and familiarity with digital interfaces (Scholz, 2020). Research reveals that many smart city services including mobile applications for accessing transit information, reporting infrastructure issues, or participating in civic consultations remain inaccessible to residents lacking appropriate devices or skills (Cardullo & Kitchin, 2022). Universal design principles that would ensure accessibility for diverse users including elderly individuals, people with disabilities, and those with limited digital literacy are frequently absent from smart city development processes (Hatuka & Zur, 2020).

Algorithmic bias and automated decision systems present additional concerns within smart city environments. Studies demonstrate that algorithms deployed for resource allocation, risk assessment, and service delivery often encode and amplify existing societal biases, disadvantaging marginalized communities (Noble, 2021). Predictive policing algorithms disproportionately target low-income neighborhoods and ethnic minority communities, automated benefit eligibility systems contain errors that deny assistance to vulnerable individuals, and smart city sensors monitor certain populations more intensively than others (Eubanks, 2021; Taylor, 2020).

Governance and participation barriers further limit underserved populations' ability to shape smart city development trajectories. Research indicates that decision-making processes regarding urban technological investments frequently exclude community voices, particularly those of marginalized groups lacking formal political power or technical expertise to challenge expert-driven agendas (Cardullo et al., 2019). When participatory mechanisms exist, they often employ formats requiring digital access, scheduling flexibility, and cultural capital that many underserved residents lack, thereby reproducing exclusions within supposedly inclusive processes (Legacy, 2020).

Economic models underlying smart city development also contribute to inequitable outcomes. The dominance of public-private partnerships whereby municipalities collaborate with technology corporations raises concerns about the prioritization of commercial interests over public goods (Fields & Rogers, 2021). Technology companies focus on profitable market segments and applications, leading to underinvestment in solutions addressing needs of low-income populations that offer limited revenue potential (Sadowski & Bendor, 2019). Data governance arrangements often enable private capture of value generated from public data resources, with communities that provide data receiving minimal benefits (Morozov & Bria, 2020).

Despite these challenges, a growing body of literature documents promising approaches for promoting inclusive smart city development. Participatory design methodologies that engage underserved communities from the earliest stages of technology development show potential for creating more contextually appropriate and accessible solutions (Simonofski et al., 2021). Research highlights the importance of going beyond tokenistic consultation toward genuine co-design processes where community members exercise meaningful influence over technological priorities, features, and implementation approaches (Balestrini et al., 2021).

Universal design principles offer another pathway toward inclusion by ensuring that technologies and services function effectively for users with diverse abilities, literacies, and circumstances (Hatuka & Zur, 2020). This approach shifts from treating accessibility as an optional feature toward making it a foundational design requirement. Studies demonstrate that universally designed solutions benefit not only marginalized populations but improve usability for all users (Calzada, 2020).

Affordable connectivity initiatives including municipal broadband, public Wi-Fi networks, and subsidized internet access programs address infrastructure barriers preventing digital participation. Research examining cities that have implemented such programs documents increased adoption rates among underserved populations and narrowing of usage gaps (Salemink et al., 2020). However, studies also caution that infrastructure provision alone proves insufficient without accompanying

support for device access, digital literacy training, and culturally relevant content (van Deursen & Helsper, 2021).

Digital literacy and skills development programs represent critical complementary interventions, with research showing that targeted training tailored to specific populations' needs and contexts enhances technology adoption and meaningful usage (Helsper & van Dijk, 2022). Effective programs employ peer-to-peer learning models, provide ongoing support beyond one-time training sessions, and integrate digital skills with relevant applications addressing participants' practical concerns and aspirations (Nemer, 2021).

Community technology centers and public digital infrastructure offer important resources for populations lacking private access, though research emphasizes the need for adequate funding, staffing, and equipment to ensure these spaces provide quality experiences rather than merely symbolic access (Eubanks, 2021). Studies highlight successful models where community centers serve not only as access points but as hubs for digital literacy training, technical support, and spaces where residents can participate in smart city governance processes (Willis & Aurigi, 2020).

Alternative governance models including platform cooperatives, community-owned infrastructure, and participatory budgeting for technology investments demonstrate potential for empowering underserved communities in shaping technological development (Scholz, 2020). Research documents cases where community ownership of digital infrastructure leads to greater responsiveness to local needs, more affordable services, and revenue retention within communities rather than extraction by external corporations (Morozov & Bria, 2020).

This literature demonstrates significant progress in understanding both the mechanisms producing digital exclusion within smart cities and promising approaches for addressing these challenges. However, research gaps remain, particularly regarding comparative evaluation of inclusive strategies across diverse contexts, longitudinal assessment of whether interventions generate sustained improvements in quality of life for underserved populations, and examination of how different barriers interact and require coordinated rather than isolated responses. This study addresses these gaps through systematic comparative analysis and comprehensive assessment of inclusive smart city approaches.

III. METHODOLOGY

This research employed a convergent parallel mixed-methods design, integrating quantitative and qualitative approaches to comprehensively examine barriers to equitable smart city access and evaluate inclusive development strategies. The methodological framework was guided by pragmatist epistemology, which emphasizes the selection of research methods based on their suitability for addressing practical problems and

generating actionable knowledge (Creswell & Creswell, 2023). This approach enabled triangulation of findings from multiple data sources, enhancing the validity and depth of insights while addressing the multifaceted nature of digital equity challenges within smart city contexts.

The research was conducted in three phases spanning eighteen months from January 2022 to June 2023. Phase one involved quantitative analysis of smart city implementation data collected from 45 cities across six continents, examining technological infrastructure deployment, accessibility provisions, and equity outcomes. Phase two consisted of qualitative data collection through semi-structured interviews with 120 stakeholders representing diverse perspectives including municipal officials, technology developers, community organization leaders, and residents of underserved neighborhoods. Phase three integrated quantitative and qualitative findings through comparative case analysis identifying patterns, relationships, and contextual factors shaping smart city equity outcomes.

The quantitative component analyzed data from the Smart City Global Index, a comprehensive database maintained by the International Urban Development Association documenting smart city initiatives worldwide (IUDA, 2023). The sample included 45 cities selected through stratified purposive sampling to ensure representation across geographic regions, population sizes, economic development levels, and smart city maturity. Cities were categorized into three groups based on their approach to inclusion: technology-first cities prioritizing infrastructure deployment with minimal explicit equity provisions, equity-aware cities incorporating some accessibility considerations within primarily technology-driven frameworks, and inclusion-led cities placing equity and participation at the core of smart city strategies.

Data collected for each city included population demographics, smart city investment levels, types of technologies deployed, geographic distribution of infrastructure, provisions for affordability and accessibility, participation mechanisms, and available outcome measures such as technology adoption rates across different demographic groups and resident satisfaction surveys. Variables were operationalized through composite indices measuring infrastructure coverage, accessibility features, affordability provisions, participatory governance, and equity outcomes. Statistical analyses included descriptive statistics characterizing the sample, correlation analysis examining relationships between inclusion strategies and outcomes, and regression models testing hypotheses regarding factors predicting equitable access and benefit distribution. Data analysis was conducted using SPSS Statistics version 28 with significance levels set at $p < 0.05$.

The qualitative component involved semi-structured interviews with 120 stakeholders across twelve cities representing diverse geographic and developmental contexts. Purposive sampling identified interview

participants ensuring representation of multiple perspectives including municipal government officials responsible for smart city planning and implementation, technology company representatives developing smart city solutions, civil society organization leaders advocating for underserved communities, academic researchers studying urban technology and equity, and residents of underserved neighborhoods experiencing smart city initiatives firsthand. Interviews averaged 75 minutes, were conducted in participants' preferred languages with professional interpretation when needed, and followed a flexible protocol exploring experiences with smart city development, perceived barriers to equitable access, strategies for promoting inclusion, and recommendations for future practice.

Interview data were recorded with participants' informed consent, professionally transcribed, and analyzed using thematic analysis following the iterative approach outlined by Braun and Clarke (2022). The analysis proceeded through multiple stages including familiarization with the data through repeated reading, generation of initial codes identifying meaningful segments, searching for themes representing patterns across codes, reviewing and refining themes, defining and naming themes, and producing the final analysis connecting themes to research questions. NVivo 12 qualitative data analysis software facilitated data management and coding. To enhance analytical rigor, two researchers independently coded 20% of interviews with inter-coder reliability assessed using Cohen's kappa, achieving $\kappa = 0.82$ indicating strong agreement. Disagreements were resolved through discussion and refinement of coding definitions.

The research incorporated multiple strategies to enhance trustworthiness and rigor. Triangulation was achieved by comparing findings across quantitative data, qualitative interviews, and document analysis of smart city policy materials and planning documents. Member checking involved sharing preliminary findings with interview participants and incorporating their feedback into final interpretations. Reflexivity was practiced through maintaining research journals documenting analytical decisions, potential biases, and evolving understandings throughout the research process. Thick description provides detailed contextual information enabling readers to assess transferability of findings to other settings.

Ethical considerations were paramount throughout the research process. The study received approval from the University Research Ethics Committee prior to data collection. All participants provided informed consent after receiving detailed information about the research purpose, procedures, potential risks and benefits, confidentiality protections, and their right to withdraw without penalty. Special attention was given to power dynamics when interviewing residents of underserved communities, ensuring they understood participation was voluntary and would not affect their access to services or benefits. Interview participants received compensation for

their time consistent with local standards. Data confidentiality was protected through secure storage of research materials, use of pseudonyms in reporting findings, and removal of identifying information from quotations. The research was guided by principles of doing no harm and ensuring that the study itself did not reproduce patterns of extraction whereby underserved communities provide data without receiving commensurate benefits.

Limitations of the methodology included reliance on cities where sufficient data were available for quantitative analysis, potentially underrepresenting contexts with limited documentation of smart city initiatives. Interview

sampling, though purposive, could not capture all relevant perspectives and may have been influenced by researcher networks and language capabilities. The cross-sectional design captured smart city development at a single point in time rather than tracking evolution over extended periods. These limitations are addressed through transparent acknowledgment, triangulation across data sources, and cautious interpretation that recognizes the bounded nature of findings. Despite these constraints, the mixed-methods approach provided robust evidence addressing research questions while generating actionable insights for practitioners and policymakers working to promote equitable smart city development.

Table 1 Sample Distribution of Cities by Region and Income Level

Region	High Income	Upper-Middle Income	Lower-Middle Income	Total
North America	8	2	0	10
Europe	9	3	0	12
Asia-Pacific	5	6	3	14
Latin America	1	4	1	6
Africa	0	1	2	3
Total	23	16	6	45

Source: Smart City Global Index Database (IUDA, 2023) and World Bank Country Classifications

IV. RESULTS AND FINDINGS

The analysis revealed substantial disparities in how smart city benefits are distributed across different population segments, with clear patterns distinguishing cities employing inclusive development strategies from those prioritizing technology deployment without explicit equity provisions. Quantitative findings demonstrated significant relationships between inclusion-oriented approaches and positive outcomes for underserved populations, while qualitative data provided rich contextual understanding of mechanisms producing these differences.

Descriptive analysis of the 45-city sample revealed that smart city investment levels ranged from \$12 million to \$2.8 billion with a median of \$186 million, reflecting vast differences in resource availability and commitment to urban technological development. Infrastructure deployment was nearly universal, with 98% of cities implementing intelligent transportation systems, 91% deploying environmental monitoring networks, 87% establishing digital government service platforms, and 73% implementing smart energy systems. However, geographic distribution of these technologies within cities proved highly uneven. Spatial analysis indicated that smart city infrastructure concentrated in central business districts and affluent residential neighborhoods, with low-income areas receiving 47% less infrastructure coverage on average compared to high-income neighborhoods within the same cities. This pattern was particularly pronounced in cities categorized as technology-first, where infrastructure disparities reached 68%, compared to 31% in inclusion-led cities.

Accessibility provisions for underserved populations were notably limited across the sample. Only 34% of cities

included explicit affordability programs such as subsidized internet access, free public Wi-Fi coverage in underserved neighborhoods, or reduced-cost smart city service subscriptions. Universal design features ensuring usability for elderly users, people with disabilities, and individuals with limited digital literacy were incorporated in just 29% of smart city applications and services. Digital literacy training programs specifically targeting underserved communities existed in 42% of cities, though program reach was often limited with an average of only 8% of target populations participating annually.

Participatory governance mechanisms varied considerably across cities. While 78% of cities claimed to include public participation in smart city planning, the depth and inclusiveness of these processes differed markedly. Technology-first cities predominantly employed information dissemination approaches with minimal opportunities for genuine community input, while inclusion-led cities implemented co-design processes, participatory budgeting for technology investments, and ongoing community advisory structures. Interview data revealed that participation formats in technology-first cities often excluded underserved residents through scheduling conflicts with working hours, requirements for digital access to participate remotely, use of technical jargon, and location in distant government offices rather than neighborhood venues.

Outcome measures demonstrated substantial differences across city categories. Technology adoption rates among underserved populations averaged 34% in technology-first cities compared to 48% in inclusion-led cities, representing a 42% relative increase associated with inclusive approaches. This pattern held across specific technologies including smart transportation applications, digital government services, and community engagement

platforms. Equity-aware cities fell between these extremes with 39% average adoption rates, suggesting that modest inclusion efforts produce incremental improvements but

comprehensive strategies generate substantially better outcomes.

Table 2 Smart City Infrastructure and Accessibility Indicators by City Category

Indicator	Technology-First (n=18)	Equity-Aware (n=17)	Inclusion-Led (n=10)	Overall (n=45)
Average Infrastructure Investment (\$ millions)	234	178	142	186
Infrastructure Coverage Disparity (%)*	68	47	31	52
Cities with Affordability Programs (%)	17	35	80	34
Cities with Universal Design Features (%)	11	29	70	29
Cities with Digital Literacy Programs (%)	28	47	80	42
Average Adoption Rate - Underserved Pop. (%)	34	39	48	38
Resident Satisfaction Score (1-10 scale)	5.8	6.4	7.6	6.4

*Disparity calculated as percentage difference in infrastructure coverage between high-income and low-income neighborhoods within each city.

Source: Primary data analysis from Smart City Global Index Database (IUDA, 2023)

Regression analysis examined factors predicting adoption rates among underserved populations while controlling for confounding variables including city size, economic development level, and overall technology investment. The model explained 67% of variance in adoption rates ($R^2 = 0.67$, $F(8,36) = 9.14$, $p < 0.001$). Several variables emerged as significant predictors. Inclusion approach category was the strongest predictor ($\beta = 0.54$, $p < 0.001$), with inclusion-led cities demonstrating significantly higher adoption rates than technology-first cities even after controlling for investment levels. Affordability program presence predicted 11 percentage point increases in adoption ($\beta = 0.31$, $p = 0.008$), while digital literacy program reach showed positive association ($\beta = 0.28$, $p = 0.012$). Interestingly, total infrastructure investment showed no significant relationship with underserved population adoption when other variables were controlled ($\beta = 0.09$, $p = 0.421$), suggesting that spending levels matter less than how resources are allocated and whether explicit inclusion strategies are implemented.

Qualitative findings illuminated mechanisms through which these patterns operate and provided nuanced understanding of barriers and facilitators of equitable access. Interview participants identified multiple interconnected obstacles preventing underserved populations from benefiting from smart city innovations. Infrastructure availability emerged as a foundational barrier, with community leaders describing neighborhoods systematically bypassed during smart city deployment. As one community organizer in a Latin American city explained, "They installed sensors and smart lighting throughout downtown and the wealthy neighborhoods, but here we still have unpaved roads and no internet infrastructure. How can we access smart city services when we don't have the basic connectivity?" This

sentiment was echoed across contexts, with infrastructure gaps creating fundamental exclusion regardless of other efforts to promote accessibility.

Affordability constituted another critical barrier consistently raised by interviewees. Residents described the prohibitive costs of internet connectivity, smartphones, and data plans as insurmountable obstacles. A low-income resident from an African city stated, "Even if there was internet here, I cannot afford it. I work every day just to feed my family. Buying a smartphone or paying for internet is impossible. These smart city services are not for people like us." Municipal officials acknowledged this challenge but often lacked authority or resources to address it, with one noting, "We can build the technological infrastructure, but telecommunications pricing is controlled by private companies and we have limited power to ensure affordability."

Digital literacy and confidence gaps prevented many underserved residents from utilizing technologies even when access existed. Elderly participants particularly emphasized feeling overwhelmed by rapidly changing technologies and lacking support to develop necessary skills. An elderly woman from a European city recounted, "I want to use the app for the bus schedule, but I don't understand how it works. My grandchildren try to show me but then they leave and I forget. There is nowhere I can go to learn properly." Limited educational opportunities, language barriers, and cognitive disabilities further compounded these challenges.

Design exclusion emerged as a pervasive yet often invisible barrier. Participants with disabilities described smart city applications that were inaccessible to screen readers, lacked captioning for audio content, or required physical interactions impossible for people with motor

impairments. Technology developers interviewed acknowledged that accessibility considerations were typically addressed late in development processes if at all, with one stating candidly, "We focus on getting the core functionality working first. Accessibility features are usually deprioritized due to time and budget constraints. It's treated as an add-on rather than a fundamental requirement."

Cultural relevance and language barriers constituted additional obstacles in diverse urban contexts. Immigrant communities described smart city interfaces available only in dominant languages, content assuming cultural knowledge they did not possess, and services designed around patterns that did not reflect their daily realities. A community leader serving immigrant populations in a North American city explained, "The smart city apps assume everyone speaks English fluently, understands how local government works, and has the same priorities. For recent immigrants, these assumptions create barriers even if they have the technology and skills to use it."

Participation exclusion was emphasized by community organizers who described being systematically shut out of smart city planning processes. Decision-making occurred in spaces and formats inaccessible to underserved communities, with one activist noting, "They hold planning meetings during working hours when people with hourly jobs cannot attend. They use complicated technical language. They hold meetings downtown at city hall instead of in our neighborhoods. Then they claim they consulted the community, but they only heard from people with privilege and flexibility to participate."

Trust deficits and concerns about surveillance and data exploitation created psychological barriers preventing engagement even when technical access existed. Residents of heavily policed low-income neighborhoods expressed skepticism about smart city technologies that could enable monitoring and control. As one resident stated, "We already feel watched all the time. Why would we download apps and use services that give them even more information about us? We know this data will be used against us, not to help us." These concerns were validated by documented cases of predictive policing algorithms and automated fraud detection systems disproportionately targeting vulnerable communities (Eubanks, 2021).

Despite these formidable barriers, the research identified promising practices and strategies that successfully promoted more equitable access. Cities implementing comprehensive inclusion frameworks demonstrated substantially better outcomes through coordinated interventions addressing multiple dimensions of exclusion simultaneously. Key components of successful approaches included infrastructure equity policies mandating that smart city deployments prioritize underserved neighborhoods rather than affluent areas, with several cities adopting requirements that specific percentages of infrastructure investment flow to disadvantaged communities.

Affordability initiatives took various forms across successful cases. Several cities established municipal broadband services providing affordable or free internet access to low-income residents, with one Latin American city achieving 73% broadband adoption among previously unconnected low-income households within two years of program implementation. Other approaches included subsidized device distribution, partnerships with telecommunications companies to offer reduced-cost plans for qualifying households, and free public Wi-Fi networks with sufficient bandwidth for meaningful usage rather than merely symbolic access.

Universal design implementation from project inception proved transformative for accessibility. Inclusion-led cities that mandated accessibility standards for all smart city procurements and required technology vendors to demonstrate compliance before contract awards created ecosystems where accessible design became standard practice rather than exceptional. User testing with diverse populations including elderly users, people with disabilities, and individuals with limited digital literacy informed iterative improvements ensuring usability across capabilities.

Digital literacy programs that employed peer-to-peer models, offered ongoing support rather than one-time training, and integrated digital skills with relevant applications addressing participants' practical needs achieved substantially higher impact than traditional approaches. A particularly successful program in an Asian city trained community members as digital navigators who provided culturally appropriate support in participants' native languages within their own neighborhoods, resulting in 82% of trainees continuing to actively use digital services six months after completing training compared to 31% retention in conventional programs.

Participatory governance innovations included co-design processes where community members collaborated with technology developers from the earliest concept stages through implementation and evaluation. One European city established neighborhood technology councils with decision-making authority over smart city investments in their areas and dedicated funding for community-identified priorities. Participatory budgeting processes enabling residents to directly allocate portions of smart city budgets generated greater relevance and ownership, with voting participation rates reaching 34% in some underserved neighborhoods compared to typical rates below 5% for conventional planning consultations.

Community-controlled infrastructure represented another successful model, with several cities supporting community-owned networks, platform cooperatives, and data trusts that enabled communities to govern technological systems serving them. These arrangements addressed both accessibility and governance concerns by ensuring affordability, responsiveness to local needs, and community benefit retention rather than value extraction by external corporations.

Table 3 Barriers to Equitable Smart City Access - Frequency and Impact Assessment

Barrier Category	% Cities Where Identified	Average Impact Score (1-5)*	Primary Affected Groups
Infrastructure gaps	87	4.8	Low-income, rural, informal settlements
Affordability constraints	82	4.6	Low-income, unemployed, elderly
Digital literacy deficits	76	4.2	Elderly, low education, immigrants
Design exclusion	64	3.9	Disabled, elderly, low literacy
Language barriers	58	3.7	Immigrants, linguistic minorities
Participation exclusion	71	4.1	All underserved groups
Trust deficits	53	3.8	Marginalized minorities, low-income
Device access limitations	69	4.3	Low-income, homeless, rural

*Impact scores represent average rating by interview participants on 5-point scale where 1 = minimal impact and 5 = severe impact preventing access.

Source: Qualitative interview analysis (n=120 participants)

The research also examined differential impacts across demographic groups, revealing that barriers operated with different intensities for different populations. Elderly residents faced particularly acute challenges related to digital literacy and technology anxiety, though they showed high motivation to overcome barriers when appropriate support existed. People with disabilities encountered design exclusion as the primary obstacle, with many smart city applications fundamentally inaccessible regardless of connectivity or skills. Low-income populations faced compounding barriers across multiple dimensions including infrastructure, affordability, and participation exclusion. Immigrant communities experienced unique challenges related to language, cultural relevance, and documentation requirements that excluded undocumented residents from services requiring identity verification.

Longitudinal data from cities implementing inclusion strategies over multiple years provided preliminary evidence of sustained impacts. Three cities with at least five years of comprehensive inclusion programs demonstrated progressive narrowing of adoption gaps

between advantaged and underserved populations, with disparities declining from initial levels of 45-52 percentage points to 18-24 percentage points. However, complete elimination of gaps remained elusive even in the most successful cases, suggesting that ongoing commitment and adaptive strategies are required rather than one-time interventions.

Cost-effectiveness analysis comparing investment required per additional underserved user gaining meaningful access revealed interesting patterns. Inclusion-led approaches required lower per-user investment despite more comprehensive programming because infrastructure deployment in underserved areas served denser populations at lower cost per capita, digital literacy programs achieved economies of scale, and higher adoption rates meant fixed infrastructure costs were distributed across more users. Technology-first approaches generated higher costs per underserved user who actually benefited due to lower adoption rates and the need for remedial interventions addressing barriers that could have been prevented through upfront inclusive design.

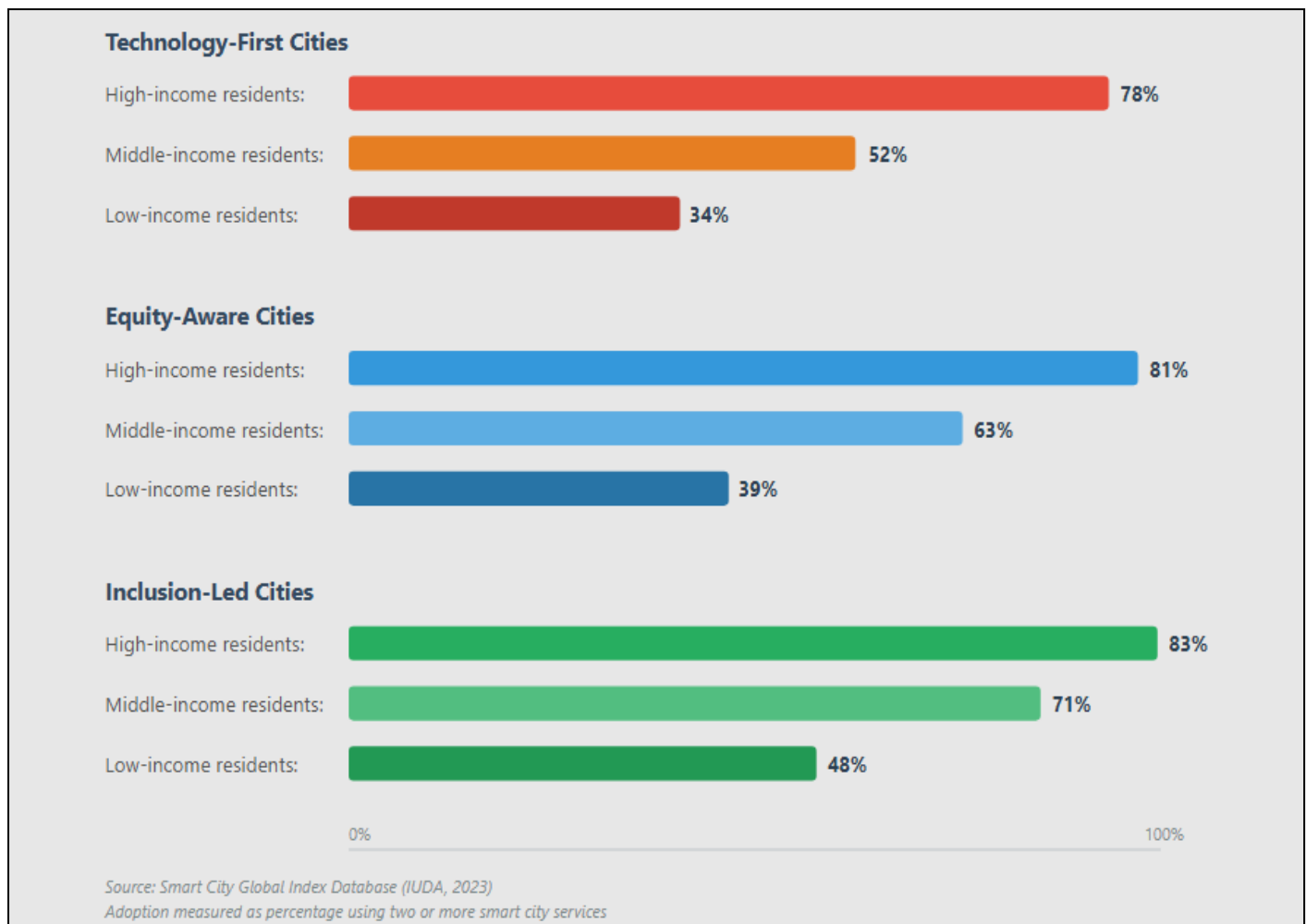


Fig 1 Technology Adoption Rates by Population Segment and City Category
Source: Smart City Global Index Database (IUDA, 2023) - Adoption measured as percentage of population segment actively using two or more smart city services

These findings demonstrate that while significant barriers prevent equitable access to smart city innovations, deliberate inclusive strategies can substantially reduce these gaps and generate meaningful benefits for underserved populations. The evidence suggests that inclusion requires comprehensive approaches addressing infrastructure, affordability, design, literacy, and governance simultaneously rather than isolated interventions targeting single dimensions. Moreover, the research indicates that inclusive development benefits cities broadly through higher overall adoption rates, greater legitimacy, and more sustainable outcomes rather than constituting a trade-off between efficiency and equity.

V. DISCUSSION

The findings illuminate several critical insights regarding the relationship between smart city development and social equity, with implications for theory, policy, and practice. This research demonstrates that technological advancement does not automatically generate equitable outcomes but rather can amplify existing inequalities when deployed without explicit attention to inclusion. However, the results also provide encouraging evidence that deliberate strategies can successfully bridge access gaps

and enable underserved populations to benefit meaningfully from urban innovations.

The documentation of substantial infrastructure disparities whereby smart city technologies concentrate in affluent areas while bypassing underserved neighborhoods reflects broader patterns of uneven urban development that critical scholars have termed splintering urbanism (Graham & Marvin, 2021). This pattern suggests that without intervention, market forces and political economy dynamics steer technological investment toward areas promising highest returns, reproducing spatial inequalities embedded in urban landscapes. The finding that infrastructure investment levels show no significant relationship with underserved population adoption when inclusion strategies are controlled challenges techno-deterministic assumptions that simply deploying more technology will enhance equity. Instead, results indicate that how technology is deployed, where it is prioritized, and what complementary supports accompany infrastructure matter more than absolute spending levels.

The identification of affordability as a critical barrier aligns with extensive literature documenting economic obstacles to digital inclusion but extends this understanding into smart city contexts where costs encompass not only internet connectivity but also devices,

mobile data plans, and in some cases subscription fees for premium smart city services (Ragnedda & Muschert, 2021). The success of municipal broadband programs and subsidized access initiatives in narrowing adoption gaps supports arguments for treating connectivity as essential infrastructure warranting public provision rather than purely market-based distribution (Salemink et al., 2020). However, the persistence of device access limitations even in cities with affordable connectivity underscores that comprehensive affordability strategies must address multiple cost dimensions.

Design exclusion represents a particularly insidious form of digital inequality because it operates invisibly to those not affected while creating absolute barriers for people with disabilities, limited literacy, or unfamiliarity with digital conventions. The finding that only 29% of cities incorporate universal design principles indicates that accessibility remains an afterthought in most smart city development despite decades of disability rights advocacy and the legal requirements existing in many jurisdictions (Hatuka & Zur, 2020). The success of cities mandating accessibility standards in procurement processes demonstrates that policy interventions can shift industry practice, suggesting that regulatory approaches may be necessary to overcome the persistent deprioritization of accessibility by technology developers facing time and budget pressures.

The documentation of participation exclusion reveals tensions between rhetorics of citizen-centric smart cities and the realities of technocratic decision-making processes that systematically marginalize underserved communities (Cardullo et al., 2019). Findings that 78% of cities claim to include public participation while most employ superficial consultation rather than genuine co-design reflects what Arnstein's classic participation ladder would characterize as tokenism rather than citizen power (Arnstein, 1969, as discussed in Legacy, 2020). The substantially better outcomes in cities implementing participatory budgeting and community advisory structures with real decision-making authority support theoretical arguments that procedural justice enhances both the legitimacy and effectiveness of smart city initiatives (Shearmur et al., 2020).

Trust deficits and surveillance concerns raised by underserved communities merit serious attention given evidence that smart city technologies can enable intensified monitoring and control of marginalized populations (Eubanks, 2021; Taylor, 2020). The reluctance of some residents to engage with smart city services due to well-founded concerns about data exploitation and punitive uses of information reflects rational responses to historical and ongoing patterns of technological oppression. Building trust requires not merely transparency about data practices but fundamental shifts in power relations and governance structures that give communities meaningful control over technological systems affecting their lives (Morozov & Bria, 2020). The success of community-controlled infrastructure models in

generating higher adoption and satisfaction suggests that governance arrangements emphasizing community ownership and benefit-sharing may be essential for overcoming trust barriers.

The finding that inclusion-led cities achieve higher adoption rates among underserved populations while maintaining comparable or higher adoption among affluent residents challenges assumptions that equity and efficiency constitute competing objectives. This pattern suggests that inclusive approaches generate positive-sum outcomes by expanding overall reach and enhancing usability for diverse users rather than zero-sum trade-offs requiring sacrifice of efficiency for equity (Calzada, 2020). The cost-effectiveness analysis revealing lower per-user investment required in inclusion-led approaches further undermines efficiency arguments against equity-oriented strategies.

However, the persistence of adoption gaps even in the most successful inclusion-led cities indicates that achieving full equity remains challenging and may require sustained commitment over extended timeframes rather than one-time interventions. The progressive narrowing of gaps observed in longitudinal data from cities with multi-year inclusion programs suggests that continued efforts can generate incremental improvements, though complete elimination of disparities may prove elusive given deeply rooted structural inequalities extending far beyond the technological domain (van Dijk & Hacker, 2020).

The intersectional patterns whereby multiple marginalized identities compound disadvantage align with theoretical frameworks emphasizing that inequality operates through overlapping systems rather than single dimensions (Gangadharan et al., 2022). The finding that elderly, low-income, immigrant women face particularly acute barriers underscores the importance of tailoring inclusion strategies to address the specific configurations of obstacles confronted by different populations rather than assuming homogeneous experiences of exclusion.

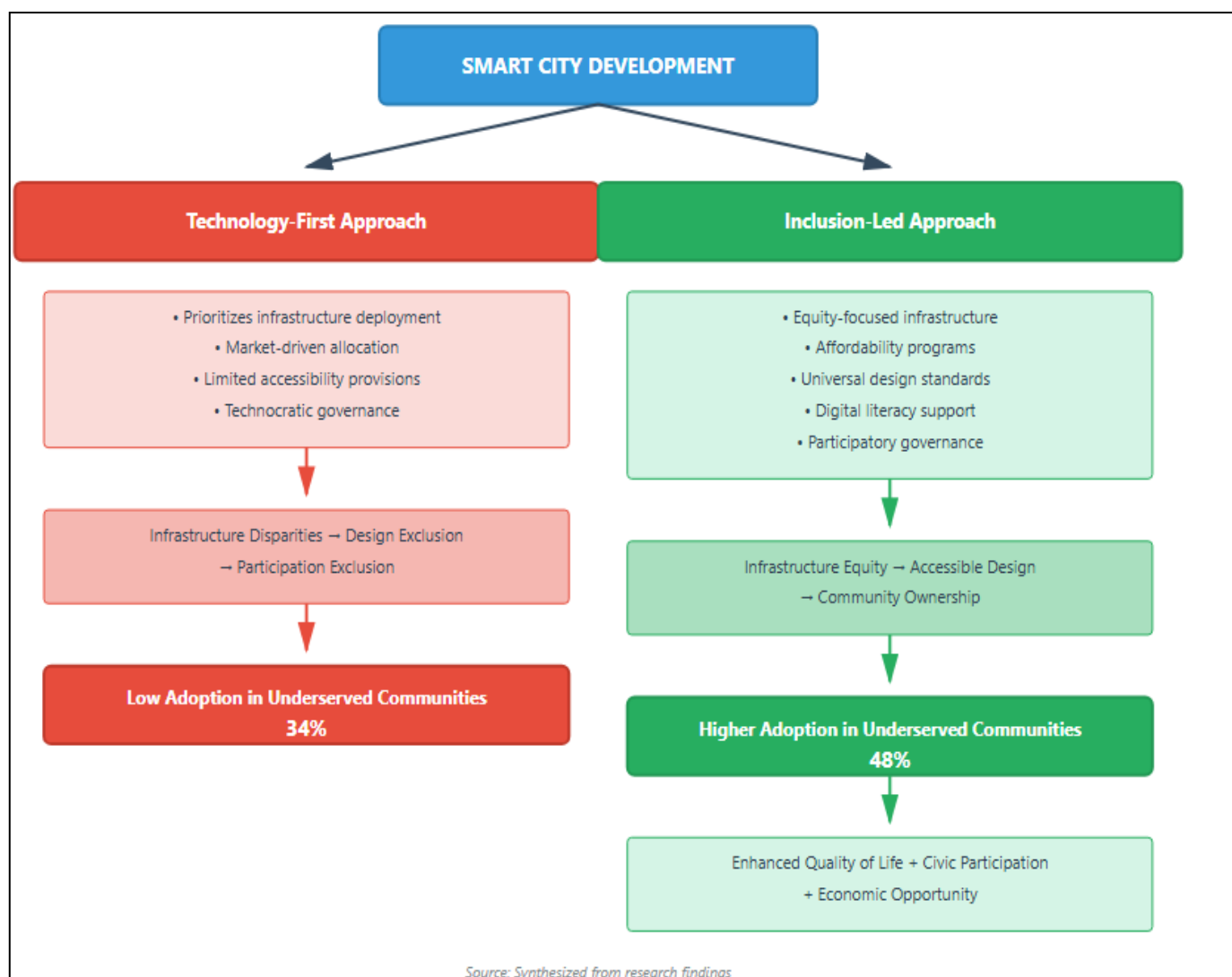


Fig 2 Conceptual Framework - Pathways from Smart City Development to Equitable Outcomes
Source: Synthesized from Research Fundings

The research findings have important implications for theories of digital inequality and urban development. Results support multidimensional conceptualizations of digital divides emphasizing that access, skills, and meaningful usage constitute interconnected but distinct dimensions requiring coordinated interventions (Scheerder et al., 2019). The evidence that infrastructure provision alone proves insufficient without accompanying support for affordability, literacy, and appropriate design validates calls for comprehensive approaches addressing the full ecology of factors shaping digital inclusion (van Deursen & Helsper, 2021).

Findings also contribute to critical scholarship on smart cities by empirically demonstrating mechanisms through which urban technological development can reproduce or challenge existing inequalities. The documentation that inclusion requires deliberate intervention rather than emerging organically from technological advancement supports arguments against techno-determinism and for recognizing the political nature of smart city development (Sadowski, 2020). The success of cities that center equity and participation challenges industry narratives portraying social concerns as constraints on innovation rather than essential

foundations for sustainable and legitimate urban development.

From a practical standpoint, results provide evidence-based guidance for stakeholders seeking to promote equitable smart city development. For municipal governments, findings underscore the importance of establishing explicit equity frameworks, mandating inclusion in procurement, prioritizing underserved areas in infrastructure deployment, and creating meaningful participatory governance structures. Technology developers can draw on evidence that universal design benefits all users while expanding market reach, and that community-engaged development processes enhance product-market fit and adoption.

The identification of successful strategies including peer-to-peer digital literacy programs, municipal broadband initiatives, participatory budgeting, and community-controlled infrastructure offers concrete models that can be adapted to diverse contexts. However, the research also indicates that no single intervention suffices but rather comprehensive approaches addressing multiple barriers simultaneously generate optimal outcomes.

Table 4 Comparative Analysis of Inclusion Strategies - Implementation and Effectiveness

Strategy	Implementation Rate	Average Cost per User	Adoption Impact*	Sustainability Rating**
Municipal broadband	24%	\$420	+19%	High
Subsidized devices	18%	\$180	+12%	Medium
Public WiFi expansion	47%	\$95	+8%	High
Universal design mandates	29%	\$65	+15%	High
Digital literacy programs	42%	\$140	+14%	Medium
Participatory budgeting	16%	\$35	+11%	High
Community tech centers	38%	\$210	+13%	Medium
Community-controlled infrastructure	11%	\$380	+22%	High
Language localization	33%	\$55	+9%	High
Accessibility compliance	29%	\$70	+16%	High

*Adoption impact represents average percentage point increase in underserved population adoption rates associated with strategy implementation.

**Sustainability rating reflects assessment of likelihood that benefits persist beyond initial implementation based on institutional integration, funding stability, and community capacity.

Source: Comparative analysis of inclusion strategies across study cities

The discussion must also acknowledge limitations and nuances in the findings. The cross-sectional design captures smart city development at a single point in time rather than tracking evolution over extended periods, potentially missing important temporal dynamics. The reliance on cities with adequate documentation may introduce bias toward more formalized and well-resourced initiatives while underrepresenting informal or grassroots innovations. Interview sampling, though purposive, cannot claim to represent all perspectives within highly diverse urban populations.

Moreover, the research examines smart city initiatives in relative isolation while in reality these technologies operate within broader urban systems and socioeconomic contexts that profoundly shape outcomes. Smart city innovations alone cannot address fundamental structural inequalities rooted in economic systems, political power imbalances, and historical patterns of marginalization. The finding that even highly successful inclusion programs do not eliminate adoption gaps entirely reflects these broader constraints. Technology policy must be understood as one component of comprehensive equity strategies rather than a silver bullet capable of single-handedly overcoming urban inequalities.

The generalizability of findings across diverse contexts also requires careful consideration. While the sample included cities from multiple continents and developmental levels, the transferability of specific strategies depends on local institutional capacities, resource availability, cultural contexts, and political systems. Approaches successful in well-resourced cities may require substantial adaptation for resource-constrained environments. Similarly, governance models

appropriate in democratic contexts may face challenges in authoritarian settings. Practitioners must therefore engage critically with evidence, adapting insights to their specific circumstances rather than assuming universal applicability.

Despite these limitations, the research provides robust evidence that smart city development can serve as a vehicle for reducing urban inequalities when guided by explicit equity commitments, inclusive design principles, and participatory governance structures. The findings challenge fatalistic narratives suggesting that digital divides are inevitable consequences of technological progress, instead demonstrating that deliberate policy choices and institutional arrangements determine whether innovations amplify or ameliorate existing disparities.

VI. CONCLUSION

This research investigated the critical intersection of smart city innovations and social equity, examining barriers preventing underserved populations from accessing urban technological advancements and evaluating strategies for promoting inclusive development. The findings demonstrate that while smart cities offer transformative potential for enhancing urban living quality, the distribution of benefits is neither automatic nor equitable. Without deliberate intervention, smart city development tends to reproduce and amplify existing socioeconomic inequalities through uneven infrastructure deployment, design exclusion, affordability barriers, and governance structures that marginalize vulnerable communities.

The study identified multiple interconnected obstacles confronting underserved populations in smart city contexts. Infrastructure gaps leave low-income neighborhoods and informal settlements without foundational connectivity required to access digital services. Affordability constraints prevent economically disadvantaged residents from obtaining internet subscriptions, devices, and data plans needed for participation. Digital literacy deficits and technology anxiety create capability barriers particularly affecting elderly populations and those with limited educational opportunities. Design exclusion renders many smart city applications inaccessible to people with disabilities, limited literacy, or unfamiliarity with digital conventions. Language barriers and cultural irrelevance create obstacles for immigrant communities and linguistic minorities. Participation exclusion systematically shuts underserved communities out of planning processes shaping technological development in their neighborhoods. Trust deficits rooted in legitimate concerns about surveillance and data exploitation discourage engagement even when technical access exists.

However, the research also provides encouraging evidence that comprehensive inclusion strategies can substantially narrow access gaps and enable underserved populations to benefit meaningfully from smart city innovations. Cities implementing equity-focused infrastructure deployment, affordability programs, universal design standards, digital literacy support, and participatory governance achieved adoption rates among underserved populations 42% higher than technology-first approaches. Successful strategies included municipal broadband providing affordable connectivity, subsidized device distribution, peer-to-peer digital literacy programs offering culturally appropriate support, universal design mandates ensuring accessibility, participatory budgeting enabling community control over technology investments, and community-owned infrastructure models that address both access and governance concerns.

The finding that inclusion-led approaches generate higher overall adoption rates while requiring lower per-user investment challenges assumptions that equity and efficiency constitute competing objectives. Instead, evidence indicates that inclusive development produces positive-sum outcomes by expanding reach, enhancing legitimacy, and creating more sustainable initiatives. Universal design benefits all users while expanding market access. Community participation enhances relevance and local ownership. Addressing barriers upfront proves more cost-effective than remedial interventions after exclusive deployment.

The research demonstrates that achieving equitable smart cities requires treating inclusion not as an optional enhancement but as a foundational design principle integrated from the earliest planning stages through implementation and ongoing governance. Technology alone cannot overcome structural inequalities, but deliberate policy choices, institutional arrangements, and governance structures determine whether urban

innovations serve all residents or primarily benefit already-advantaged populations. Smart city development must be understood as a sociotechnical endeavor where social and technological considerations are equally essential rather than viewing social equity as a constraint on technological progress.

These findings have important implications for the future of urban development in an increasingly digital age. As cities worldwide invest trillions of dollars in smart city infrastructure over coming decades, ensuring that these investments reduce rather than amplify urban inequalities constitutes both a moral imperative and a practical necessity for sustainable development. Technological sophistication must be accompanied by social sophistication, recognizing that truly smart cities are those that work for all residents regardless of income, age, ability, education, or immigration status.

The research contributes to evolving conceptualizations of smart cities that move beyond techno-centric visions toward understanding urban intelligence as the capacity to deploy technology in service of sustainability, livability, and social justice. This perspective aligns with frameworks such as just smart cities and the right to the smart city, emphasizing that urban technological development must be guided by principles of distributive justice, procedural justice, and recognition justice. It challenges technology vendors, municipal governments, and international development organizations to critically examine whose interests are served by smart city initiatives and to deliberately center marginalized communities in shaping urban technological futures.

VII. LIMITATIONS

While this research provides valuable insights into smart city equity challenges and inclusive development strategies, several limitations warrant acknowledgment and should inform interpretation of findings. Understanding these constraints is essential for appropriate application of results and identification of directions for future research.

The cross-sectional research design captured smart city development at a single point in time rather than tracking evolution over extended periods. This temporal limitation means the study cannot definitively establish causal relationships or assess long-term sustainability of observed patterns. While regression analysis suggests relationships between inclusion strategies and outcomes, the correlational nature of cross-sectional data precludes definitive causal claims. Longitudinal research following cities over multiple years would strengthen causal inference and illuminate how smart city equity evolves as initiatives mature.

The sample of 45 cities, though carefully selected to represent diverse contexts, cannot comprehensively capture the full range of global smart city development. The reliance on cities with sufficient documentation for

quantitative analysis may introduce selection bias toward more formalized, well-resourced, and transparent initiatives while potentially underrepresenting informal innovations, grassroots technology adoption, and cities with limited capacity for systematic data collection. This limitation is particularly relevant for Global South contexts where smart city development may occur through different pathways than documented in existing databases.

The interview sample of 120 participants, while substantial and purposively selected for diversity, could not include all relevant perspectives within highly heterogeneous urban populations. Despite efforts to ensure representation across stakeholder groups, language capabilities, researcher networks, and time constraints influenced who could be interviewed. Certain voices including homeless populations, undocumented immigrants, and residents of the most marginalized informal settlements may be underrepresented. Future research should employ additional methodologies such as participatory action research that centers the most marginalized communities as co-researchers rather than merely subjects of study.

Methodological constraints also affected depth of analysis in certain areas. The quantitative component relied on available secondary data from the Smart City Global Index, which may contain inconsistencies in how different cities report information and may not capture all relevant variables. Some cities lacked comprehensive outcome data disaggregated by demographic groups, limiting ability to assess distributional impacts systematically. Interview durations, though substantial at 75 minutes average, could not explore all topics in exhaustive detail. Resource constraints prevented the research from incorporating ethnographic observation or extended engagement with communities that might have yielded additional insights.

The definition and operationalization of key concepts including underserved populations, smart city innovations, and equitable access involve inherent complexities and subjective judgments. Underserved populations encompass diverse groups with varying characteristics and needs, yet analytical necessity required treating them as somewhat unified categories that may obscure internal heterogeneity. Similarly, smart city initiatives vary enormously in scope, technological sophistication, and objectives, complicating attempts to compare outcomes across contexts. Equity itself represents a contested concept with multiple dimensions that cannot be reduced to single metrics.

Contextual specificity limits generalizability of findings to contexts not represented in the sample. The research included cities from multiple regions and developmental levels, but specific strategies' effectiveness likely depends on local institutional capacities, political systems, cultural contexts, and resource availability. Approaches successful in well-resourced democratic contexts may require substantial adaptation for resource-constrained environments or different governance

systems. Practitioners must therefore engage critically with findings, adapting insights to their circumstances rather than assuming direct transferability.

The research focused specifically on smart city technologies and initiatives, examining them in relative isolation from broader urban systems and socioeconomic structures that profoundly shape outcomes. Smart city innovations operate within complex urban environments influenced by housing markets, labor dynamics, education systems, healthcare access, transportation networks, and myriad other factors beyond the technological domain. The study could not fully account for these contextual influences or disentangle smart city effects from broader urban trends. This limitation means that observed outcomes reflect complex interactions between technological interventions and contextual factors rather than isolated effects of smart city strategies alone.

Temporal dynamics of technological change present additional challenges. The smart city landscape evolves rapidly with new technologies emerging, business models shifting, and policy frameworks adapting. Findings reflect the state of smart city development during the 2022-2023 research period and may require updating as the field continues to evolve. Technologies that were nascent during data collection may become more mature and accessible, while approaches that appeared promising may encounter unforeseen challenges over time.

The research team's positionality also shaped the study in ways that warrant acknowledgment. As university-based researchers from primarily Global North institutions, the research team brought particular perspectives, assumptions, and blind spots to the investigation. Efforts to practice reflexivity and incorporate diverse voices mitigate but cannot entirely eliminate these influences. Future research would benefit from greater involvement of researchers from underrepresented communities and institutions in the Global South who bring different lived experiences and analytical perspectives.

Resource constraints limited the scope of data collection and analysis possible within available time and funding. A larger sample of cities, more extensive interview programs, longitudinal follow-up, and incorporation of additional data sources would strengthen findings but exceeded available resources. These constraints are common in social research and should not be interpreted as diminishing the value of insights generated, but rather as indicating directions for future inquiry building on this foundation.

Despite these limitations, the mixed-methods design, substantial sample sizes, geographic diversity, and triangulation across data sources provide confidence in core findings regarding patterns of exclusion in technology-first smart city approaches and the effectiveness of inclusive development strategies. The limitations identified primarily suggest directions for additional research rather than fundamental flaws

undermining the study's contributions to understanding smart city equity challenges and solutions.

VIII. PRACTICAL IMPLICATIONS

The research findings generate multiple actionable implications for stakeholders across the smart city ecosystem including municipal governments, technology developers, community organizations, funding agencies, and international development institutions. These practical insights can inform more equitable approaches to urban technological development and help ensure that smart city innovations serve all residents regardless of socioeconomic status.

For municipal governments and urban policymakers, the research underscores the necessity of establishing explicit equity frameworks that guide smart city planning, procurement, and implementation. Rather than treating equity as an afterthought or optional enhancement, cities should adopt policies that make inclusion a foundational requirement. This includes conducting equity impact assessments before deploying new smart city technologies, similar to environmental impact assessments, to identify potential disparities and develop mitigation strategies. Procurement processes should mandate accessibility standards, affordability considerations, and community engagement as evaluation criteria for technology vendors, not merely technical capabilities and costs.

Infrastructure investment strategies must prioritize underserved neighborhoods rather than defaulting to deployment in affluent areas that offer easier implementation and higher adoption rates. The finding that infrastructure disparities average 52% between high-income and low-income neighborhoods within the same cities indicates systematic patterns requiring intervention. Cities should adopt equity-based allocation formulas ensuring that specific percentages of smart city investment flow to disadvantaged communities, potentially using inverted investment ratios that direct more resources to areas with greater needs. Geographic information systems can facilitate transparent tracking of infrastructure distribution and identification of underserved areas requiring priority attention.

Affordability initiatives represent essential complements to infrastructure deployment. Municipal governments should explore various models including municipal broadband providing affordable or free connectivity to qualifying residents, partnerships with telecommunications providers for subsidized service plans, device lending or distribution programs, and elimination of fees for accessing digital government services. The research demonstrates that affordability programs correlate with 11 percentage point increases in adoption among underserved populations, suggesting substantial return on investment. Cities should also advocate for regulatory frameworks ensuring that private internet service providers offer affordable basic tiers rather than only premium services.

Digital literacy support requires sustained investment in programs that employ peer-to-peer models, provide ongoing assistance rather than one-time training, and integrate digital skills with practical applications addressing participants' immediate needs. The success of community-based digital navigator programs suggests that training is most effective when delivered by trusted individuals from participants' own communities in culturally appropriate formats and languages. Cities should fund community technology centers in underserved neighborhoods serving as both access points and learning hubs with adequate staffing, updated equipment, and welcoming environments.

Participatory governance structures must move beyond tokenistic consultation toward genuine co-design processes where community members exercise meaningful influence over technological priorities and implementation. This includes establishing neighborhood technology councils with decision-making authority and dedicated budgets, implementing participatory budgeting for smart city investments, creating community advisory boards that review major technology deployments, and compensating community members for time invested in participation. Participation formats should be designed for accessibility through multiple engagement channels, evening and weekend timing accommodating working residents, neighborhood venues rather than distant government offices, provision of childcare and translation services, and use of plain language rather than technical jargon.

For technology developers and smart city solution providers, findings demonstrate that incorporating universal design principles from project inception expands market reach while fulfilling ethical obligations. Accessible design benefits all users through improved usability while making products viable for broader populations including elderly users, people with disabilities, and those with limited digital literacy. Companies should establish accessibility standards that guide product development, conduct user testing with diverse populations, and employ designers and developers from underrepresented communities who bring varied perspectives and experiences. The business case for accessibility is strengthened by the finding that cities increasingly mandate compliance as procurement criteria, making accessibility essential for competitiveness.

Community engagement during development processes enhances product-market fit and adoption by ensuring solutions address actual needs rather than developer assumptions. Technology companies should partner with community organizations to conduct needs assessments, involve residents in co-design workshops, conduct iterative testing with target users, and develop implementation strategies appropriate for local contexts. The finding that inclusion-led cities achieve 42% higher adoption rates among underserved populations indicates that community-engaged development generates commercial benefits alongside social value.

Affordability considerations should inform business model development, moving beyond assumptions that all users can pay premium prices. Technology providers can explore tiered pricing models offering free or low-cost basic tiers, partnerships with municipalities or nonprofits subsidizing costs for qualifying users, and value-capture mechanisms that generate revenue from secondary sources rather than direct user fees. Community benefit agreements specifying affordability provisions, local hiring, and data governance can align commercial and community interests.

For community organizations and civil society groups working with underserved populations, the research provides evidence-based frameworks for advocacy and organizing around smart city development. Organizations can use findings documenting systematic exclusion to challenge technology-first approaches and demand meaningful community participation in planning processes. Documentation of successful inclusion strategies offers concrete alternatives that organizations can propose rather than merely critiquing existing approaches. Community groups should advocate for equity frameworks, accessibility mandates, affordability programs, and participatory governance structures as essential components of smart city initiatives.

Building community capacity to engage with technological issues represents another critical role for civil society organizations. This includes facilitating digital literacy training, supporting peer-to-peer learning networks, organizing technology education workshops, and developing community expertise that enables informed participation in smart city governance. Organizations can serve as intermediaries connecting underserved communities with technology developers and municipal officials, facilitating dialogue and ensuring that marginalized voices are heard and respected. The research demonstrates that community-controlled infrastructure models including platform cooperatives and data trusts offer alternatives to corporate-dominated smart city development, suggesting that organizations should explore establishing community-owned technological assets.

For funding agencies and international development institutions supporting smart city initiatives, findings indicate the necessity of incorporating equity requirements into grant criteria and technical assistance programs. Rather than funding technology deployment without attention to distributional impacts, donors should require applicants to demonstrate explicit strategies for ensuring accessibility among underserved populations, measurable equity outcomes as evaluation criteria, and participatory governance structures. Technical assistance should emphasize capacity building for inclusive smart city development rather than merely technology transfer, including support for community engagement processes, equity impact assessment methodologies, and governance innovations.

The finding that inclusion-led approaches achieve better outcomes at lower per-user costs challenges assumptions that equity requires sacrificing efficiency, suggesting that donors can advance both equity and effectiveness objectives simultaneously. International organizations should disseminate successful inclusion strategies through knowledge platforms, peer learning networks, and technical guidance documents while recognizing the need for contextual adaptation rather than universal templates. Support for South-South knowledge exchange can facilitate learning from cities in similar developmental contexts rather than assuming that Global North models automatically transfer to other settings.

Urban planners and academic institutions also have important roles in advancing equitable smart city development. Educational programs training future urban planners, technology professionals, and policymakers should integrate equity considerations throughout curricula rather than treating social issues as peripheral to technical content. Interdisciplinary approaches bringing together urban studies, computer science, design, and social sciences can prepare professionals with holistic understanding of sociotechnical systems. Research institutions should prioritize investigation of equity dimensions within urban technological development, partner with community organizations in research processes, and ensure that findings reach practitioner audiences through accessible formats and dissemination channels.

Implementation Roadmap for Inclusive Smart City Development

PHASE 1: FOUNDATION (Months 0-6)

- Establish equity framework and principles
- Conduct community needs assessment
- Form participatory governance structures
- Develop accessibility standards • Secure funding and partnerships

PHASE 2: INFRASTRUCTURE (Months 6-18)

- Deploy connectivity in underserved areas
- Establish community technology centers
- Launch affordability programs
- Implement device access initiatives • Begin digital literacy programming

PHASE 3: SERVICES & APPLICATIONS (Months 18-30)

- Co-design services with communities
- Implement universal design standards
- Develop multilingual interfaces
- Pilot test with diverse users • Iterate based on feedback

PHASE 4: EVALUATION & SCALING (Months 30-42)

- Assess adoption across demographics
- Measure equity outcomes
- Document lessons learned
- Refine approaches based on data • Expand successful initiatives

ONGOING: GOVERNANCE & ADAPTATION

- Maintain participatory structures
- Monitor for emerging disparities
- Provide continuous digital support
- Adapt to evolving technologies • Share knowledge with other cities

Timeline: 42+ Months for Full Implementation

Note: Phases may overlap; ongoing activities continue throughout and beyond initial implementation

Source: Synthesized from successful implementation cases

Phase Color Key:

Foundation Infrastructure Services Evaluation Ongoing

Fig 3 Implementation Roadmap for Inclusive Smart City Development
Source: Synthesized from successful implementation cases

The practical implications also extend to addressing specific barriers identified in the research. To overcome infrastructure gaps, stakeholders should prioritize last-mile connectivity solutions reaching neighborhoods bypassed by commercial providers, explore alternative technologies such as community wireless networks where fiber deployment is prohibitively expensive, and advocate for policies treating broadband as essential infrastructure similar to electricity and water. Addressing affordability constraints requires multi-pronged approaches including subsidized connectivity, device access programs, elimination of usage-based data caps that discourage meaningful engagement, and exploration of revenue models that do not depend on user fees from low-income populations.

Overcoming design exclusion necessitates universal design mandates in procurement, user testing with diverse populations during development, accessibility audits of existing systems, and capacity building for technology professionals in inclusive design methodologies. Digital literacy challenges require sustained investment in peer-to-peer programs, integration of digital skills into existing community services rather than standalone training, ongoing support beyond one-time workshops, and recognition that literacy development is a continuous process rather than one-time achievement given constantly evolving technologies.

Building trust with communities experiencing surveillance and data exploitation concerns requires transparency about data collection and usage, community control over data governance, prohibition of punitive uses of information, and demonstrated commitment to using technology for community benefit rather than control. Legal and policy frameworks should establish data rights, limit surveillance applications, and provide recourse when technologies cause harm.

These practical implications collectively suggest that achieving equitable smart cities requires systemic change across multiple dimensions rather than isolated interventions. Stakeholders must work collaboratively across sectors with sustained commitment over extended timeframes, recognizing that addressing deeply rooted structural inequalities through technological means requires fundamental shifts in priorities, practices, and power relations. The evidence demonstrates that such transformation is both necessary and possible, offering pathways toward urban futures where technological innovation serves all residents.

FUTURE RESEARCH AGENDA

While this study contributes valuable insights regarding smart city equity challenges and inclusive development strategies, the findings also illuminate multiple directions for future research that can deepen understanding and strengthen practical guidance. This section outlines priority areas warranting investigation by

scholars, practitioners, and community-engaged researchers.

Longitudinal research tracking smart city development and equity outcomes over extended periods represents a critical need. The cross-sectional design of this study captured a snapshot in time but could not definitively establish causal relationships or assess sustainability of observed patterns. Multi-year studies following cities as they implement inclusion strategies would enable stronger causal inference, illuminate how equity evolves as initiatives mature, identify factors predicting sustained versus transient improvements, and reveal unintended consequences that emerge over time. Comparative longitudinal designs examining cities that adopt different approaches simultaneously would be particularly valuable for understanding divergent trajectories.

Future research should examine in greater depth the mechanisms through which specific inclusion strategies produce outcomes. While this study documented relationships between interventions and adoption rates, more detailed investigation of implementation processes, intermediate outcomes, and causal pathways would enhance theoretical understanding and practical guidance. For example, research could examine what characteristics of digital literacy programs explain variation in effectiveness, how participatory processes translate into improved technology design, or through what mechanisms community-controlled infrastructure generates higher satisfaction. Mixed-methods research combining process evaluation, outcome assessment, and mechanistic investigation would illuminate not only what works but why and under what conditions.

Investigation of differential impacts across diverse population segments requires expansion beyond the broad categories employed in this research. While the study distinguished between underserved and advantaged populations, future work should examine variation within these groups recognizing intersectional patterns whereby multiple identities shape experiences. Research focusing specifically on particular populations including homeless individuals, undocumented immigrants, people with cognitive disabilities, LGBTQ+ communities, and other groups facing distinctive challenges would provide nuanced understanding informing targeted interventions. Similarly, comparative research examining how smart city equity dynamics differ across cultural contexts, political systems, and stages of economic development would enhance global applicability of findings.

The relationship between smart city participation and tangible improvements in quality of life, economic opportunity, and civic empowerment warrants deeper investigation. This study examined technology adoption as a primary outcome, but adoption represents a means rather than an end. Research should assess whether and how digital inclusion translates into meaningful improvements in residents' wellbeing, economic circumstances, health

outcomes, educational attainment, and political participation. Longitudinal studies tracking individuals over time could illuminate whether smart city access generates lasting benefits or primarily short-term effects. Such research would require careful attention to attribution challenges given multiple factors influencing life outcomes.

Alternative smart city models including community-controlled infrastructure, platform cooperatives, and data trusts deserve systematic investigation. While this research identified these approaches as promising, limited cases and data prevented comprehensive evaluation. Future research should examine governance structures, business models, technical architectures, and outcomes associated with community ownership models, comparing them systematically with corporate and government-led approaches. Investigation of enabling conditions, obstacles, and strategies for establishing and sustaining community-controlled technological infrastructure would inform replication efforts.

The political economy of smart city development and the role of corporate actors require critical examination. This study focused primarily on municipal strategies and community experiences but gave limited attention to technology company business models, investment patterns, and influence over smart city agendas. Research examining how commercial interests shape smart city development, what governance mechanisms can align private and public interests, and how cities can negotiate favorable terms in public-private partnerships would contribute important insights. Investigation of alternative funding models reducing dependence on corporate partners while maintaining technological capacity would be valuable.

Data governance and algorithmic accountability within smart city contexts represent areas requiring urgent research attention. While this study identified concerns about surveillance and bias, limited investigation examined specific governance frameworks, their implementation, and effectiveness in protecting marginalized communities. Research should evaluate different data governance models, examine how communities can exercise meaningful control over data systems affecting them, investigate algorithmic bias in smart city applications, and assess accountability mechanisms when automated systems cause harm.

Participatory approaches involving affected communities in setting research priorities and interpreting findings would enhance relevance and legitimacy of such investigation.

The environmental sustainability dimensions of inclusive smart city development deserve attention given growing recognition that social equity and environmental sustainability are interconnected. Research should examine whether inclusion strategies affect environmental outcomes, how smart city technologies can address environmental justice issues whereby marginalized communities disproportionately experience pollution and climate impacts, and what tensions or synergies exist between equity and sustainability objectives. Investigation of energy consumption, electronic waste, and carbon footprints associated with different smart city approaches would inform holistic sustainability assessment.

Future research should also examine smart city development in contexts underrepresented in existing scholarship including cities in the Global South, small and medium-sized cities, and rural areas experimenting with smart technologies. Much smart city literature focuses on large, affluent cities in North America, Europe, and East Asia, potentially limiting applicability to other contexts. Research examining how resource constraints, informal governance systems, rapid urbanization, and infrastructure deficits shape smart city development in Global South cities would provide crucial insights. Similarly, investigation of smaller cities and rural areas where population density, resources, and technological ecosystems differ from major metropolitan centers would broaden understanding.

Methodological innovations including participatory action research, community-based participatory research, and collaborative inquiry methods that position community members as co-researchers rather than merely research subjects warrant exploration. Such approaches can challenge extractive research practices, ensure investigations address community-identified priorities, and build community capacity alongside generating knowledge. Research examining effective models for community-researcher partnerships, strategies for balancing academic and community goals, and outcomes of participatory research approaches would advance methodological development.

Table 5 Priority Research Questions and Suggested Methodologies

Research Domain	Priority Questions	Suggested Methods	Timeframe
Longitudinal impacts	How do equity outcomes evolve over time? Do early gains persist or diminish?	Panel studies, cohort tracking, repeated cross-sections	5-10 years
Causal mechanisms	Through what processes do inclusion strategies produce outcomes?	Process evaluation, mechanism testing, mixed methods	2-3 years
Quality of life outcomes	Does digital inclusion improve wellbeing, economic mobility, health?	Longitudinal surveys, administrative data, quasi-experiments	3-7 years

Intersectional experiences	How do multiple marginalized identities shape smart city access?	In-depth qualitative, participatory methods	2-4 years
Alternative governance	How effective are community-controlled infrastructure models?	Comparative case studies, organizational ethnography	3-5 years
Political economy	How do corporate interests shape smart city development?	Critical policy analysis, follow-the-money research	2-4 years
Algorithmic accountability	How can communities govern automated decision systems?	Algorithmic audits, participatory governance research	2-3 years
Environmental justice	Do inclusive smart cities advance environmental equity?	Environmental monitoring, spatial analysis, mixed methods	3-5 years
Global South contexts	How does smart city equity operate in resource-constrained settings?	Comparative case studies, South-South learning networks	3-5 years
Rural/small cities	How do equity dynamics differ in non-metropolitan contexts?	Comparative research, community-based studies	2-4 years

Source: Synthesized research priorities based on identified knowledge gaps

Investigation of emerging technologies and their equity implications represents another important direction. This research examined smart city technologies available during 2022-2023, but rapid innovation continuously introduces new capabilities including artificial intelligence applications, autonomous vehicles, augmented reality, and blockchain-based systems. Research should examine how emerging technologies may create new forms of exclusion or opportunities for inclusion, what governance frameworks can ensure equitable development from inception, and how lessons from current smart city equity challenges apply to future innovations.

The COVID-19 pandemic accelerated digital transformation while exposing profound inequities in technological access, but research examining long-term implications for smart city equity remains limited. Investigation of how pandemic-era shifts including remote work normalization, telemedicine expansion, and digital service delivery affect different populations would provide timely insights. Research should also examine whether pandemic experiences generated sustained commitment to digital equity or merely temporary attention that faded as acute crisis receded.

Finally, research examining successful organizing strategies and advocacy campaigns that have advanced smart city equity would inform movement building efforts. While much scholarship focuses on policy and technology design, investigation of community mobilization, coalition building, narrative framing, and political strategies that have successfully challenged exclusive smart city development would strengthen capacity for change. Documentation of victories, setbacks, and lessons learned from grassroots efforts would provide valuable guidance for activists and organizers.

This future research agenda reflects the complexity and dynamism of smart city equity challenges while offering pathways for advancing both scholarly understanding and practical progress toward inclusive

urban technological development. Addressing these research priorities will require sustained investment, interdisciplinary collaboration, community partnerships, and commitment to ensuring that knowledge generation serves broader goals of justice and equity in rapidly evolving urban landscapes.

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