Participatory Design in Precarity: “Smart” Technologies for Tiny House Villages

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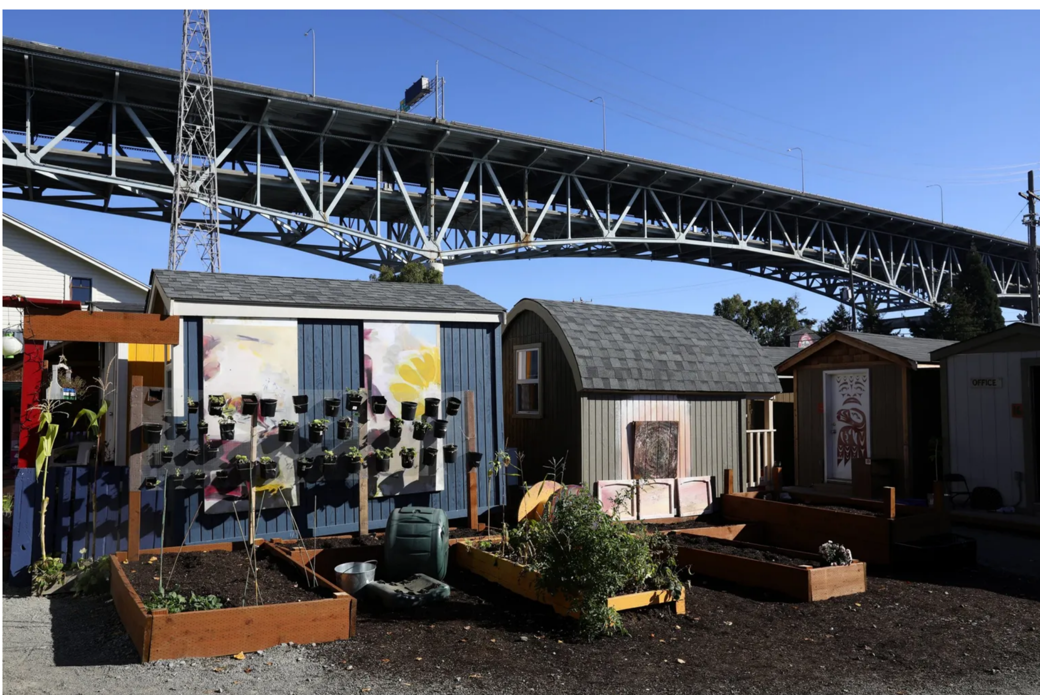

Fig. 1. The Nickelsville Northlake Tiny House Village. Photo credit: Kurtis Heimerl

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In tiny house villages (THVs), land ownership, local regulations such as zoning, and management frameworks affect how formerly unhoused residents can leverage and augment their built infrastructure with "smart" technologies. These dynamics influence THV residents' lived experiences, creating both constraints and opportunities for deploying networked sensors in support of communication, physical security, and shared governance. Through a series of participatory design (PD) workshops and visits with residents of two villages, we identified how residents balance privacy and security concerns when considering Internet-of-Things (IoT) sensor design and deployment. We find, for example, that residents impose constraints on designed sensors for the group's protection, such as a strict ban on camera-based visual or audio surveillance and a preference for local as opposed to cloud data storage. They also identify opportunities for diverse sensors and actuators to improve village accessibility and to alleviate resource sharing tensions. Meanwhile, differences between public and private land ownership directly impact the regulation and infrastructure possibilities for THVs, and historical and current zoning of land shapes the social problems that the community must navigate. Our findings deepen the CSCW research agenda by examining parameters for successful "smart" and data-driven technology interventions among low-resourced urban groups experiencing housing precarity and homelessness.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**; *Field studies*; Accessibility technologies; • **Security and privacy** → *Social aspects of security and privacy*.

Additional Key Words and Phrases: Participatory Design, Tiny House Village, Homelessness, Smart, Community, Sensing, IoT

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1 Introduction

Homelessness, a "...fundamental lack of long-term shelter deemed adequate and sustainable for individuals seeking housing resources" [117], is on the rise in North American cities. In 2023, the U.S. Department of Housing and Urban Development (HUD) estimated that 653,100 individuals in the United States (two in every 1,000 people) experienced homelessness on a single night, with approximately 59% of the homeless population located in urban areas. [41] In King County, Washington (home of Seattle, the setting for this study,) over 7,600 people were estimated to be unhoused on a given night [12]. The scale of this crisis invites novel housing solutions.

Tiny House Villages (THVs) are a type of emergency shelter increasingly implemented in the Pacific Northwest of the U.S. to bring people indoors for short-term relief. Small, easy-to-construct standalone sheds or "Tiny Houses" are used as rooms, akin to individual hoteling as a shelter solution. Unlike many shelter models, the private units provide lockable personal space and allow families and pets to stay together [3, 39, 65]. Organized "villages" of these homes can provide people with not only transitional housing but also social support structures while they seek financial stability. In the context of rapid gentrification, historically restrictive zoning, and slow timelines for permanent housing construction, THVs crucially address an insufficient supply of affordable longer-term housing options. However, the same conditions that curtail the housing supply also severely limit the availability of public or contributed land for these shelters.

Through collaborative design with THV residents in Seattle, WA, this multi-disciplinary work explores tensions that arise when bringing "IoT" ("Internet-of-Things") or "smart" home and city

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technologies into the context of homelessness and housing insecurity. The past decade has seen an explosion of research on and deployments of smart city infrastructure, ranging from technical innovations in sensing and mapping to uses in governance and activism to analyses of surveillance and discrimination [11, 38, 73]. A core issue is that large-scale IoT initiatives are consistently designed, planned, and implemented top-down by powerful actors (e.g., city governments or corporations), with insufficient community ownership and oversight. The plethora of existing commercial IoT products such as smart doorbells with cameras for monitoring, lights with a programmability layer, and myriad others often marketed as high-end accessories for luxury homes, can be an awkward fit for low-resourced communities. Worse, they can cause users to feel actively targeted and threatened, such as when data is sold to third parties or leveraged against users by law enforcement.

This research is a first step in supporting THV communities in iteratively co-designing and implementing their own "smart village" sensing systems with as complete ownership as possible. We engage with villages that are self-managed by residents who collectively organize for political advocacy. In this village context, sensing and automation exist in a middle ground between city- and home-scale IoT, offering novel applications and opportunities for community cooperation and technical innovation.

Through an ongoing partnership with the Seattle Community Network (SCN) [84], a mutual-aid group that builds free WiFi and internet infrastructure in THVs, we use participatory design workshops to ground iterative installation and user feedback cycles to design appropriate technologies for this context. In doing so, we explore opportunities and limitations of leveraging community-driven sensing systems to support resilience, collective politics, and data sovereignty in contexts where people experience housing *precarity*, i.e., a state of persistent insecurity. We find that self-managed THVs struggle with precarities in their housing infrastructure based on underlying insecurities faced by their residents and a collective lack of ownership and agency in their land use arrangements. We explore these issues in the remainder of the paper, with a particular emphasis on how possibilities for implementing THV infrastructure are shaped by local land use policies and laws, social concerns around privacy and security, power dynamics, accessibility issues, and tensions related to resource sharing. We conclude with a discussion of open design problems and opportunities for IoT in low-resourced, self-managed communal settings like THVs.

2 Related Work

2.1 Homelessness, Informal Housing, and Precarity

This work argues for increased research at the intersection of housing precarity and smart infrastructure. Existing research on homelessness, informal housing, and precarity highlights the need to better understand the potential roles (and limits) of technologies for urban transformation in support of those experiencing housing instability [106, 113].

Homelessness and housing instability encompass a diverse range of experiences, with variations in how it is experienced both temporally (e.g., it can be transitional, episodic, or chronic) and spatially (e.g., individuals may live in vehicles or tents, "doubled up" with others, etc.) [87, 95]. A common thread that unites these experiences is exposure to increased risks resulting from lack of consistent access to adequate shelter [117]. For instance, homelessness has been documented to increase the risks of negative impacts associated with policing, disability, mental and physical illness, poverty, violence, climate change, harsh environmental conditions, discrimination, and more [6, 20, 44, 50, 107, 111]. Furthermore, homelessness disproportionately impacts groups already experiencing structural forms of marginalization, including members of BIPOC and LGBTQ communities [49].

Discussions of homelessness can be usefully contextualized within a broader examination of urban precarity. Within the social sciences, precarity first emerged to describe research on poverty, and later evolved to refer more broadly to forms of labor outside of the permanent labor contracts that characterize classic Fordist economics (i.e., modern, industrialized capitalism grounded in mass production and consumerism) [85]. More recently, scholarship on precarity has expanded beyond solely economic concerns, to explore how a range of class, labor, and identity positions (e.g., age, race, and gender) produce and mediate conditions of vulnerability [7, 32, 33, 60]. This work highlights precarity as a pervasive, global condition that has expanded through the shift to neoliberal economics [23]. Despite the ubiquity of precarious conditions, however, there remains a special relationship between precarity and urban spaces. Scholars in urban studies have long associated cities with precarity, pointing to how city life produces "unique challenges in terms of vulnerability, uncertainty, and risk" [34, pg. 285]. Many of these scholars highlight processes of possession and dispossession of property as playing a central role in shaping urban precarity [14, 99].

Scholars and policy-makers alike have sought to find solutions to precarity generally, and homelessness in particular. Of most relevance to this paper, sanctioned encampments are one intervention that has been tentatively embraced by some service providers and local governments. Within this intervention, land access is secured through agreements with land owners or governments to provide homeless individuals with a space to set up tents or other forms of provisional shelter [48, 97]. In the Pacific Northwest, these encampments typically have some level of infrastructural provision for electricity, water, and waste management in place. People can live in encampments for longer periods of time without needing to vacate premises during the day, as is typical in shelter systems, or move from site to site in order to avoid sweeps by police [55]. Shelter structures at these encampments can include vehicles, tents, other self-made constructs, or "Tiny Houses," prefabricated structures that provide individual sleeping and storage space accompanied by shared bathrooms and kitchens [39]. These are detailed further in Sec. 4.

Others criticize these interventions, arguing that they do not go far enough in supporting well-being and addressing the fundamental drivers of urban vulnerability. These scholars argue that continued feelings of precarity may provide the conditions for the emergence of more radical interventions, including new movements toward "world-building and social transformation" [34, pg. 285] and the design of more resilient cities (e.g., [7]). In this paper we investigate the potential role of technologies—and of new innovations in sensor and IoT technologies in particular—for supporting new forms of world-building amongst the housing precarious. As a collective and as individuals, villagers intuitively adopt and mobilize the concept of "data sovereignty," broadly defined in literature and common discourse as "meaningful control, ownership, and other claims to data or data infrastructures" [35][1]. These examples help to highlight the opportunities, challenges, and limitations of leveraging technologies to address precarity. In doing so, they establish the foundation for a more expansive CSCW research agenda around urban precarity.

2.2 Smart Cities, Home IoT, and the Participatory Design of New Technologies

A growing body of work describes the potential of 'smart' and IoT technologies for supporting transformations in city life [17–19, 81], but this research rarely engages with individuals experiencing housing precarity. Instead, this work tends to focus either on generalized benefits of IoT technologies at the broad city scale, or on specific benefits for individuals that are housed. For instance, at the city level, researchers have explored how real time data on local conditions—from

[1]and more specifically applied to Indigenous sovereign nations: "the right of a nation to collect and manage its own data" [101]

traffic disruptions and crime to pollution—can be fed into automated analyses and visualizations to provide city managers with urban dashboards and other governance tools [81]. At an individual level, researchers have examined the implications of IoT and smart home devices for households in areas such as security of cloud-based sensors (including user perspectives [120], collaborative decision making [45], and others), but also interactions between these devices and upcoming AI innovations [96]. While these projects often address how to reduce barriers to access, they nevertheless underexamine the potential role of these technologies in communities experiencing housing precarity.

This gap is particularly problematic given that some IoT technologies have been shown to negatively impact other historically marginalized and underserved communities. Scholars have pointed to the ways that smart technologies undermine privacy, promote data centralization and surveillance, and encourage the adoption of instrumental rationalities that can limit alternate views of local politics [27, 31, 80, 81, 116]. A rapidly growing literature on AI ethics similarly highlights the ways in which new AI solutions reinforce existing negative social biases such as racism and misogyny [21, 47, 72, 94]. Only a small body of literature has specifically explored the dangers and opportunities that these technologies present to individuals experiencing housing precarity. For instance, proposals for smart city applications in Barcelona in 2015 included features that addressed homelessness directly, using plans for improved wireless connectivity for advanced mapping and tracking of homeless people and their needs or providing direct donations to them online [89]. More research is needed to understand the potential and risks of these technologies.

We argue that research approaches that involve participatory methods provide some of the greatest promise for addressing this gap. Researchers from diverse fields, including human-computer interaction, ubiquitous computing, and assistive technologies, have conducted user-centered design research in IoT for both home and smart city use cases. Here we highlight work using participatory design (PD) approaches [51, 76, 119]. Researchers have, for example, used PD to reveal the potential of smart technologies to increase feelings of anxiety amongst those within public housing, especially with regard to recordings and questions of data access [54, 83]. At the same time, other studies have demonstrated the positive potential of these technologies for supporting group coordination [74], neighborhood advocacy work [10], and arguments for rights to the city and more inclusive urban governance [63, 64, 116].

To date there exists only a small body of research that explicitly leverages PD to explore IoT technologies within housing-unstable contexts. Dantec's "community resource manager," a communications system iteratively co-designed and deployed with management staff in a women's homeless shelter, allowed residents to post to public message boards and send "private" messages to the staff in a manner sensitive to management hierarchies and different "publics" at the shelter. Residents notably "would not necessarily identify as part of a 'homeless' public, eschewing the stigma of homelessness and more readily self-identifying as individuals overcoming adversity" [86]. Finally, Halperin and McElroy's first-person reflexive ethnographic work examines technology developed for advocacy against housing precarity where the authors are participants in the advocacy organization Anti-Eviction Mapping Project [58], echoing our own use of participant observation as researchers involved with the Seattle Community Network (SCN).

2.2.1 IoT Technologies & Accessibility Research. Another rich and relevant area of human-centered IoT research is the design of assistive technologies to allow people with mobility or other access challenges greater independence. This work is relevant because individuals facing housing precarity often navigate accessibility issues; people with disabilities are statistically over-represented among homeless populations [20, 44], at 51% in King County according to the 2022 point-in-time count [12]. Their access challenges intersect with those of the wider public in leveraging built infrastructure.

In the realm of accessible smart cities, there is some work on proximity-sensing IoT technologies using RFID to enable virtual interaction (for mobility-impaired people) or audio-description (for visually impaired people) with objects, e.g., in "Smart Shelves" for shops and libraries [102]. However, most studies focus on smart home scenarios where individuals with disabilities are living alone or with limited assistance from caretakers. "Ambient assisted living systems" have proposed using data-intensive monitoring sensors, including wearables, cameras, and location tracking, as well as machine learning algorithms to estimate residents' activities or mental and physical health; these designs clearly prioritize personal safety and system responsiveness over data privacy or freedom of choice [1, 9]. In a few studies, acceptability has been explored among elderly and disabled users for smart home technologies, including control modes (voice, remote control) and automation of configurations (lights, window blinds, thermostats, appliances) [88, 90, 98, 100]. Smart home needs of vision-impaired residents were notably distinct from others, emphasizing descriptive features such as voice-based labels [40, 88]. In contrast, elderly users [100] and people with Multiple Sclerosis [57] shared a dislike of automating away tasks that helped to provide them with a sense of purpose, routine, or agency, or that put them in social contact with others. In engaging stakeholders with diverse needs in our PD process, it has been helpful to keep these accessibility applications in mind.

2.3 Community Networks and "DIY" Infrastructure

While city-level connectivity and home IoT applications are often well supported for their intended beneficiaries, those experiencing housing precarity tend to have far less access to resources and basic infrastructure. Our work draws on a rich body of literature on *Community Networks* (CNs) [68], small-scale Internet access networks that operate unlike traditional commercial or nation-scale Internet service providers (ISPs) by being owned, operated, or managed in a local, cooperative- and community-focused manner. CNs often focus on "connecting the unconnected" [42] and bringing the ostensible benefits of Internet access to low-income or marginalized groups. CN research explores questions of economic feasibility and business models [13], power consumption [62], repair [53, 70], edge computing [92], Internet of Things (IoT) [108], and others that are also relevant to networked sensor technologies. Our research extends CN work into the domain of THVs, an adjacent area with significant community shared infrastructure. The authors' prior research experiences with CNs have informed some project methods as well as expectations, including gender norms in technology use and adoption [24], opportunities for resource sharing [75], and potential issues with federated data models [61]. Garrison et al. [53] and other CN work demonstrates the value of building and repairing core IT infrastructure in a participatory fashion with community.

Closely tied to CNs is the concept and political ethos of Do-It-Yourself or "DIY," commonly involving hands-on implementation and ownership of tools or infrastructure [43]. DIY brings infrastructure into the foreground via the process of building, which makes it visible to those who interact with the build process. As theorized by Star, Graham and Thrift, and Jackson in their studies of infrastructure, breakdown, and repair [56, 66, 67, 110], when successfully maintained, technical infrastructure achieves a degree of invisibility. We can conceptualize a lack of infrastructure as an extreme "broken-world" scenario, where the infrastructure's function and social dependencies (such as repair personnel) required to maintain it must all be built up from scratch. However, this initial nothingness also offers some freedom from barriers to entry for DIY ownership and maintenance, since preexisting or formalized technical infrastructures may come with standards or requirements, e.g., for specialized expertise or certifications, financing, legal requirements, or certain physical and psychological abilities, to maintain without excessive danger, difficulty, or

Table 1. Age demographics for participants.

Age Range	Count
25-34	2
35-44	3
45-54	3
55-64	4
65+	1
Total	13

liability. Non-professionals can often design and build infrastructure that meets their needs and is within the scope of their skills and resources to maintain, in addition to sometimes extending and repairing professionally installed infrastructure as demonstrated in less formalized settings [8, 69], though the success of this activity can be mixed [52, 112]. The IoT interventions proposed in this paper are part of a larger ecosystem of DIY infrastructure that includes the SCN network.

We note that other researchers, such as Kaziunas et al., have framed such unusual or workaround solutions provided outside of standard infrastructure as "precarious interventions" and as "care work" [77] implemented in response to broken systems that fail to provide services (in their case, health care). In this paper we note examples wherein the THVs' basic needs such as water can be met only in the "infrastructural shadows" due to structural conditions such as low financial resources. The remainder of this paper further explores how this DIY ethos can be married with emerging IoT technologies to support those experiencing housing precarity.

3 Methods

This project used *participatory design* (PD) to explore the opportunities and limitations of community-driven sensing systems for supporting individuals experiencing housing precarity. PD is a methodological approach that includes end users in design processes. It has its origins in trade union projects meant to include workers in the design of better workplaces[16, 26, 91], but it has since expanded to applications ranging from designing technologies and information systems [109] to decolonizing pedagogies and creating educational justice [15, 59, 82]. Core values of PD approaches include the advancement of democratic practices, the empowerment of end users through design, mutual learning by expert designers and participants, and the recognition that end users can lend critical insights to the design process [25]. In this project, PD helps incorporate the lived experiences and knowledge of those experiencing housing precarity into the design of new technologies.

Before initiating data collection through a series of PD workshops, the research design was submitted to and approved by the University of Washington (UW)'s Institutional Review Board (IRB). Team members worked with the SCN volunteer group to install wireless network infrastructure in each village. Implementation of these networks both provided the technical infrastructure necessary for IoT sensor development during the current study and built trust between the research team and residents. Team members collected field notes during these installations (and, later, sensor installations), which were included as a data source during analysis of workshop data, to triangulate and validate conclusions and provide additional context about the THVs when writing the paper.

The primary data for this paper, however, came from PD workshops. Two workshops were conducted at each village, at Northlake Village in January 2023 and Central District (CD) Village in June 2023, involving 13 residents in total. Prior to each set of workshops, the research team first attended a community meeting to request permission to hold the workshops and then worked with leadership to identify convenient times. The workshops were advertised in advance, held in a community space within the village, and open to all residents. Each workshop lasted between two to three hours. Given that this research involved a population facing housing insecurity and other vulnerabilities, the research team made a conscious decision to not require collection of specific sensitive information such as demographics related to gender, race, and income as part of the study. Many studies document the over-surveillance of individuals facing housing precarity, with implications for privacy and the ability of the research team to build trust with participants [28, 46]. Instead, participants were given the option whether or not they wished to contribute this information. Based on these optional contributions, statistics from the THV partners, as well as our observations, we can share that there were four masculine-identifying and two feminine-identifying participants at Northlake (coded N1-N6), and four masculine-identifying and three feminine-identifying participants at CD (coded C1-C7). They were comprised of a variety of different racial identifications in both communities, with a notably larger proportion of Black-identifying participants in the Central District (a historically Black neighborhood) village. We did feel that age data were particularly important for assessing the transferability of the study, and so collected age ranges for all participants. The participants were all over the age of 18 (see Table 1) with the Central District participants having a higher average age. All but two individuals attended both workshops at their village. This comprised around one-third of the overall villagers in the Nickelsville community, which supports grounded insights into the experiences of living in these villages. The mixture of participants present, and the deep conversations held, provide rich insights transferable to other communities grappling with housing precarity.

Within each community, the first day of the workshop series focused on identifying highlighting potential goals or design considerations for implementing community-based sensing infrastructure. At the beginning of this workshop, the research team introduced themselves, explained the purpose of the project (including the concept of networked sensors, using cars, phones, and other everyday objects as references), and conducted a prior and informed consent process. The researchers stressed that this workshop was designed to be the first step in what they hope to be a much longer term relationship with the community. Once consent was obtained, the researchers invited participants to respond to several prompts in writing. These prompts asked participants to reflect on (1) things they wished that technology could do for them, (2) notable experiences that they have had with sensors, (3) challenges that their community is facing, and (4) ways in which technology might help to address those challenges. Allowing participants to first write responses to these prompts gave them individual time to think about their answers, so that they could collect their thoughts before engaging in discussion. Even if participants could not write, they could take this quiet time to put their thoughts together. After this writing period was complete, participants were asked to share their responses. This then led into an open discussion about each question. This was a semi-structured approach, and the research team would ask follow-up questions based on the evolution of the conversation. The aim of this discussion was to identify needs and challenges, and generate a list of ideas for sensing technologies (for example "air quality sensor," "temperature sensor," or "door alarm") that could be further developed into solutions.

The goal of the second workshop within each community was to sketch out possible technology solutions to some of the needs the community identified during the first workshop. Once again, this second workshop began with introductions and an informed consent process. The research team then presented back to the participants a summary of some of the outcomes from the first workshop. This summary was created through a rapid qualitative analysis of field notes, that occurred between the first and second workshop with each community. The goal of this analysis was to identify problem-solution pairs that were described by participants (e.g., problem: community security | solution: alarms attached to motion sensors at the gates to the community). The remainder of that workshop was used to identify further design criteria for developing technology solutions to identified challenges. This took the form of an unstructured focus group, which we felt made the participants most comfortable in sharing their ideas. After this workshop, analysis of the results was informally shared back to community members to ensure correctness and inform the following sensor implementation stage, which is ongoing but out of scope for this paper.

All workshop sessions were audio recorded, and these audio recordings were later transcribed. At the end of each workshop, participants were provided with research subject payments in recognition of the time and knowledge they shared with the research team.

The research team performed a thematic analysis of the qualitative interview data [29], an inductive approach that involves reading through data to identify patterns that can be generalized into more abstract themes. Thematic analysis also requires the use of reflexivity, the examination of how one's own experiences and feelings shape the process of data interpretation, to mitigate the risk of introducing bias into the analysis. To further minimize the effects of individual biases, two members of the team separately engaged in open coding of workshop transcripts using the software `Atlas.ti`. This was a bottom-up coding process in which each researcher labeled quotes with relevant thematic codes, such as "data privacy" or "communal living tensions." After both had completed an initial round of open coding, they shared the results with one another and the broader research team. The team met to collate similar codes and discuss differences in codes until they reached agreement and produced a final code book. Any differences were rigorously discussed with references to broader sets of related literature and other field observations, until consensus was achieved across the team. The team also discussed relationships between the codes and grouped them into potential higher level themes. The two lead coders then used the final code book to re-code the transcripts, after which the full team met again to review and revise themes into broader second-level themes through axial coding. All authors collected the quotes associated with the broader themes identified and used them to write this paper.

4 Context: Tiny House Villages

A standardized definition of a tiny house does not exist [115]; the type and size of these small houses may vary [105]. In the U.S., a 'Tiny House Village' (THV) refers to a constellation of small dwellings, each encompassing a modest area ranging from 100 to 400 square feet [30, 117]. The housing clusters are alternatively known as dignity villages, tiny homes, micro homes [30, 104, 117], or micro dwellings [115]. Today, THVs are promoted in multiple states as affordable housing alternatives (temporary or permanent) for individuals experiencing homelessness [115]. Oregon and Washington, especially receptive to tiny houses, have collaborated with local governments to create and designate THVs as affordable and rapid housing for the homeless.

More broadly, THVs represent a form of "decommodified housing," which Colburn and Aldern describe as housing stock maintained outside of commodity markets and their pricing pressures [37]. Despite advantages such as affordability, sustainability, mobility, and communal orientation, THVs face many challenges. These include institutional and regulatory barriers, such as strict state and local zoning, building, and housing codes [104, 114, 115]. The non-standard nature of the dwellings also complicates financing options [114] and conflicts with local restrictions on minimum footprint [115]. Detailed insights into zoning and building code requirements are provided in [115].

4.1 Tiny House Village Ecosystem in Seattle

The Low Income Housing Institute (LIHI), a large regional low-income housing non-profit, runs the majority of THVs in Seattle. As of January 2024, there are 18 LIHI villages across three counties in the Puget Sound region. LIHI management and authority structures are top-down in the interest of keeping the environment "low-barrier" for residents, though they may use democratic governance practices such as weekly meetings to encourage personal empowerment. LIHI also provides supportive services, such as case management and mental health counseling.

In contrast, other shelters in the region have long-standing traditions of self-management and governance. One is “Tent City 3,” a tent encampment with about 60 residents, supported by the nonprofit organization Share/Wheel, which receives temporary permits to occupy a given location for three to ten months at a time before having to relocate [103]. Our research is conducted in collaboration with Nickelsville, a small housing advocacy nonprofit that currently operates two resident-managed THVs.

4.2 Nickelsville

Nickelsville is a 501(c)(3) nonprofit composed of a set of communally self-managed, rent-free, permanent cooperative housing “villages” for people transitioning out of homelessness. Nickelsville began in 2008 as a self-organized homeless encampment established on public land in response to sweeps by then-Mayor Greg Nickels. Having grown to 170 residents at its peak, they partnered with LIHI for help with case management and opening new locations. Participants described that in these early days *[N4:] “Nickelsville was helping set them up [(with the THV model)].”* Over subsequent years, some villages objected to LIHI and city management practices, breaking away and establishing their own organization. After several forced relocations due to population growth, management challenges such as crime, and waves of public opposition or support, two Nickelsville locations remain, Northlake and Central District (CD), each containing around 15-20 households [93]. These are the communities we work with in this paper.

Nickelsville stresses the importance of communal self-governance and participation over top-down management. From their website, “Nickelsville’s goal is not only to survive homelessness, but to help solve homelessness while living in an empowering, self-managed setting” [93]. Each village is led by an elected “Triad” consisting of a Bookkeeper & External Coordinator, Arbitrator, and Head of Security, as well as a number of smaller elected roles such as Intake Coordinator, Kitchen Coordinator, and Infrastructure Master. The Nickelsville Central Committee (NCC) is open to members from all villages and the broader public and meets weekly, making decisions for Nickelsville as a whole.

A hard requirement is that residents must already be drug free since all villages maintain strictly drug- and alcohol-free environments. Residents must also attend weekly village meetings and earn a minimum number of monthly “credits” for service activities. These may include weekly three-hour security shifts, village cleaning and upkeep, attending NCC meetings, political advocacy, and more. The villages have strict policies against speaking directly with their neighbors or land owners about village issues to prevent external interference with decision making and to limit individual liability.

4.3 Infrastructural Context

New village plans are permitted by the King County Regional Homelessness Authority (RHA) and the Seattle Human Services Department (HSD), after which Nickelsville must put up public community notices and hold a public meeting to solicit neighborhood feedback before establishing a new village. The installation and setup of houses are often non-standard or improvised for these unusual plots of land, with specific terms for designated-temporary use.

Both CD and Northlake Villages have land use and construction limitations that give rise to core challenges when living in and managing the villages. Northlake Village is located on land owned by Seattle’s public electric utility company, in an industrial and maritime-zoned neighborhood (Code IC-65 (M)) [36]. No ground disturbance or ground coverage (such as of paved walkways or ramps) is allowed for construction because of the infrastructure buried under the village, which may require immediate access by the utility company at any point. Residents report that the mainly

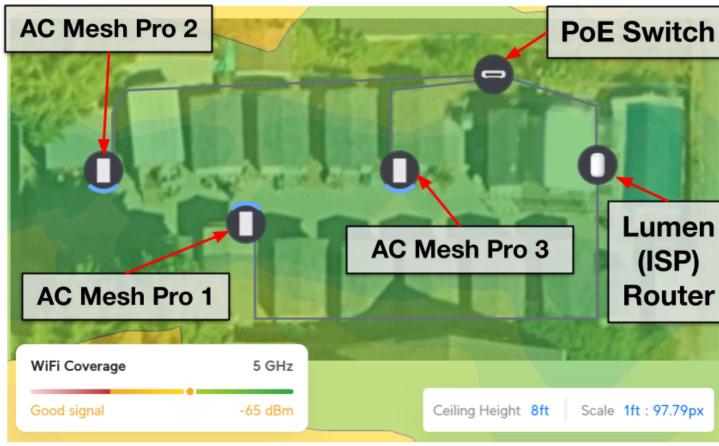

Fig. 2. Nickelsville CD WiFi network devices and signal strength heatmap (showing 5GHz coverage), overlaid on a satellite-view map (Google Maps). The heatmap is an approximation produced using the WiFi equipment vendor (Ubiquiti)’s online simulation tool. Photo credit: SCN

commercial neighborhood’s relative emptiness at night and the village’s direct adjacency to a large parking lot attracts crime, described in Sec. 5.

CD Village was built on an otherwise empty plot in a gentrifying residential neighborhood (zone code NR3) that generally allows detached single-family houses and attached/detached accessory dwellings. The village is permitted under Municipal Land Use Code Subtitle III Section 23.42.054 [2], specifically regarding “transitional encampments” on property “owned or controlled by a religious organization;” their faith sponsor is the Kadima Reconstructionist Community, a progressive Jewish nonprofit that supports local mutual aid initiatives, and the land owners are members who live across the street. One of their primary concerns is that they could be asked to move because of neighbors complaining to the City, unhappy about the intrusion into their single-family neighborhood, as detailed in Sec. 5.

4.3.1 Internet at Nickelsville. The Seattle Community Network (SCN) [84], a local volunteer-based community networking organization, installed the Nickelsville CD Village’s WiFi in 2021 on a 100 Mbps 4G LTE connection, and upgraded it to a gigabit fiber connection in 2022 once the service became available. They installed the Nickelsville Northlake Village’s WiFi in 2022 directly on gigabit fiber as it was already available. Villagers report generally good coverage, with some issues with limited signal penetration into the tiny homes further from the transmitters (see Figure 2). SCN works with THVs and other underserved groups to build and maintain free Internet access infrastructure. They deploy village-wide WiFi, connected upstream to City or other grant and nonprofit-supported Internet connections, train users on its operation and maintenance, and provide ongoing support and upgrades. Our interactions with Nickelsville developed through volunteering with SCN and its connectivity infrastructures provide the substrate for our implementation of IoT devices in this work.

5 Results

Our PD workshops revealed basic infrastructural precarities that both villages experience, with consequences for appropriate technology designs. For example, residents face resource constraints related to availability and cost of utilities, exacerbated by the utility infrastructure’s ad hoc and outdoor construction. Furthermore, an increased resident population density compared to the typical number (often just a few households) on a given plot of land can create resource pressure on utilities and appliances, as do the challenges of collective governance of these shared resources.

THV residents are constantly engaged in infrastructuring work to counteract these precarities, including both internal communal management practices and external community advocacy. They rely upon resident participation and "DIY" maintenance for this work, based on commonly expressed values of autonomy and sustainability. However, it can be challenging to navigate this participation with individuals' various capacities, boundaries, and accessibility needs. The PD process revealed social tensions, such as trade-offs between individual privacy and security.

Despite their infrastructuring work, because residents are designated as temporary emergency occupants, they have neither the well-understood occupancy rights of home owners nor the protections for tenants. The villages face differing external threats based on their land situations, including legal liabilities and neighborhood social dynamics that threaten their existence. These physical and social challenges constrain the design and building of infrastructure and accompanying sensing technologies. While their differing land situations produce different precarities, the villages' common situation, experiences, and governance result in a sharing of concerns, solidarity, and advocacy practices that work to combat precarity. We examine these emergent themes in more detail below.

5.1 Precarious Infrastructures: Water and Power

We illustrate the villages' infrastructural precarities, communal management tensions, and infrastructuring work through their challenges with water and electricity. We examine the narratives, root causes, and manifestations of the problems they proposed to address using IoT deployments.

5.1.1 Resource Constraints. Financial constraint, a core challenge faced by both villages, was a foundational source of precarity and sense of impermanence among residents. Nickelsville pays for utilities collectively via public grants and private donations, resulting in organizational pressure to keep utility costs as low as possible. Prior to these grants received starting a few years ago, individual residents had been expected to pay $90 USD a month per house for utilities. This structure reinforces residents' narrative of the village as transitional housing and the expectation or hope that they will move on. Several participants called the village a "stepping stone:"

> *[C2:] I think people want to make this their own little house. It's not. You're still homeless, you know. Somebody else is paying your bill, and we just need to be grateful for what we have. ...This is a stepping stone to get into your own home, and you cannot make it your own home because somebody else is paying your bill. And when the bills start to get higher and higher, that's when they start coming down and saying, hey, what's going on?*

In exchange for the lack of individual financial burden comes a reduced sense of individual ownership and permanence. Some residents feel that outside funding decreases individual accountability and efficiency: *"[C7:] nobody really knows where exactly in the details of it or whose pocket it's coming out of. ...if it's coming out of your pocket, you're going to respect it more. That's just nature."* Residents also have anxieties about inviting criticism from those inside and outside of Nickelsville who pay for their utility usage. Thus, its residents expressed needing to hold themselves collectively accountable to the organization's collective values such as energy efficiency, being *"eco-friendly," (N6)* and *"going green" (C6).*

5.1.2 Ad hoc, Outdoor Construction. As a result of both financial constraints and the land use constraints described in Sec. 4.3, installed village infrastructure is generally ad hoc, i.e., not built from a standardized, heavily tested design. This occasionally results in insufficient scaling of infrastructure. Both villages struggle with electrical and water systems being under-provisioned or insufficiently hardened for the outdoors environment. For example, Northlake's electrical system is *[N5:] "not wired for [a stove and an oven like the CD village]. So all of that has to be taken into account when you do anything here because we don't have the same breaker boxes."* Northlake also has *[N5:] "a tankless hot water heater that is designed for a normal house, not for 20 people,"* which causes erratic heating and cooling during showers. One winter, Northlake residents went without water for one and a half weeks because of frozen pipes, which were caused in part by the outdoor installation of pipes without insulation.

Relieving resource constraints would help, but not solve all of the infrastructural problems. According to residents discussing an ongoing new village build, Nickelsvilles are built for a twentieth the cost of new LIHI villages, which at $1.6 million USD provide electrical infrastructure to accommodate an air conditioner in each tiny house, a full kitchen, and modest multi-unit laundry room for a village size of 40 or more households. LIHI currently has 18 operating THVs throughout the state; each iteration, customized to the land plot used, is a chance to standardize and update the construction and design for robustness. Recently some of their THV plans and designs have been made available online to help guide other non-profits, and the THV ecosystem as a whole benefits from this now "open source" knowledge. However, despite implementing these more robust, expensive designs, when researchers visited the newest LIHI village, we met with a full-time dedicated on-site infrastructure manager with an electrical engineering degree who had been employed to deal with local maintenance and fixes, which highlights the ongoing difficulties.

5.1.3 Greater Need for Detailed Knowledge and DIY Maintenance of Infrastructure. The ad hoc living infrastructure at THVs, while faster and cheaper to build, requires more active management, resources, and knowledge to maintain than typical permitted housing structures due to their non-standardized setup and outdoor environment. We encountered circumstances where residents needed a detailed understanding of their utility infrastructure and its configuration, often poorly documented, to troubleshoot problems or add IoT sensors.

For example, Nickelsville CD residents proposed village-wide power monitoring to help with frequently tripping circuit breakers (every few days), which they thought was due to power overconsumption. However, this proved to be a knowledge and electrical maintenance issue. During one visit, the SCN team noticed that the breaker for the shower lights and heater had tripped and would not reset. A volunteer familiar with electrical work noticed that all of the village circuits were installed with GFCI protection (required by electrical code for outdoor circuits), which meant that any faulty electrical appliance or moisture causing current to leak to ground would cause the breaker to trip. After conversing with residents, he found and repaired the heater fault, which fixed the breaker issue. Though Nickelsville has a handyman to call when needed, his labor is too expensive to use as frequently as maintenance is needed given the organization's financial constraints. Thus, the village always turns first to a resident, appointed "Infrastructure Master," who tries to handle the problem. However, this level of maintenance can be difficult to DIY since it requires more than a typical resident's (or community's) expertise and knowledge of how the infrastructure is built and functions, and could potentially lead to costly mistakes.

The villages' water systems have led to similar challenges. For example, due to the prohibitive costs of adding a new dedicated water line to the neighborhood's clay piping, the CD village water is piped in from an outdoor spigot on a neighbor's house via an insulated hose buried underground between the two properties, adding a layer of precarity via potential failures at other households. In one instance, *[C5:] "Our water completely turned off at ten o'clock at night. We found out the reason was because somebody turned off the water from the main site completely by accident. And*

Fig. 3. Nickelsville Northlake brown water sample, collected by residents and shown to researchers in Sep. 2023. Photo Credit: Kurtis Heimerl

then it came back down in the morning at eight o'clock, but [all night] there was no water for people to shower, flush your toilet, nothing like that." This neighbor's water is now shared with an accessory dwelling unit in addition to the village, which affects water pressure. One workshop outcome was to plan an installation of a smart water flow, temperature, and pressure sensor for shutoff alerts, located at the water source in the neighbor's yard (after multiple days of investigation, neither our team nor the residents could find an accessible entry point for the water pipe on the village side). However, this initial attempt was stymied by lack of permission to access a suitable power source on the neighbor's plot, leaving the problem unsolved.

In contrast, Northlake has its own water main and meter, hooked up to a trailer-style portable bathroom and kitchen similar to newer LIHI THVs'. However, residents described water quality problems where they have *"[N5:] brown water"* or *"[N5:] small flakes, almost like pepper"* every three to four months. One resident purchased bottled water because the tap water *"[N2:] made me sick for a while. ...Once we stopped using it, I was no longer sick."* Some cited possible *"[N4:] backlogs"* of contaminated water in the past due to misconfigurations of their water hoses and trailer hookups, highlighting that specialized knowledge is often needed to correctly install and troubleshoot ad hoc infrastructure.

Village leadership contacted Seattle Public Utilities to test the water, which returned inconclusive results and an unsatisfying explanation of annual fire hydrant testing causing the brown water (which occurs more often than annually). The source of contaminants remains an open question after many months. Villagers proposed a water quality monitor on their water supply to detect and alert on bad water events in real time. Unfortunately, the only such devices that already exist are very expensive and designed for more industrial, rather than at-home DIY IoT. This poses a significant quality of life problem that would likely not persist in a neighborhood with large numbers of homeowner residents pressuring the utility company or City to resolve the situation.

5.1.4 Arguments for Human Solutions. In light of the self-reliance and communal responsibilities their housing situation requires, participants had important concerns about the reliability and maintainability of the IoT sensors and automation. While most expressed excitement about the technology, they also considered possible advantages of alternative human management or policy solutions to their infrastructure problems.

We often heard from residents that they preferred self-reliant or human rather than technology-based solutions to their problems. Given the failure rate of electrical appliances in the village (such as the broken bathroom heater and clothes dryer we encountered), the residents' DIY responsibility over them, and the more challenging outdoor setting, we note that being able to live gracefully without any given technology for a period of time could be an important element of emotional resiliency. Some cited a general conservatism around changing their working village systems for fear of disrupting their situation, as explained in Sec. 5.2. Others were hesitant to be saddled with technologies that might fail and need maintenance beyond their abilities: *[N4:] we like to be as self reliant as we can. We might not have the mechanical aptitude to keep that up to date. I just don’t want to have a pile of really expensive components, most [without] usability after a year.* Some anticipated developing bad habits from expecting automation, such as leaving faucets running *“[C7:] for like 15 minutes”* in bathrooms that are not automated, expecting them to turn off on their own. A few felt that being able to live without automation should be a default mentality and learned skill, especially given that utilities are paid for by others, which they believed should necessitate respectful and restrained usage:

> *[C2:] it was drilled in from the time that you’re walking, if you’re cold, you put a coat on. You don’t turn up the heat because Mom and Dad pay the bill. You don’t pay the bill. ...If you don’t turn the light off, you get your butt turned back around and you turn that light off. ...if technology wasn’t around, people wouldn’t even know how to live.*

Finally, some residents were reluctant to assume the additional responsibility of responding to sensor readings since there are already many self-management duties in the village. A few participants wondered, *[C2:] “Who is going to take responsibility for all these little sensors, or all the data? What are you supposed to do, you know?”* One posited that *[C7:] “It’s a lot of stress when you’ve got to deal with all that stuff.”* An important design consideration not to have sensor readings introduce stress or burden without commensurate benefit into the residents’ lives, *e.g.* by reporting false positives or bothering people with alerts when they cannot do anything about a given problem. For example, displaying sensor alerts if the Nickelsville CD water flow is cut off may be most effective in the neighbor’s house, where it can notify them to check if they have shut off the wrong valve by accident. Automated actuation in response to sensors may reduce this burden, but only if reliable and maintainable.

Ultimately, despite these reservations, community members did not want to block improvements and resources from coming to the village. They seemed to trust the Nickelsville leadership’s approval processes and iterative co-design to ensure the researchers would not implement any sensors that would risk trouble or liability for them.

5.2 Personal Health and Accessibility

On top of environment-based health concerns, many workshop participants mentioned underlying health precarities such as disability which impacted their attitudes towards adopting IoT devices. For example, some residents of the CD village expressed risk aversion with respect to modifying their infrastructure in any way because they believed the village could be evicted with 30 days’ notice if they offended or disturbed their neighbors, *e.g.* with light or sound-based sensor alerts. [2] Those with health conditions seemed most strongly concerned about risking loss of their housing:

> *[C5:] I can’t be cold because of my health issues. There are several other people here that can’t be cold because of their health issues.*

We note the particularly severe consequences for health and safety of being disabled while unhoused:

> *[C2:] being older and homeless and more disabled, I guess the fear of upsetting anybody, the neighbors, it scares me to death, because I can’t live on the streets again. ...So, for me,*

[2]NCC leadership later informed the researchers that this is untrue—only the religious sponsors or landowners can require them to leave.

> *it's just I don't want to ruffle any feathers. I just want to go back in my little house I have and be safe and not have to worry about somebody coming in to beat me or beat my dog, because that's where I was at.*

We further explore perceived housing insecurities due to neighborhood social tensions as well as lack of clarity around THVs' policy status in Sec. 5.3.

5.2.1 Accessibility. Accessibility is a broad issue across the THVs, with numerous villagers self-identifying as having significant physical disabilities. Nickelsville residents know and care for each other's accessibility needs as much as they can during their DIY infrastructuring work. For example, when the SCN team installed a new automatic gate closer, we asked a participating resident to make sure the weight of the gate was acceptable. She took care to call over and test it with another resident with mobility issues whom she knew would have the most trouble. However, both villages are constrained in terms of the accessibility accommodations they can make due to their construction restrictions. Participants from both groups stated that they would have liked to install more accessible walkways and ramps, but neither village is allowed to dig to install anything permanent on or underground, at the CD site due to not knowing the depth or locations of already buried infrastructure on the plot, and in the Northlake site due to Seattle's uses for the land (Sec. 4.3). Thus, both villages use gravel paths, which do not readily accommodate mobility aids such as wheels.

They also have to account for each other's accessibility and health needs in their communal processes, which sometimes presents tensions and challenges. At Northlake, the group strives for full communal participation of three hard-of-hearing residents (one fully deaf and two using hearing aids). On their weekly required security and gate monitoring shifts, hard-of-hearing residents cannot hear a typical auditory doorbell or knocking at the gate, and residents occasionally have to *"jump fence"* to get inside. Northlake workshop participants insisted on sensor data reporting with both audio and visual elements to accommodate hard-of-hearing residents, such as a loud noise and flashing lights when doors are left open by accident. We further discuss these design considerations in Sec. 6.

These discussions surfaced the issue of accessible group communications with hard-of-hearing members, who are expected to participate equally in group discussions, e.g., community meetings for decision-making and voting. One resident can sign in ASL and another can read lips, but a third cannot hear or speak. As N4 described, *"We're self managed. So one of the big things is...being able to give feedback on proposals that we're making...And so, this isn't gonna get made without their input, without their consent..."* While note-takers are assigned for their benefit, complex nuances and cross-talk are often lost in translation. Another explained that they try their best to be inclusive but still struggle, e.g., reach the limits of commonly available automated transcription technologies:

> *[N5:] It can be a little bit difficult trying to write things down and make sure that they fully understand what's being written down, you do the best you can...They're trying to have it so that [we] speak into something and it shows up, say on a screen, so that during our meetings, [the hearing impaired members] can follow along. We do include them. And I don't know how easy it would be to follow along. If you have other people cross talk, or if [N4] is speaking and then I'm interrupting, how does that go in?*

We note that accurate automated speech-to-text transcription in complex group settings is still a challenge in computing and an application area that would improve social participation for hearing-impaired people both in THVs and elsewhere.

Addressing inclusivity along different lines, participants at both villages also noted that not all community members have access to web-enabled devices. They proposed that the security resident on duty should be the primary point of contact to receive alert messages (e.g., SMS texts) generated from sensor data on a daily or weekly basis because they are assigned a village-owned phone for their shift and would be ready to take action if necessary. However, some proposed that texts should go to NCC leadership directly since they have the greatest authority and knowledge to make infrastructure decisions based on the available budget, policies, and liability considerations.

5.2.2 Quality of Life and Mental Health. Many participants brought up mental health as a major challenge in the village, though they did not go into enough specifics for us to address the issue directly. We thus explore how the villages' housing precarity relate to general quality of life and emotional well-being. We find that residents of both villages often feel socially discriminated against based on their experiences with homelessness. However, both also emphasized feeling grateful for their situation and not expecting luxuries. Meanwhile, we see other impacts on quality of living based on differences in both built and social environments between the villages.

Discrimination and Antagonism. Both villages described common public misconceptions about them. A Northlake participant mentioned hearing *"[N5:] a drug guy who literally said this is Tweaker Central. And we're like, what are you talking about? ...Yes, A lot of people associate homelessness with with drugs, drugs and mental health, that's across the board. ...[N4:] we run clean and sober."* Others in the neighborhood perhaps do not know the Nickelsville policy of remaining drug and alcohol free.

The participants mused that in addition to broad stereotypes about homeless people, mistaken impressions may arise due to non-residents who deal and use drugs in the large commercial parking lot beside the village, a prominent feature of the historically industrial and maritime-zoned neighborhood. Residents described the parking lot as *"[N5:] a place that the RVs will go and park for months at a time. And they're not the people that you want hanging out here."* Inconsiderate parking lot users often cause noise pollution that affects residents' sleep quality. People spend time in their cars late at night, sometimes playing music with the bass turned up and setting off fireworks, activities that would typically be considered unacceptable in residential neighborhoods. One participant felt unsafe because *[N6:] "I have a window that faces right up against [the fence]. And I mean, there's people that come out late at night and they just sit there with their car running."* They were especially frustrated by what they called *[N4:] "a mega bass concert:" [N6:] "It's- no boy, no. No. Rude. Rude...You can see [our] houses right here."* This problem is exacerbated because the tiny houses are constructed outdoors, with less sound insulation than typical homes.

In contrast, Nickelsville CD is located in a rapidly gentrifying residential area, where neighbors occupy a higher socio-economic class. Here as well, neighbors' treatment of residents has an impact on their emotional health, constraining their behavior and affecting their sense of security about their housing in different ways. One resident felt that their neighbors did not want them around, describing when his truck had been towed from the street in front:

> *[C4:] their issue comes from their condition, from how they see the world. If you're not well to do...then you are in a category that people don't want you around. You could be a good person ...They towed my truck. I paid three hundred and some dollars to get it out. I had to put a note on it, and the note read, "I'm not really a bad guy, if you want to talk to me, we could talk about it, and I could move it if that would make you happy. You don't have to call the cops on me because we can talk about it, and I could move it or whatever. We could work together." ...Like last week, I went and cut their grass...the thing is that we're trying to get along with them, but they can't soften up enough to see.*

The group called a few particular neighbors *[C6:]"a great challenge,"* citing multiple noise complaints to the City in the past. There was a hope that IoT data could legitimize their experiences. For example, they proposed that noise sensors might provide *"[C6:] some ammunition at least"* against false accusations. Residents have made lifestyle changes to accommodate the complaints, not knowing if they were true: *[C6:] "One of those [noise] sensors would help quite a bit. ...every time [one resident] goes somewhere, she has to take her dog. She's got to go to work and all these places..."* There were concerns that even with the sensor data, the neighbors would find other things to complain about because they were always looking for faults: *[C7:] "it's not the noise itself; it's just because they can say something and mess with us."*

Gratitude. Despite these challenges, CD residents greatly appreciated kindness and human connection from neighbors through donations or even casual interactions, such as being hired for manual work. These welcoming interactions with neighbors likely reduce anxieties about Nickelsville residents' precarity in the neighborhood:

> *[C6:] Yeah, there's some really good people around here. Really good neighbors. They bring food. I'm talking about some of them take the time to cook the meal then bring it. I do yard work for a few of them. So, I get to know them a little bit more personally and stuff, and they are good people.*
> *[C3:] Their recognition of you too is important.*

People are known to experience considerable social stigma and isolation when unhoused, and in their appreciation of basic friendly recognition, we note contrasts participants draw with rougher circumstances they may have come from. The neighborhood dynamics in some ways echo the historical experiences of racial minorities attempting to move into and desegregate majority White neighborhoods. Though in general the CD village encounters much less hostility and violence than in those racially motivated cases, it appears that less hostility is needed to destabilize them due to the substantial legal precarity of their presence on the land.

Both villages also emphasized gratitude for their physical infrastructure, with all its limitations. A Northlake resident insisted that the village did not need luxuries, perhaps as a value. This attitude was especially pertinent to appliances and technology, including the proposed IoT sensors, which were initially considered a luxury: *[N5:] We don't need a modern village. This is a homeless village, and we don't need fancy—very basic.* A CD resident expressed:

> *[C2:] from where Nickelsville was in 2013, electricity, what's that? Wi-Fi, what's that? ...there was no such thing as a refrigerator. A light, there was no such thing as a light because you know. You have port-a-potties. You were issued a garbage can to put your food in. You could only have dry things because of the rats. The rats were this big. ...Our dryer is not working right now. Okay, I understand, but that's not a right to have. It's a privilege and a luxury to have that. ...It's just really hard for me to understand, you know, getting all this new technology when it's like nobody has to do this for anybody. We should be grateful for what we have, just a little bit.*

We note the difference between their attitude and that of renters, who are explicitly encouraged to bring problems with their large appliances to landlords; in turn, landlords are in most cases required to make repairs.

5.3 Legal and Policy Status

While the villages' status in public policy as emergency and temporary housing has made it possible for them to be allocated land in a decommodified way, the rules around this status combined with their resource constraints make it more difficult to build and improve their own infrastructure, limiting their DIY capabilities. Despite their lack of a policy framework or occupancy rights, village residents essentially carry the same responsibilities and liabilities as homeowners but without the housing security and other benefits. For example, one mentioned that their kitchens (and those of other emergency shelters) must comply with local codes or risk being shut down: *[N5:]*

"we do have to follow the county health rules here for our kitchen...you pass or fail. Tent City 3 failed miserably. Their village layouts and gates are also regularly inspected by the City Fire Marshal.

Not all residents are familiar with the many rules that must be followed and their associated consequences, as evidenced by the initial misunderstanding in CD village about the risk of being asked to leave by their neighbors (Sec. 5.2). For DIY infrastructure modification, we see again that detailed knowledge is crucial—not only of the infrastructure's physical configuration, but also its policy environment and regulation. Villages go through upper Nickelsville management to approve any changes, worrying about violating the terms of their land use. As one CD resident put it, they have *[C2:] "to make sure it's okay within our contract [to install sensors] because this isn't our property...really what I want to stress is I don't want- if we get [an alarm] coming out with 'back gate is open,' [the owners are] going to be going, 'What in the world is that? That's not your property. That's not your decision.' "*

5.4 Public Advocacy Using Data

To combat some of the social antagonism and discrimination they may experience, both villages noted opportunities to share environmental sensor data publicly as a form of advocacy and positive social contribution. One Northlake participant said *"[N4:] I think 90 percent of [the data] should go online"* and specifically noted water sensors as a chance to *"be involved in the wider discussion nationwide about water quality and water property."* Another resident saw monitoring water quality as *[N5:] "being neighborly"* and *"paying back the community"* for their support: *"if we find that there's an issue, it is at the taxpayers' expense because taxes go toward those things...It holds [the City] a little more accountable."* Further, they felt that making the data public to mobilize popular and political support would be more effective than just informing the City themselves: *[N5:]"the City would be more apt to act if it's common knowledge versus, 'Oh, yeah, we'll get [to] it' because homeless people are a lower priority. And I think that the reaction would be better if it was in public, or everybody was aware."*

After years of organizing, the Nickelsville communities have developed deep knowledge and strategies around political collective action to combat their neighborhood challenges and housing precarities. Sharing sensor data related to public goods such as water and other environmental variables could be a strategy to increase their housing stability by providing value to their neighborhoods as well as increasing their public visibility as a whole.

5.5 Security, Privacy, and Communal Power Dynamics

In general, we see a culture of solidarity, understanding, and forgiveness within and between the villages that facilitates resource sharing and the use of rules such as management approval to protect each other against liability. Some participants use familial terms such as *[C1, C5:] "family"* or *[N3:] "brothers"* to refer to other residents. At the same time, when brainstorming freely about "what technology could do for them" during the first workshop, one Northlake participant joked that they would want a *[N3:]"free private apartment so you're not sharing with some asshole,"* the levity softening implications about the real tensions of sharing a home. Residents are not necessarily living there because they prefer life in large communal settings, making internal tensions especially important to alleviate. Discussions revealed conflicts in opinions, desires, and actions that impact sensor design, particularly in the space of tradeoffs between privacy and physical security from both internal and external threats.

Security was an obvious and pervasive concern, but traditional off-the-shelf IoT security devices, especially cameras, were not seen as a viable solution because the communities were not willing to collect and manage video and audio data. This opinion was widely shared despite physical security and safety being a top-of-mind concern for both villages, whose outdoor grounds are bounded by only a fence (that is regularly jumped), which necessitates security guard shifts at all times. We perceive that this type of data, even contained within the village, could give residents too much power over each other for their comfort, a preference stemming from a history of abuse of camera data from previous organizational management.

5.5.1 No Cameras: Privacy and Power Dynamics. At the time of the design workshops, both villages had encountered recent instances of "fence jumping" that brought security and safety to the group's attention. At Northlake, non-residents had been jumping the fence to use the showers and bathrooms, which residents had decided must be left unlocked for their quick access. At CD, after a recent burglary at a neighboring house, the burglar had opportunistically jumped the fence into the village to flee and was caught because the Nickelsville security on duty had promptly called the police. Participants at both villages mentioned times when the front gate had been accidentally left open or unlocked, sometimes overnight, and proposed both light and sound-based alarms for gate status.

Security concerns at Northlake village were especially attributed to the surrounding environment, where *"[N5:] [the police] don't come down here. Even if we call."* N5 recounted calling the police when someone had been shaking doors at the village and a restaurant across the street, and they had never arrived. She explained the difficulty of obtaining public services such as police and ambulances in terms of the built environment, again a consequence of zoning and land use histories: *"(in the construction zone next door) they're still building but there's nobody there. They're closed. Nobody lives in that house. I don't think people realize that there are people that live out there. And then you've got this wide open parking lot that you can easily escape (after committing a crime)."*

In addition to external risks, a few residents described having had safety concerns inside the village in the past. A CD member had heard of individual rooms being broken into before his time, though he did not feel in danger of it now. Another at Northlake had recurring panic attacks due to problematic former residents coming to her door in the middle of the night. She had asked to install a camera outside her door *[N5:] that literally faces the fence. The only way anyone would be seen is if they're on my porch, and [the leadership still] said if you do that you will be barred [from living here]."*

Nickelsville maintains a strict policy of disallowing monitoring cameras in their villages. Longer term members currently at Northlake described that when they had been under LIHI management, staff would use camera feeds to listen in on private conversations to justify evicting residents, or even to *[N4:] "enter the village, knowing that leadership wasn't in the village, and start to say, 'We've got to do this'...kind of usurping them democratically"* to control village decisions. Once under their own management, Nickelsville had *[N4:] "decided not to allow cameras pointing into the village."* Participants at CD village agreed that even cameras recording the street outside the gate could be problematic because it still allowed someone to track who was going in and out: *[C2:] "Who is going to be watching that camera?...I wouldn't want everybody else to know what I'm doing, and when I'm coming, and when I'm going."* One resident described this as being *"[C1:] really in jail."* Even without LIHI's top-down management, the villages still have internal tensions and power dynamics, akin to any family or small town, that could be shifted by privacy-impacting technologies.

While N6 expressed support for N5 in the workshop by suggesting a re-vote on the policy, the consensus at both villages remained to respect the "no camera" rule and implement motion sensors or other alarms as lower-fidelity evidence or as subtle deterrents for crimes: *[C4:] "[With a sensor alarm] we don't know who it is, but we know somebody was there around that time...Say the door's beeping and somebody is trying to come in, maybe [they] might not want to, because it's beeping. Somebody might hear it and just walk off."* This way, no one could be personally identified or tracked unless there was an incident, in which case the residents would collectively investigate further.

Residents recognized the tension between respecting individual autonomy while protecting group interests. In a discussion about power monitoring to help reduce the utility bill, one Northlake resident explained Nickelsville's philosophy while another defended her own choices:

> *[N4:] in our community the way we set it up, we really tried to avoid having too many eyes in individuals' private choices and lives. So yeah, I realized that I was kind of spearheading to monitor every house if it wasn't for that.*
> *[N5:] I knew that you weren't singling out my air conditioner.*

N5 had purchased an air conditioner[3] during the heat wave two summers ago because her house cat had almost died, and people had complained about her power usage. *[N5:] "But it's a life or death situation. And so I don't want anything to read what I'm using."* In this case she expressed fear of group judgment based on sensor readings, which if made public could either absolve (as in the noise sensor case above) or incriminate monitored individuals and constrain their freedom of choice. While we note that electricity usage data could be made privately visible only to each house resident, we can imagine how the mere availability of the data in such a close-knit communal setting could result in social or political pressure to share it unless there are explicit policies against doing so. Even so, the benefits of surrendering data privacy might in some cases outweigh the risks, for example, where a noise sensor monitoring on a group level could protect the village from external neighborhood power dynamics that threaten the stability of their housing. The questions of whom sensor data empowers and for what benefits are critical to design decisions about both data collection and sharing for IoT devices.

5.5.2 A Focus on Smoothing Over Consequences. Rather than cameras, participants preferred sensors to help them avoid unintentional mistakes with infrastructure that could affect others. Both Northlake and CD participants suggested sensor alerts for when the refrigerator door is left ajar, a common problem in both villages. At CD, their older refrigerator was frequently left open by people in a hurry while cooking, whereas a newer one's built-in beeping door alert greatly reduced the problem; this realization inspired the idea for the open-door sensors on the front gates.

We highlight the added difficulty of maintaining infrastructure and appliances (especially older or ad hoc ones) in heavy-use shared settings where an increased number of users creates more opportunities for damage, wear, or accidents in addition to group accountability challenges. Northlake participants recalled a situation when a former resident either carelessly or maliciously cut power to the refrigerators repeatedly and caused everyone's food to spoil: *[N5:] "We've had people here that literally will cut the power off to the refrigerators just to affect everyone else...So no one is allowed in the breaker box. This happened in the kitchen where the surge protector was shut off. Nothing is locked...I mean we don't typically have issues with it, but we did with her."* Northlake residents proposed a sensor-based alert for when power is out in the kitchen to avoid this problem, looking to smooth over consequences or prevent negative incidents that can affect their quality of life rather than assign blame despite prior bad-faith experiences.

6 Discussion: Challenges and Opportunities

While our THV participants broadly believe IoT and sensing technologies hold promise in improving infrastructure in their community, we identified a number of factors that constrain appropriate

[3]Many Nickelsville residents have jobs and income sources they rely on for food, daily necessities and comforts, and to save up for moving out.

THV Needs & Proposed Sensor Examples	Challenges and Requirements	IoT sensor features/ design recommendations
Utility monitoring on unreliable/non-standard infrastructure; Environmental monitoring/alerts that affect health: e.g. air and water quality Examples: • Village water shutoff sensor that alerts upstream household of shutoff; • Real-time water quality sensor with accessible boil water alert; • Removable water flow sensor not requiring in-line splice; • Per-circuit power outage monitor and alert;	• Affordability; • DIY Maintainability; • Outdoor, ad-hoc setting; • Construction restrictions (land precarity); • Monitoring need may be outside of the village or due to another party's actions; • Limited technical knowledge of user; • Must be resilient to power/network unreliability; • Must actuate or monitor unreliable or non-standard infrastructure	• Reliable, robust, and rugged for outdoor use; • Non-invasive/destructive, portable, or removable; • Low maintenance needs; • Easy to understand and use; • Shared neighborhood notifications/alerts
Physical Security; Utility usage monitoring and internal community accountability Examples: • Power monitoring; • Motion sensors on doors with light and sound alarms; • Automatic door closing and locking;	• Affordability; • DIY Maintainability; • Outdoor, ad-hoc setting; • Construction restrictions; • Limited technical knowledge of user; • Must be resilient to power/network unreliability; • Must actuate or monitor unreliable or non-standard infrastructure; • Strong individual privacy concerns	• Reliable, robust, and rugged for outdoor use; • Non-invasive/destructive, portable, or removable; • Low maintenance needs; • Easy to understand and use; • Self-hosted platforms with local storage; • Sensor modularity; • Monitoring sensors with lower fidelity than cameras; • Reliable automation of actuators; • Data privacy nutrition labels implemented for IoT platforms; • Granularly enforceable privacy and sharing policies with collective management features, for example multi-admin agreement required to access data;
Automation for improved accessibility and personal autonomy: e.g. reducing physical labor Examples: • Motion sensing lights throughout village; • Automatic gate opening and closing	• Affordability; • DIY Maintainability; • Outdoor, ad-hoc setting; • Construction restrictions; • Limited technical knowledge of user; • Must be resilient to power/network unreliability; • Must actuate or monitor unreliable or non-standard infrastructure	• Reliable, robust, and rugged for outdoor use; • Non-invasive/destructive, portable, or removable; • Low maintenance needs; • Easy to understand and use; • Reliable automation of actuators; • Easily customizable (no-code) multi-modal alerts;
Accessibility for collaboration: e.g. hearing impairment Examples: • Haptic and visual buzzers for sensor alerts; • Speech-to-text applications supporting group conversation needs- e.g. speaker detection, multi-speaker transcription; • Heads-up AR displays with live caption overlay for multi-speaker context	• Affordability; • DIY Maintainability; • Must be resilient to power/network unreliability; • Technical challenge- products not readily available on market	• Reliable, robust, and rugged for outdoor use; • Non-invasive/destructive, portable, or removable; • Low maintenance needs; • Easy to understand and use; • Easily customizable (no-code) multi-modal alerts; • Requires technical development;
Public advocacy against discrimination Examples: • Public physical display board or website for environmental sensor data; • Neighborhood noise sensor	• Affordability; • DIY Maintainability; • Construction restrictions; • Limited technical knowledge of user; • Must be resilient to power/network unreliability; • Community privacy needs	• Reliable, robust, and rugged for outdoor use; • Non-invasive/destructive, portable, or removable; • Low maintenance needs; • Easy to understand and use; • Self-hosted platforms with local storage; • Sensor modularity • Shared neighborhood notifications/alerts

Fig. 4. A summary of sensor and automation needs found at the Tiny House Villages, challenges or requirements for effective implementation, and design or feature recommendations. The feature recommendations are color coded to highlight commonalities and differences between problem domains.

designs as well as areas of interest ripe for future innovation, which we frame as a primary contribution of this work.

6.1 Transferability of Results

Our primary goal in this study is not to produce results generalizable to the broader public, but gather specific and useful insights towards developing IoT technologies supporting our community partners' service to local unhoused populations. Similar to other community-based, qualitative research studies, our goal is transferability of generated understandings to related or similar contexts. Our findings may be relevant to many similar communities outside of those studied here. As a result of the ongoing homelessness crisis throughout the US, "camps" or "encampments" of homeless people sharing or creating infrastructure have become a relatively common model of organization. Our focus on THVs provides a particular perspective on this style of infrastructure, and we believe many of our findings can transfer to these types of situations outside of our local environment. Specifically, the technological limitations and shared governance issues around IoT and other technology interventions in these environments is very likely relevant in other camps. Precarity caused by underlying insecurities and lack of ownership or agency almost certainly repeats and is likely exacerbated in communities lacking the formalism and permanency of THVs. Similarly, our findings show that there are likely still significant opportunities for impactful technology interventions that can navigate existing precarities, even in informal camps.

6.2 Accessibility and Inclusion

Accessibility research presents one of the most compelling areas of possible intersection between this work and other fields. As discussed in 5.2, there is a disproportionately high overlap between the unhoused and those with disabilities or health conditions, implying that these populations' personal sensing, health monitoring, and smart appliance needs, as well as their data privacy and sovereignty needs, are also likely to have overlap. Likewise, we found that our participants expressed many of the same values, concerns, and attitudes regarding IoT as found in assistive and health monitoring research. THV residents' emphasis on self-reliance and autonomy echo the traditional focus of accessibility research on enabling greater independence and autonomy for people with disabilities. At the same time, some recent accessibility work has favored social interdependence and relationship building as alternative goals in technology design [22, 57]. This mirrors the Nickelsvilles' strategic reliance on social support from community, policy support from government, and financial support from both. Both housing-unstable and accessibility research communities work to build a patchwork of strategies, independent and interdependent, for stability and solidarity out of precarity and vulnerability. We anticipate many *opportunities for fruitful cross-pollination between assistive or accessible technology research and design in support of the unhoused.*

We have seen that accessibility problems can cause tension when people have differing and competing needs in co-living situations, particularly when they are co-living out of necessity. Larger living groups will need more diverse and multi-modal affordances for sensors and actuators to accommodate differently abled members. To illustrate, for reporting poor water quality Northlake village members recommended accessible haptic buzzers and beep sounds, visual alerts such as a red light (already common in water filter sensors), and text messages with descriptors such as "brown" and instructions such as "Don't use. Boil your water first". Easy no-code *extensibility* of sensor platforms will be important for adding wide varieties of off-the-shelf actuators and scripted automations to sensing elements. We propose adding visual programming functionality, like a Scratch language integration, to the popular open source platform `Home Assistant` [4] we used for initial sensor installations, to make these automations more accessible for the broader public.

Finally, we present an open challenge to *improve the accessibility of multi-speaker group discourse including both hearing and deaf or hard-of-hearing (DoHH) individuals*, especially important in governance contexts such as community forums or "town hall"-discussions. Innovating on machine learning algorithms for speech-to-text mobile apps can incrementally improve DoHH individuals' experiences. However, we observed that group conversations are still difficult to navigate for DoHH residents using speech-to-text tablets, as they have to focus their gaze on reading screen text and often do not realize who is speaking or when they are being spoken to. Augmented Reality (AR) heads-up-style displays overlaying caption text over live visuals are one concrete proposal for improving inclusivity, with the caveat that designs must also be made low-cost and rugged enough for housing-unstable contexts.

6.3 Privacy and Security

Despite the prevalence of group settings, technologies for housing-unstable people must enforce strong individual privacy. We were struck by how strongly the 'no-camera' rule was held by participants despite their concerns about village physical security and safety. Participants from both villages playfully described other modes of intrusion deterrence that could work well enough, such as mock cameras or alarm lights and sounds. Design studies of smart and automated homes in other contexts, such as among elderly and vulnerable populations in assisted living, have revealed similar preferences against cameras except in the case of especially debilitating medical conditions [100]. Thus, we acknowledge that shelter residents in general might have different preferences than our participants regarding video surveillance in communal settings with higher perceived threats to safety or lower internal trust of other residents. These nuances are exactly why we believe *participatory and collaborative methods are crucial for just smart and sensing installations in communal settings.*

Regardless of the data collected, *the villages' consensus was to prefer storing all sensor data locally on-premises,* echoing concepts of data sovereignty preferred by other marginalized groups in strategic protection of their own interests [101]. This preference also informed our choice of the open source `Home Assistant` platform, locally self-hosted on a Raspberry Pi single-board computer, for initial installations. We have found so far that other off-the-shelf smart sensors typically exfiltrate data to the cloud, failing to meet these groups' privacy needs.

For proprietary or cloud-based IoT platforms, we see strong needs for *improved transparency and granularity of data sharing and storage,* especially compared to the often inscrutable privacy policies displayed to users upon sensor installation. Though individuals had wide-ranging preferences about what they cared about keeping private or sharing, many expressed an intense desire to understand what data is collected about them, who it would be made accessible to, and how it could be used, not only from our proposed sensors but from latent technologies such as their mobile phones. They carefully considered multiple levels of data sharing (personal, village, external, public or online) throughout the design process. To support this decision making, we call for *rigorous standards for IoT products explaining data retention and sharing policies*, such as the clear "Data Privacy Nutrition Labels" which were proposed by security researchers as early as 2009 [78, 79] and adopted in 2020 by Apple [5].

6.3.1 *Reducing Management Labor.*

As urban housing needs grow, supporting the management of dense or shared living arrangements will become increasingly important. *Appropriate implementations of sensing and automation could make collective resource management smoother and more efficient*, for example via beeping refrigerator doors, automatic gate closing and locking, and other conveniences participants proposed that minimize the effect of accidents.

In LIHI-style managed THVs, effective home automation could decrease management labor needs or improve communications between residents and staff as in the case of Dantec's Community Resource Manager. However, in these cases, we expect sensing infrastructure deployed top-down by management to reproduce and ossify existing power hierarchies, rules, and constraints based on the context and purposes for which they were designed, not necessarily according to residents' preferences [118]. (For example, all LIHI villages are equipped with CCTV monitoring.) The participatory and consent-based nature of our sensor design and installation processes with Nickelsville, especially in promoting shared knowledge and understanding of the deployed technology, importantly means that *it can be uninstalled or shut down by residents at any time.*

6.4 Land Ownership and Resources

Finally, we sum up the technical implications of precarity surrounding the THVs' permissions and particular terms of existence on the land, and resulting limits on what they can build. IoT devices require minimum levels of infrastructure reliability to function, made difficult by underlying infrastructural limitations unless devices are appropriately designed or hardened to deal with the conditions. Despite our urban use cases, we see many opportunities for cross-context collaboration with research in rugged outdoor or off-grid, rural, and agricultural sensors.

We were also constrained by unfavorable terms of land use for THVs including potentially finite timelines for occupancy, or even uncertainty around whether such timelines might be enforced in the future. Thus, *portability, non-destructiveness, and ease of installation and removal are necessary sensor features* for THVs and broader unhoused communities. For example, water flow sensing on a whole-residence scale usually involves modifications to plumbing. Flow sensors using other physical properties such as sound exist for industrial uses, but are currently cost-prohibitive for resource-constrained THVs. We also found that enacting ownership via infrastructure building crucially requires knowledge and expertise. While the CD village's land owner may have allowed digging on their property with perfect knowledge or documentation of the infrastructure underground, without it they deemed digging too risky despite the potential benefits to the residents.

There is much room for sensors themselves to be made *more usable by laypeople without specialized expertise.* To illustrate—there are simple, off-the-shelf per-circuit power sensors similar to common handheld current meters that need only to be clamped around the outsides of wires. However, these are designed for wiring directly into electrical panels, drastically reducing their usability by novices without electrician skills. When sensors are user-friendly, we see *ripe opportunities for hands-on technical learning using IoT and sensors,* a strategy long adopted by educational platforms such as Arduino to teach basic programming and hardware prototyping. Our repeated engagements with residents including on-site build days and a public weekend hackathon have shown that tinkering with and installing IoT devices can be a low-barrier-to-entry exercise that encourages basic familiarity with both computing technology and village infrastructure. It can also engage teams of people with broad experience levels in problem solving together. The installations have made utilities infrastructure more visible to village residents and encouraged them to develop their household DIY skills, which can be invaluable in these resource-constrained living settings. [4] While DIY knowledge can be considered digitally more accessible than ever (such as via online demonstrations on YouTube), this is crucially dependent on Internet access, another layer of infrastructure that cannot be taken for granted.

How to address the root problem of ownership is an open question, related to that of resource limitation among the housing-precarious. Community land trusts, such as the nonprofit Homestead in Seattle, work to combat neighborhood displacement by providing alternative routes to home ownership for low-income applicants, holding land at low prices that must be resold under the same conditions in perpetuity. This particular solution is designed to help single families build generational wealth, not for transitional groups seeking emergency shelter; however, such policies could be adapted to fit nonprofits intending to operate long-term shelters like Nickelsville.

Even with the existing restrictions and red tape of conditional and permitted land use, it is clear that the THVs' permission to exist and occupy their space for the long term is the most basic and crucial need for the residents' sense of stability. With adequate resources, ingenuity, and community support, THVs' infrastructure has been reliable enough to meet crisis needs where land would otherwise lie fallow. As our participants pointed out, *installing environmental sensors*

[4] We note that the THV environment already cultivates development of these skills by providing "training grounds" with real break-fix scenarios for practice, as described in repair literature [53, 71].

reporting public data could turn the villages into valued informational infrastructure for their neighborhoods and the City and support their case for continued existence there. The data may also help increase their public visibility, making them harder to remove without public notice. We believe that such creative and cost-effective solutions for rapid and emergency housing should continue to be explored and supported since there will always be a need for decommodified, dignified, and socially supportive shelter environments.

7 Conclusion

While IoT may be of limited use in directly addressing the housing crisis, we have identified potential ways for appropriately designed IoT to support Tiny House Village residents' quality of living in their built environment. Collaborative design and installation of the villages' sensing solutions made visible the infrastructure underlying our intended technologies to both the researchers and the residents participating in the design choices. We found this infrastructure to crucially include details of land ownership and the social and political arrangements surrounding its use, which affected our ability to implement sensors. Historical and current zoning of land, in especially scarce supply for THV communities, has also impacted the social and physical environment which shapes residents' infrastructural and sensing needs. The resulting design features for "village-scale" sensing (*e.g.* ruggedness for outdoor use, summarized in Fig. 4) reflects conditions closer to remote rural or municipal use cases than inside typical urban homes.

We found that sensors may support villagers' housing stability by improving their neighborhood standing and providing a basis for public advocacy through data sharing. Participants also looked to automation and alerts to prevent or fix human-caused infrastructure failures such as accidental water shutoff or gate unlock, alleviating tensions from communal sharing and improving quality of life. Meanwhile, residents imposed strict privacy constraints on data collection for community protection, not only from outside entities (*e.g.* by refusing cloud data storage) but towards maintaining individual autonomy from surveillance by one another. Finally, they also identified opportunities to improve village accessibility through diverse sensors, actuators, and new technologies, for example more effective multi-speaker captioning for inclusion of deaf or hard-of-hearing (DoHH) residents in communal decision-making discussions. Given the growing incidence of people experiencing housing precarity and the multi-dwelling villages or encampments where they may find shelter, we hope to have deepened the CSCW community's understanding of their environmental conditions and constraints towards more inclusive design of IoT.

8 Research Team

This participatory research was conducted by an interdisciplinary team of researchers and community partners. Community members' input was sought and implemented from the beginning to the completion of the research. In addition to the invaluable expertise of the community, our research team included a social scientist and a Ph.D. candidate in community-based ICT research from the UW's Information School; two computer scientists from the UW's School of Computer Science; a collaborator from a local research organization focused on supporting digital equity in Black communities; and an experienced social science field researcher with a Ph.D. in History. This diverse team ensured a comprehensive approach to the research, integrating various perspectives and expertise. The research was conducted under IRB approval.

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References

[1] 2020. 12 Personal autonomy in elderly and disabled: How assistive technologies impact on it. In *Aging between Participation and Simulation*, Joschka Haltaufderheide, Johanna Hovemann, and Jochen Vollmann (Eds.). De Gruyter, 185–198. doi:10.1515/9783110677485-012

[2] 2023. 23.42.054 - Transitional encampments located on property owned or controlled by a religious organization. https://library.municode.com/wa/seattle/codes/municipal_code?nodeId=TIT23LAUSCO_SUBTITLE_IIILAUSRE_CH23.42GEUSPR_23.42.054TRENLOPROWCOREOR

[3] 2023. Tiny Houses. https://www.lihihousing.org/tinyhouses. Accessed: 2023-01-06.

[4] 2024. Home Assistant. https://www.home-assistant.io/ Accessed: 2023-01-14.

[5] 2024. Privacy - Labels. https://www.apple.com/privacy/labels/

[6] Hana Abdelatty, Dimitri English, Adan Garcia, Selena Melgoza, and Austin Mendoza. 2023. Turning down the heat: Addressing heat inequities of frontline communities in Los Angeles. https://escholarship.org/uc/item/8kr3h6jm

[7] W Neil Adger, Ricardo Safra de Campos, Tasneem Siddiqui, and Lucy Szaboova. 2020. Commentary: Inequality, precarity and sustainable ecosystems as elements of urban resilience. *Urban Studies* 57, 7 (2020), 1588–1595.

[8] Syed Ishtiaque Ahmed, Nusrat Jahan Mim, and Steven J Jackson. 2015. Residual mobilities: infrastructural displacement and post-colonial computing in Bangladesh. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 437–446.

[9] Riyad Al-Shaqi, Monjur Mourshed, and Yacine Rezgui. 2016. Progress in ambient assisted systems for independent living by the elderly. *SpringerPlus* 5, 1 (Dec. 2016), 624. doi:10.1186/s40064-016-2272-8

[10] Mariam Asad and Christopher A. Le Dantec. 2017. Tap the "Make This Public" Button: A Design-Based Inquiry into Issue Advocacy and Digital Civics. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, Denver Colorado USA, 6304–6316. doi:10.1145/3025453.3026034

[11] James Ash, Rob Kitchin, and Agnieszka Leszczynski. 2018. Digital turn, digital geographies? *Progress in Human Geography* 42, 1 (2018), 25–43.

[12] King County Regional Homelessness Authority. 2022. 2022 POINT IN TIME COUNT. https://kcrha.org/wp-content/uploads/2022/06/PIT-2022-Infograph-v7.pdf.

[13] Roger Baig, Lluís Dalmau, Ramon Roca, Leandro Navarro, Felix Freitag, and Arjuna Sathiaseelan. 2016. Making Community Networks Economically Sustainable, the Guifi.Net Experience. In *Proceedings of the 2016 Workshop on Global Access to the Internet for All* (Florianopolis, Brazil) *(GAIA ’16)*. ACM, New York, NY, USA, 31–36. doi:2940157.2940163

[14] Jutta Bakonyi, Stefanie Kappler, Eva-Maria Nag, and Lena S Opfermann. 2021. Precarity, mobility and the City: Introduction to the Special Issue. *Global Policy* 12 (2021), 5–9.

[15] Megan Bang and Shirin Vossoughi. 2016. Participatory design research and educational justice: Studying learning and relations within social change making. 173–193 pages.

[16] Jørgen Bansler. 1988. Systems development in Scandinavia: Three theoretical schools. *Office Technology and People* 4, 2 (1988), 117–133.

[17] Michael Batty. 2013. *The new science of cities.* MIT press.

[18] Michael Batty. 2017. Cities in disequilibrium. In *Non-Equilibrium social science and policy*. Springer, Cham, 81–96.

[19] Michael Batty. 2017. Producing smart cities. *Understanding Spatial Media. London: Sage Publications* (2017), 204–215.

[20] Andrew Beer, Lyrian Daniel, Emma Baker, and Laurence Lester. 2020. The Shifting Risk of Homelessness among Persons with a Disability: Insights from a National Policy Intervention. *International Journal of Environmental Research and Public Health* 17, 18 (2020), 6512.

[21] Ruha Benjamin. 2019. *Race After Technology: Abolitionist Tools for the New Jim Code.* Polity Press.

[22] Cynthia L. Bennett, Erin Brady, and Stacy M. Branham. 2018. Interdependence as a Frame for Assistive Technology Research and Design. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility*. ACM, Galway Ireland, 161–173. doi:10.1145/3234695.3236348

[23] Lauren Berlant. 2020. *Cruel optimism.* Duke University Press.

[24] Nicola J Bidwell. 2020. Women and the sustainability of rural community networks in the global south. In *Proceedings of the 2020 International Conference on Information and Communication Technologies and Development*. 1–13.

[25] Susanne Bødker, Christian Dindler, Ole S Iversen, and Rachel C Smith. 2022. What can we learn from the history of participatory design? In *Participatory Design*. Springer, 15–29.

[26] Elizabeth Bonsignore. 2017. *Participatory Design for Learning.* Routledge.

[27] Danah Boyd and Kate Crawford. 2012. Critical questions for big data: Provocations for a cultural, technological, and scholarly phenomenon. *Information, communication & society* 15, 5 (2012), 662–679.

[28] Jade Boyd, David Cunningham, Solanna Anderson, and Thomas Kerr. 2016. Supportive housing and surveillance. *International Journal of Drug Policy* 34 (2016), 72–79.

[29] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[30] Emily Brown. 2016. Overcoming the barriers to micro-housing: Tiny houses, big potential. (2016).

[31] Simone Browne. 2015. *Dark matters: On the surveillance of blackness.* Duke University Press.

[32] Judith Butler. 2004. *Precarious life: The powers of mourning and violence.* verso.

[33] Judith Butler. 2015. *Notes toward a performative theory of assembly.* harvard university Press.

[34] Brian Campbell and Christian Laheij. 2021. Introduction: Urban Precarity. *City & Society* 33, 2 (2021), 283–302.

[35] Anupam Chander and Haochen Sun (Eds.). 2023. *Data Sovereignty: From the Digital Silk Road to the Return of the State* (1 ed.). Oxford University PressNew York. doi:10.1093/oso/9780197582794.001.0001

[36] Department of Construction City of Seattle, Office of Planning Inspections, and Community Development. 2023. Current Land Use Zoning Detail. https://data-seattlecitygis.opendata.arcgis.com/datasets/SeattleCityGIS::current-land-use-zoning-detail/explore.

[37] Gregg Colburn and Clayton Page Aldern. 2022. *Homelessness is a housing problem: How structural factors explain U.S. patterns.* University of California Press.

[38] Johan Colding and Stephan Barthel. 2017. An urban ecology critique on the "Smart City" model. *Journal of Cleaner Production* 164 (2017), 95–101.

[39] Seattle City Council. [n. d.]. Tiny House Villages. https://web.archive.org/web/20250303105042/http://seattle.gov/council/issues/pas issues/tiny-house-villages.

[40] Gabriela A. A. De Oliveira, Otávio De Faria Oliveira, Stenio De Abreu, Raphael W. De Bettio, and André P. Freire. 2022. Opportunities and accessibility challenges for open-source general-purpose home automation mobile applications for visually disabled users. *Multimedia Tools and Applications* 81, 8 (March 2022), 10695–10722. doi:10.1007/s11042-022-12074-0

[41] Tanya de Sousa, Alyssa Andrichik, Ed Prestera, Katherine Rush, Colette Tano, and Micaiah Wheeler. 2023. The 2023 Annual Homelessness Assessment Report (AHAR) to Congress. https://www.huduser.gov/portal/sites/default/files/pdf/2023-AHAR-Part-1.pdf.

[42] Sudhir Dixit, Ashutosh Dutta, Sandeep Agrawal, Marvin Arias Olivas, Vimal Bhatia, Carlos Daniel Altamirano Carrillo, Pranav Jha, Matogoro Jabhera, Amit Karna, Sanjram Premjit Khanganba, et al. 2023. Connecting the unconnected. In *2023 IEEE Future Networks World Forum (FNWF)*. IEEE, 1–88.

[43] Christina Dunbar-Hester. 2008. Geeks, Meta-Geeks, and Gender Trouble: Activism, Identity, and Low-power FM Radio. *Social Studies of Science* 38, 2 (April 2008), 201–232. doi:10.1177/0306312707082954

[44] Anna Durbin, Barry Isaacs, Dane Mauer-Vakil, Jo Connelly, Lorie Steer, Sylvain Roy, and Vicky Stergiopoulos. 2018. Intellectual disability and homelessness: A synthesis of the literature and discussion of how supportive housing can support wellness for people with intellectual disability. *Current Developmental Disorders Reports* 5 (2018), 125–131.

[45] Pardis Emami Naeini, Martin Degeling, Lujo Bauer, Richard Chow, Lorrie Faith Cranor, Mohammad Reza Haghighat, and Heather Patterson. 2018. The influence of friends and experts on privacy decision making in IoT scenarios. *Proceedings of the ACM on human-computer interaction* 2, CSCW (2018), 1–26.

[46] Virginia Eubanks. 2012. *Digital dead end: Fighting for social justice in the information age.* MIT Press.

[47] Virginia Eubanks. 2018. *Automating inequality: How high-tech tools profile, police, and punish the poor.* St. Martin's Press.

[48] Rebecca Finkes. 2019. *City Sanctioned Homeless Encampments: A Case Study Analysis of Seattle's City-Permitted Villages.* Thesis.

[49] Faith Fowler. 2018. *Tiny homes in a big city.* Cass Community Publishing House.

[50] Guadalupe Michelle Franco. 2021. *Wicked Problems: Understanding How Cities and Counties in California are Tackling Climate Change and Homelessness.* Master of Science. San Jose State University, San Jose, CA, USA. doi:10.31979/etd.x5qq-e2cw

[51] Batya Friedman, David G. Hendry, and Alan Borning. 2017. A Survey of Value Sensitive Design Methods. *Foundations and Trends® in Human–Computer Interaction* 11, 2 (2017), 63–125. doi:10.1561/1100000015

[52] James Galvez. 2016. PLDT Calls for Uniformity in Telco Policies. *The Manila Times Online* (Nov. 2016).

[53] Philip Garrison, Esther Han Beol Jang, Michael A Lithgow, and Nicolás Andrés Pace. 2021. " The Network Is an Excuse": Hardware Maintenance Supporting Community. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW2 (2021), 1–20.

[54] Christine Geeng and Franziska Roesner. 2019. Who's in control? Interactions in multi-user smart homes. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–13.

[55] Constance Gordon and Kyle Byron. 2021. Sweeping the City: Infrastructure, Informality, and the Politics of Maintenance. *Cultural Studies* 35, 4-5 (Sept. 2021), 854–875. doi:10.1080/09502386.2021.1895253

[56] Stephen Graham and Nigel Thrift. 2007. Out of order: understanding repair and maintenance. *Theory, Culture & Society* 24, 3 (2007), 1–25.

[57] Florian Güldenpfennig, Peter Mayer, Paul Panek, and Geraldine Fitzpatrick. 2019. An Autonomy-Perspective on the Design of Assistive Technology Experiences of People with Multiple Sclerosis. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow Scotland Uk, 1–14. doi:10.1145/3290605.3300357

[58] Brett A. Halperin and Erin McElroy. 2023. Temporal Tensions in Digital Story Mapping for Housing Justice: Rethinking Time and Technology in Community-Based Design. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*. ACM, Pittsburgh PA USA, 2469–2488. doi:10.1145/3563657.3596088

[59] Kim Halskov and Nicolai Brodersen Hansen. 2015. The diversity of participatory design research practice at PDC 2002–2012. *International Journal of Human-Computer Studies* 74 (2015), 81–92.

[60] Clara Han. 2018. Precarity, precariousness, and vulnerability. *Annual review of Anthropology* 47 (2018), 331–343.

[61] Shaddi Hasan, Mary Claire Barela, Matthew Johnson, Eric Brewer, and Kurtis Heimerl. 2019. Scaling community cellular networks with communitycellularmanager. In *16th {USENIX} Symposium on Networked Systems Design and Implementation ({NSDI} 19)*. 735–750.

[62] Kurtis Heimerl, Kashif Ali, Joshua Evan Blumenstock, Brian Gawalt, and Eric A Brewer. 2013. Expanding Rural Cellular Networks with Virtual Coverage.. In *NSDI*. 283–296.

[63] Sara Heitlinger, Nick Bryan-Kinns, and Rob Comber. 2019. The Right to the Sustainable Smart City. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow Scotland Uk, 1–13. doi:10.1145/3290605.3300517

[64] Christian Iaione, Elena De Nictolis, and Anna Berti Suman. 2019. The Internet of Humans (IoH): Human Rights and Co-Governance to Achieve Tech Justice in the City. *The Law & Ethics of Human Rights* 13, 2 (Nov. 2019), 263–299. doi:10.1515/lehr-2019-2008 Publisher: De Gruyter Section: Law & Ethics of Human Rights.

[65] Low Income Housing Institute. 2019. Tiny House Villages: a Crisis Solution to Homelessness. http://seattle.legistar.com/View.ashx?M=F&ID=7243095&GUID=B59D1097-1683-4761-8717-4061E1C1A36B. Accessed: 2023-01-06.

[66] Steven J Jackson and Sarah Barbrow. 2015. Standards and/as innovation: Protocols, creativity, and interactive systems development in ecology. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 1769–1778.

[67] Steven J Jackson, Paul N Edwards, Geoffrey C Bowker, and Cory P Knobel. 2007. Understanding infrastructure: History, heuristics and cyberinfrastructure policy. *First Monday* 12, 6 (2007).

[68] Saurabh Jain and Dharma P Agrawal. 2003. Wireless community networks. *Computer* 36, 8 (2003), 90–92.

[69] Esther Jang, Mary Claire Barela, Matt Johnson, Philip Martinez, Cedric Festin, Margaret Lynn, Josephine Dionisio, and Kurtis Heimerl. 2018. Crowdsourcing Rural Network Maintenance and Repair via Network Messaging. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–12.

[70] Esther Jang, Philip Garrison, Mary Claire Barela, Ronel Vincent Vistal, Thessa Cunanan, Philip Martinez, Mia Perez, Matthew William Johnson, Andoy Evangelista, Ishtiaque Ahmed, Josephine Dionisio, and Kurtis Heimerl. 2019. Trust and Technology Repair Infrastructures in the Remote Rural Philippines: Navigating Urban-Rural Seams. In *Proceedings of the 22nd ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW) 2019*. ACM.

[71] Esther Han Beol Jang, Philip Garrison, Ronel Vincent Vistal, Maria Theresa D. Cunanan, Maria Theresa Perez, Philip Martinez, Matthew Johnson, John Andrew Evangelista, Syed Ishtiaque Ahmed, Josephine Dionisio, Mary Claire Aguilar Barela, and Kurtis Heimerl. 2019. Trust and Technology Repair Infrastructures in the RemoteRural Philippines: Navigating Urban-Rural Seams. In *Proc. ACM Hum.-Comput. Interact.3*. ACM, Austin. doi:10.1145/3359201

[72] Brian Jordan Jefferson. 2017. Digitize and punish: Computerized crime mapping and racialized carceral power in Chicago. *Environment and Planning D: Society and Space* 35, 5 (2017), 775–796.

[73] Brian Jordan Jefferson. 2018. Policing, data, and power-geometry: intersections of crime analytics and race during urban restructuring. *Urban geography* 39, 8 (2018), 1247–1264.

[74] Tom Jenkins. 2018. Cohousing IoT: Design Prototyping for Community Life. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, Stockholm Sweden, 667–673. doi:10.1145/3173225.3173244

[75] Matthew William Johnson, Esther Han Beol Jang, Frankie O'Rourke, Rachel Ye, and Kurtis Heimerl. 2021. Network Capacity as Common Pool Resource: Community-Based Congestion Management in a Community Network. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW1 (2021), 1–25.

[76] Helena Karasti. 2014. Infrastructuring in participatory design. In *Proceedings of the 13th Participatory Design Conference on Research Papers - PDC '14*. ACM Press, Windhoek, Namibia, 141–150. doi:10.1145/2661435.2661450

[77] Elizabeth Kaziunas, Michael S. Klinkman, and Mark S. Ackerman. 2019. Precarious Interventions: Designing for Ecologies of Care. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (Nov. 2019), 113:1–113:27. doi:10.1145/3359215

[78] Patrick Gage Kelley, Joanna Bresee, Lorrie Faith Cranor, and Robert W. Reeder. 2009. A "nutrition label" for privacy. In *Proceedings of the 5th Symposium on Usable Privacy and Security*. ACM, Mountain View California USA, 1–12. doi:10.1145/1572532.1572538

[79] Patrick Gage Kelley, Lucian Cesca, Joanna Bresee, and Lorrie Faith Cranor. 2010. Standardizing privacy notices: an online study of the nutrition label approach. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Atlanta Georgia USA, 1573–1582. doi:10.1145/1753326.1753561

[80] Rob Kitchin. 2015. Spatial big data and the era of continuous geosurveillance. *DIS Magazine* (2015).

[81] Rob Kitchin, Tracey P Lauriault, and Gavin McArdle. 2017. Indicators, benchmarking and urban informatics. (2017).

[82] Karen D Könings, Tina Seidel, and Jeroen JG van Merriënboer. 2014. Participatory design of learning environments: integrating perspectives of students, teachers, and designers. *Instructional Science* 42 (2014), 1–9.

[83] Sandjar Kozubaev, Fernando Rochaix, Carl DiSalvo, and Christopher A. Le Dantec. 2019. Spaces and Traces: Implications of Smart Technology in Public Housing. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow Scotland Uk, 1–13. doi:10.1145/3290605.3300669

[84] Local Connectivity Lab. 2021. Seattle Community Network. https://seattlecommunitynetwork.org/. Accessed: 2023-01-14.

[85] Sian Lazar and Andrew Sanchez. 2019. Understanding labour politics in an age of precarity. *Dialectical Anthropology* 43 (2019), 3–14.

[86] Christopher A. Le Dantec, Robert G. Farrell, Jim E. Christensen, Mark Bailey, Jason B. Ellis, Wendy A. Kellogg, and W. Keith Edwards. 2011. Publics in practice: ubiquitous computing at a shelter for homeless mothers. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Vancouver BC Canada, 1687–1696. doi:10.1145/1978942.1979189

[87] Barrett A. Lee, Kimberly A. Tyler, and James D. Wright. 2010. The New Homelessness Revisited. *Annual Review of Sociology* 36, 1 (June 2010), 501–521. doi:10.1146/annurev-soc-070308-115940

[88] Barbara Leporini and Marina Buzzi. 2018. Home Automation for an Independent Living: Investigating the Needs of Visually Impaired People. In *Proceedings of the 15th International Web for All Conference*. ACM, Lyon France, 1–9. doi:10.1145/3192714.3192823

[89] John Travis Marshall and Jessica Venegas. 2015. The Smart Cities Movement and Advancing the International Battle to Eliminate Homelessness - Barcelona as Test Case. (2015).

[90] Nathan W Moon, Paul Ma Baker, and Kenneth Goughnour. 2019. Designing wearable technologies for users with disabilities: Accessibility, usability, and connectivity factors. *Journal of Rehabilitation and Assistive Technologies Engineering* 6 (Jan. 2019), 205566831986213. doi:10.1177/2055668319862137

[91] Michael J Muller and Allison Druin. 2012. Participatory design: The third space in human–computer interaction. In *Human Computer Interaction Handbook*. CRC Press, 1125–1153.

[92] Kim-Khoa Nguyen and Mohamed Cheriet. 2016. Virtual Edge-Based Smart Community Network Management. *IEEE Internet Computing* 20, 6 (2016), 32–41. doi:10.1109/MIC.2016.127

[93] Nickelsville. [n. d.]. https://www.nickelsville.org/ Accessed: 2023-01-14.

[94] Safiya Umoja Noble. 2018. *Algorithms of oppression: How search engines reinforce racism*. NYU Press.

[95] Roger M. Nooe and David A. Patterson. 2010. The Ecology of Homelessness. *Journal of Human Behavior in the Social Environment* 20, 2 (March 2010), 105–152. doi:10.1080/10911350903269757

[96] Leif Oppermann, Alexander Boden, Britta Hofmann, Wolfgang Prinz, and Stefan Decker. 2019. Beyond HCI and CSCW: Challenges and useful practices towards a human-centred vision of AI and IA. In *Proceedings of the Halfway to the Future Symposium 2019*. 1–5.

[97] Jade N. Orr, Jeremy Németh, Alessandro Rigolon, Laura Santos Granja, and Dani Slabaugh. 2023. Beyond Revanchism? Learning from Sanctioned Homeless Encampments in the U.S. *Urban Geography* 0, 0 (April 2023), 1–27. doi:10.1080/02723638.2023.2196141

[98] C.E. Oude Weernink, L. Sweegers, L. Relou, T.J. Van Der Zijpp, and J. Van Hoof. 2018. Lost and misplaced items and assistive devices in nursing homes: Identifying problems and technological opportunities through participatory design research. *Technology and Disability* 29, 3 (Feb. 2018), 129–140. doi:10.3233/TAD-170179

[99] Chris Philo, Hester Parr, and Ola Söderström. 2019. 'On edge?': Studies in precarious urbanisms. *Geoforum* 101 (2019), 150–155.

[100] François Portet, Michel Vacher, Caroline Golanski, Camille Roux, and Brigitte Meillon. 2013. Design and evaluation of a smart home voice interface for the elderly: acceptability and objection aspects. *Personal and Ubiquitous Computing* 17, 1 (Jan. 2013), 127–144. doi:10.1007/s00779-011-0470-5

[101] Stephanie Carroll Rainie, Jennifer Lee Schultz, Eileen Briggs, Patricia Riggs, and Nancy Lynn Palmanteer-Holder. 2017. Data as a Strategic Resource: Self-determination, Governance, and the Data Challenge for Indigenous Nations in the United States. *International Indigenous Policy Journal* 8, 2 (March 2017). doi:10.18584/iipj.2017.8.2.1

[102] Zulqarnain Rashid, Joan Melià-Seguí, Rafael Pous, and Enric Peig. 2017. Using Augmented Reality and Internet of Things to improve accessibility of people with motor disabilities in the context of Smart Cities. *Future Generation Computer Systems* 76 (Nov. 2017), 248–261. doi:10.1016/j.future.2016.11.030

[103] Share/Wheel. 2023. https://www.sharewheel.org/tent-city-3 Accessed: 2023-01-15.

[104] Heather Shearer and Paul Burton. 2019. Towards a typology of tiny houses. *Housing, Theory and Society* 36, 3 (2019), 298–318.

[105] Heather Shearer and Paul Burton. 2023. Tiny houses: movement or moment? *Housing Studies* 38, 3 (2023), 360–382.

[106] Dilruba Showkat, Angela D. R. Smith, Wang Lingqing, and Alexandra To. 2023. "Who is the right homeless client?": Values in Algorithmic Homelessness Service Provision and Machine Learning Research. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 394, 21 pages. doi:10.1145/3544548.3581010

[107] John Song, Dianne M Bartels, Edward R Ratner, Lucy Alderton, Brenda Hudson, and Jasjit S Ahluwalia. 2007. Dying on the streets: homeless persons' concerns and desires about end of life care. *Journal of general internal medicine* 22 (2007), 435–441.

[108] M Sreeram and M Sreeja. 2017. A novel architecture for IoT and smart community. In *2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC)*. IEEE, 486–491.

[109] Fiona Ssozi-Mugarura, Edwin Blake, and Ulrike Rivett. 2017. Codesigning with communities to support rural water management in Uganda. *CoDesign* 13, 2 (2017), 110–126.

[110] Susan Leigh Star. 1999. The ethnography of infrastructure. *American behavioral scientist* 43, 3 (1999), 377–391.

[111] Forrest Stuart. 2015. On the Streets, Under Arrest: Policing Homelessness in the 21st Century. *Sociology Compass* 9, 11 (Nov. 2015), 940–950. doi:10.1111/soc4.12324

[112] Sonesh Surana, Rabin Patra, Sergiu Nedevschi, Manuel Ramos, Lakshminarayanan Subramanian, Yahel Ben-David, and Eric Brewer. 2008. Beyond Pilots: Keeping Rural Wireless Networks Alive. In *Proceedings of the 5th USENIX Symposium on Networked Systems Design and Implementation* (San Francisco, California) *(NSDI'08)*. USENIX Association, Berkeley, CA, USA, 119–132. http://dl.acm.org/citation.cfm?id=1387589.1387598

[113] Ningjing Tang, Jiayin Zhi, Tzu-Sheng Kuo, Calla Kainaroi, Jeremy J. Northup, Kenneth Holstein, Haiyi Zhu, Hoda Heidari, and Hong Shen. 2024. AI Failure Cards: Understanding and Supporting Grassroots Efforts to Mitigate AI Failures in Homeless Services. In *Proceedings of the 2024 ACM Conference on Fairness, Accountability, and Transparency* (Rio de Janeiro, Brazil) *(FAccT '24)*. Association for Computing Machinery, New York, NY, USA, 713–732. doi:10.1145/3630106.3658935

[114] Richard Tucker, Ursula De Jong, LC Johnson, Nicole Johnston, Adrian Lee, Fab Michaux, Elyse Warner, and FJ Andrews. 2024. Microvillage: assessing the viability of increasing supply of affordable, sustainable and socially integrated small homes. *Housing Studies* 39, 1 (2024), 52–74.

[115] Ciara Turner. 2016. It takes a village: Designating tiny house villages as transitional housing campgrounds. *U. Mich. JL Reform* 50 (2016), 931.

[116] Cedric Deslandes Whitney, Teresa Naval, Elizabeth Quepons, Simrandeep Singh, Steven R Rick, and Lilly Irani. 2021. HCI Tactics for Politics from Below: Meeting the Challenges of Smart Cities. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–15. doi:10.1145/3411764.3445314

[117] Jennifer H Wilson. 2021. *Operationalizing a new method for defining and scaling social innovations using tiny home communities as a case study*. Ph. D. Dissertation. University of Denver.

[118] Langdon Winner. 2017. *Do artifacts have politics?* Routledge.

[119] Heike Winschiers-Theophilus, Shilumbe Chivuno-Kuria, Gereon Koch Kapuire, Nicola J. Bidwell, and Edwin Blake. 2010. Being participated: a community approach. In *Proceedings of the 11th Biennial Participatory Design Conference*. ACM, 1–10. http://dl.acm.org/citation.cfm?id=1900443

[120] Serena Zheng, Noah Apthorpe, Marshini Chetty, and Nick Feamster. 2018. User perceptions of smart home IoT privacy. *Proceedings of the ACM on human-computer interaction* 2, CSCW (2018), 1–20.

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