Trust and Technology Repair Infrastructures in the Remote Rural Philippines: Navigating Urban-Rural Seams

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This paper analyzes the processes and challenges of technology repair in remote, low-income areas far from standard ICT repair infrastructure. Our sites of study are the fishing and farming villages of Dibut, Diotorin, and Dikapinisan in Aurora Province, Philippines, located in coastal coves against a mountain range. Residents are geographically isolated from urban areas, with the nearest peri-urban center of Baler a boat trip of several hours away, infeasible in some sea conditions. Unlike prior work in more connected rural areas, there are no local repair shops and device repair is uncommon, despite frequent breakage due to harsh conditions for electronics. The scarcity of local electronics repair limits technology access and leads to accumulation of e-waste. While prior work demonstrates that local electronics repair capability does arise in many rural areas around the world, we must also acknowledge that the successful emergence of this infrastructure depends on the intersection of many structural conditions and cannot be taken for granted.

We present the material hardships of achieving local repair in terms of seams between heterogeneous urban and rural infrastructures, which illustrate the cove communities' marginality with respect to many forms of public infrastructure. However, intermittent and informal repair infrastructures based on trust relationships emerge to patch these seams in remote settings. We show how trust affects the way people dynamically construct repair infrastructure and why, based on their remoteness and the resulting value propositions of repair. Networks of trust between repairers, their clients, suppliers, fellow repairers, and certifying or

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training institutions crucially facilitate the movement of resources and expertise across the Philippines, but also reinforce the marginality of residents and repairers in the coves. Despite these structural challenges, local people are able to maintain a robust ecosystem for rural electrical line repair, from which we generalize the model of *training grounds* as a strategy for sustaining local communities of repair experts.

CCS Concepts: • **Networks → Network manageability**; *Wireless access points, base stations and infrastructure*; • **Computer systems organization → Maintainability and maintenance**.

Additional Key Words and Phrases: Repair; Rural Development; Technology for Development; ICTD

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1 INTRODUCTION

Information technologies, especially mobile phones and associated networks, underlie much of the critical social infrastructure that billions of people rely upon every day. These devices are used daily for purposes such as health [33], education [31], and finance [6]. With their increasing importance and abundance comes growing pressure to address their maintenance, repair, and disposal.

Prior work has shown that these devices are often supported by a robust ecosystem of professionals specifically trained in the effective repair and maintenance of aging IT infrastructure. People learn for years how to handle common failures (such as broken screens), navigate software locks, and distribute media [44], enabling increased longevity and reduced waste. To date, studies have largely focused on urban areas (such as the capital city of Bangladesh [24]). Those that focus elsewhere, such as densely populated rural environments (e.g., the capital of a rural area in Namibia [29]), still see readily available parted-out devices, digital junkyards, and certified or trained personnel. Thus, these areas already fall within the ambit of the broader urban-centered infrastructure of repair.

The coastal communities of Aurora, Philippines represent geographically isolated areas more loosely connected to this kind of infrastructure. They are reachable from the nearest town center with repair shops by a several-hour boat ride, but they are cut off periodically during typhoon season each year as the seas are often too rough to travel. Even when seas are calm, basic services such as health care and remittance centers are too far away for quick access. Such communities face particularly challenging circumstances in terms of technology use and repair.

Through this paper we seek to de-center the discourse on rural ICT repair in HCI away from repair shops, even those in rural areas, to include communities lacking this sociotechnical infrastructure. These communities, many of which are located in extremely remote rural areas throughout the world, conduct and interact with repair in different, underexplored ways. Making technology more accessible to these populations requires a more inclusive understanding of repair infrastructure informed by the experiences of these remote places. It is instructive to learn how technology use and repair happens in these communities through their own efforts to transcend the limitations of their geographical isolation, as well as their more general exclusion or marginality with respect to other public infrastructure such as education and commerce. We interpret these combined efforts as an attempt to insist on inclusion in a technology-driven world, to provide what the system denies, and to subvert the imposed construction of their places as remote. Further, we advocate for electronics repair infrastructure that is more accessible to these remote communities, and open the discussion on how to encourage or facilitate it.

To this end, we investigate the ecosystem of technological devices and infrastructure and the networks by which they flow between urban and remote rural areas, as well as their passage between life stages—new, old, functional, broken, repaired, re-purposed or discarded. We take a systems [9] view of repair in these coastal areas to understand how people, infrastructure, and equipment interact; systems theory addresses the *whole* social-material network and prompts us to look for interrelationships and distant connections that shape how repair does and does not happen. Through this lens we characterize the systems of repair in the Philippines as a geographically distributed and seamful patchwork [50] of overlapping and sometimes disconnected local heterogeneous infrastructures, where the locations of seams are both created by and perpetuate context-dependent challenges. We use the language of seams rather than gaps or barriers to emphasize that local people do dynamically construct their own infrastructures to overcome these challenges, as similarly described in Jack & Jackson's work on logistical infrastructures [22]. This perspective also helps us to reveal trust, both interpersonal and system-trust [36], as critical to the activity of repair and a factor in the dynamic creation of the repair ecosystem.

We find that such challenges often tip the balance towards replacement as the more practical option over repair, even in rural Aurora where travel is difficult, and typhoons and low quality power pose consistent threats to electronics' continued function. For example, the intersection of low economic resources and the difficulty and intermittency of sea travel reveals seams between urban and rural repair infrastructures that can be fragile. Specific tools, parts, and knowledge for electronics repair are rarer in these rural areas, so device owners must bear monetary and time costs for sea and sometimes cross-country transport as well as parts and labor, along with the inherent risks of attempting repair. These costs often outweigh that of cheaply made new items, which will again break quickly and perpetuate the cycle.

As a result, repair ecosystems which are robust and functional in the capital city of Manila and the "peri-urban" provincial capital of Baler largely exclude the broken devices present in the coves. This limits technology access and sustainability, and perpetuates digital divides both between rural and urban areas and wealthy and poor users. It also results in large amounts of stagnant e-waste, often from discarded TVs and other large, frequently replaced devices.

Despite the challenges, communities succeed in patching together a repair infrastructure that meets some of their needs. We find a robust repair system for government-supported rural power infrastructure, maintained by knowledgeable local repairers who can overcome difficulties due to weather and remoteness. Leveraging Leigh Star's idea that sociotechnical infrastructure reveals itself upon breakdown and failure [46], we investigate what infrastructure is really required to make repair happen in these challenging environments.

This research contributes a description and analysis of how: (1) repair occurs in these remote, isolated communities, (2) remoteness shapes and creates a trust-based social infrastructure that can implement repair, and (3) HCI and CSCW can reenvision sustainable design and local empowerment to help mitigate the e-waste generated by the technology life-cycle in remote areas.

2 RELATED WORK

2.1 HCI and Repair

HCI has a central interest in design and use of technologies that has often sidelined our experiences with their after-use moments: obsolescence, malfunctioning, repair, recycle, etc. However, a growing body of work in HCI and related fields has begun to shed light on those moments [38, 47]. These seminal works point to the imperfection, instability, fallibility, and biases in technology, and call for human art, knowledge, craft, innovation, and collaboration to fix them.

In recent years, a series of ethnographic work on repair has been conducted in different parts of the world that builds on that theoretical framing. For example, Jackson et al. studied electronic repair practices in rural Namibia and showed how those efforts are connected with an international network of knowledge and materials [28, 29]. Jackson further developed the idea of a "broken world" that needs to be addressed with care [23]. Ahmed et al. studied mobile phone repair work in Dhaka, Bangladesh, and documented the art, craft, knowledge, and skills involved in their work [2]. Other studies in varied global contexts [1, 19, 20, 24, 27, 41, 51] discussed how repair work involves many human qualities that are often undervalued in a larger context of globalization, capitalism, and free economy. Repair is also found to be a viable business in the bustling underground markets of Bangladesh [1] and the semi-formalized "tech-shops" of Namibia [29].

2.2 Urban vs. Remote Rural Repair

While these prior studies have illuminated many aspects of repair practices, they have largely focused on visible core elements of functional repair infrastructure, such repair shops or professionals. We instead focus explicitly on areas lacking these infrastructures, seeking to build a more inclusive understanding of repair that renders visible the context-specific challenges and solutions of people in extremely remote, low-income communities.

As a consequence of their focus on functioning repair ecosystems, prior studies on rural electronics repair have largely focused on more connected areas, for example areas being reachable by road and/or larger in population. As such, their observations of repair infrastructure are very different from ours. In Wyche's work with mobile phone repairers in rural Kenya [51], most rural interviews took place in agricultural market centers such as Chwele (60,000 residents) and Webuye (22,507). These settings more closely resemble our "peri-urban" provincial capital, Baler (39,000), than our cove sites (500 to 2,000 residents). Similarly, Jackson's work on phone repair in rural Namibia [29] mainly focuses on Rundu (63,000 residents), the regional capital. While the study includes the smaller villages of Divundu (5,430) and Nkurenkuru (618), each is about a two-hour drive from Rundu on a well-established national highway.

Meanwhile, prior work on appropriate technology in rural low-resource communities such as de Laet and Mol's Zimbabwe Bush Pump paper [11] has emphasized the importance of local engagement and management structures for the continued function of rural infrastructure. Work on NGO logistical infrastructures [22] and seamful spaces in infrastructure [50] have also highlighted the necessity of local actors' efforts in maintaining and aligning multiple heterogeneous infrastructures to achieve their goals.

In our cove communities, we seek to understand the role of local actors and infrastructure in repair. In contrast to less remote settings, there are no local repair shops, for electronics or otherwise. Repair happens by, for example, walking over to *kuya's*[1] house and asking whether he's available to help before he heads out to the fields. This informal social context for repair stands in stark contrast to the professional, highly visible, busy, and/or salaried repairers' work in the aforementioned studies. When such professionalism, expertise, and business profits are stripped from repair work, the tensions surrounding it radically change. This paper contributes to the body of work on repair by focusing on places where repair is irregular or informal and expanding on the social arrangements in which it happens. We contribute findings on (1) occasional and irregular repairers, and (2) tinkerers who have informal relationships with businesses and governments.

[1] *Kuya* is a Filipino term of respect for a man, akin to an older brother.

2.3 Trust

We draw on Luhmann's formalization of trust [36] to inform our analysis of the integral roles and forms of trust involved in repair work, especially in remote areas. Luhmann proposes that people build social systems in order to manage complexity within an environment where uncertainty about the states of people and objects (such as how well a device is functioning) increase over time, and frames trust as a mechanism for reducing that complexity. Citing psychological theory, he says trust can increase tolerance of uncertainty—for example, the uncertainty that a given repair attempt by a particular repairer will succeed. Our analysis explores a number of forms of trust: trust in a device to continue to function, trust in the expertise and good faith of a repairer, and trust in acquaintances or kin based on interpersonal relationships. The former two we associate more closely with Luhmann's category of system-trust, or trust in a system (such as the process of formal certification in repair), while the latter can be seen as interpersonal trust. He also describes the ability of trust to be "object-mediated"—for example, in our setting of repair, through a contract or warranty certifying the trustworthiness of a replacement part.

2.4 Disposal and Reclamation

Concurrent to the repair discussion is an investigation of the disposal of computer equipment, especially common user-facing devices such as mobile phones and desktop computers, and the flows of this e-waste. Discarded devices are sent to recycling centers, landfills, and refuse areas near consumers [49]. In wealthy countries, rather than bury this damaged hardware, waste companies ship it to poor countries for recycling [16]. This supply of e-waste can lead to negative outcomes, such as poor health for reclaimers, but these landfills do provide a source of raw materials and a mechanism for training and learning new skills. As Jenna Burrell notes [8], youth working in the "computer import industry" in Ghana repurpose discarded computing equipment into computers for the local market as well as recycled raw metals. Lepawsky et al. went in search of e-waste in Bangladesh and instead noted that, "Amidst all this stuff we could hardly find any waste. Almost everything had value. Every object. Every component. Every material" [35].

In contrast, we find that cove residents have some limited opportunities for scrapping and recycling e-waste. However, many damaged devices are left to sit in houses and sheds with no plans for movement as it is too expensive to ship back to urban reclamation centers. Pollution of local water and soil [15] and economic waste in the constant replacement of devices follow.

2.5 Infrastructure

We use the concept of infrastructure to frame our discussion of repair and maintenance. Susan Leigh Star [45] conceives of infrastructure as embedded within social structures and notes that, when successfully maintained, technical infrastructure achieves a degree of invisibility. As Graham and Thrift [14] point out, the social dependencies of infrastructure are made visible by crashes and failures, when people must be mobilized to restore service. We see the social structures and material factors needed for maintenance and repair as themselves infrastructure, especially in disaster-prone environments where breakdowns are frequent.

Jackson and colleagues argue that standards for infrastructure represent embedded politics, and are set with assumptions that are hard to comply with for people of differing privileges [25, 26]. Many examples show how large technical infrastructures require literacy, money, expertise, legal status, and certain physical and psychological abilities to meet those standards. Lacking these characteristics, many people become detached from infrastructure-provided services and experience "residuality." This is often depicted in the struggles of refugees [42], or in the uncertainty that characterizes the lives of people living in isolated areas like the Aurora coves. The difficulties

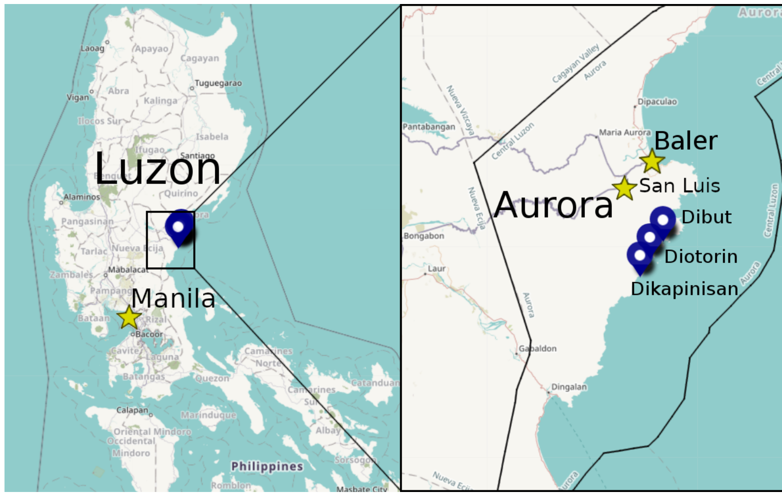

Fig. 1. The three cove sites of this study, Dibut, Diotorin, and Dikapinisan, are on the east coast of Luzon island, and the nearest large town is Baler.

of acquiring, using, and maintaining personal devices, which are also designed, produced, and embedded within a system of internationally and politically defined standards, echo those of operating infrastructure.

Thus, large infrastructure embodies and extends power, and how people repair breakdowns in infrastructure can reflect these politics. For example, Surana et al. [48] found that failures of telecommunications infrastructure were often correlated with associated infrastructure, such as power. His team advocated for keeping laypeople away from equipment and building multiple layers of fault tolerance. This is supported by a local Philippine telecom, PLDT, who asserts that up to eighty percent of service interruptions are caused by third-party action [13].

In contrast, a recent body of work shows how non-professionals can bring their creativity, innovation, and skills to maintain, fix, and extend infrastructure. For example, Ahmed et al. [3] have shown how evicted slum dwellers used their skills, innovation, and collaboration to make necessary extensions to existing infrastructure. Similarly, Jang et al. found that laypeople in another rural Philippine context had some of the skills necessary for repair of local telecommunications infrastructure [30]. Our paper builds on this work on infrastructure, repair, and the involvement of marginalized communities and compares the largely functional practices in electrical infrastructure repair with a largely inadequate device repair ecosystem. We imagine new initiatives that could create more resilient technologies and communities.

3 CONTEXT

Our sites of study are the cove communities of Dibut, Diotorin, and Dikapinisan, located on the northeastern coast of Luzon island in the San Luis municipality of Aurora Province (see Figure 1). The coves face the Pacific Ocean and are isolated from the nearby peri-urban center of Baler by the Sierra Madre mountain range.

3.1 Provincial Centers

Baler and the nearby San Luis town center are provincial centers where local government and other regional administrative offices are located. Baler has businesses serving the Aurora province—such as banks, retail shops, and other service centers—and a robust local tourism industry. Both towns have paved roads, grid power, running water, and 4G cellular service. Electricity is provided throughout the province by the public cooperative Aurora Electric Cooperative (AURELCO). However, electrical outages ("brownouts") are frequently experienced throughout the province. In our experience, land travel from the Philippine capital of Manila to Baler takes 6-8 hours.

3.2 Cove Communities

From Baler, boat travel to the coves can take 1-3 hours, with this time doubling during monsoon season. The only alternative is a full-day's walk over unpaved, thickly forested, and mountainous terrain. Due to their location, the cove sites frequently experience storms, strong winds, and typhoons, especially during September through December. These sites are also not reached by terrestrial television and radio broadcasts, and are unserved by national telecommunications companies. They are served electricity by AURELCO, but service is considered unreliable; the relatively affluent have on their own solar panels or generator sets. Water is sourced through pumps, wells or from streams where a DIY pipe network carries it to individual homes.

Dikapinisan is the largest and most prosperous of the three communities (population around 2,000) and the only one with both an elementary and high school. Dibut is the second largest around 900 residents, nearly all members by blood or marriage of the Dumagat indigenous tribe of northern Luzon. Diotorin is the smallest (around 400 residents). Dibut and Diotorin have an elementary school, but must send their children to board in Baler or Dikapinisan to continue school.

From a baseline survey conducted in November 2016, 50% of households are below the $2.00 poverty line and 90% are below the $5.00 purchasing power parity poverty line. Most people earn their income through subsistence farming and fishing, where harvested produce is often sold at big markets in Baler. In exchange, cove residents rely on Baler for consumer items such as canned goods, toiletries, and other household items to be resold in the coves.

3.3 Collaborative Community Profiles

The research team has been engaged continuously with these communities for the past few years in collaboration with an ongoing technology access project called the VBTS Project [4]. As part of our engagement in the coves, we held discussions in each site to learn about the place, people, and their shared history and to produce a collaborative text to better include the communities in their own representation. We produced the full text of the area profiles (see paper addendum) from the transcripts of those discussions, filtered through our own perspective as observers and researchers. As a sample, these excerpts from Dibut's profile detail some important local features, culture, and issues that also came up frequently during our interviews on repair, though they are not directly related to repair:

We have two leaderships, tribe and barangay [2]*, but they still have proper communication and solidarity with each other.*

We sell [banana and coconut] outside, but we cannot complain to [the produce traders] because the price and profit is set beforehand. This had been the cause of our problems and is why the farmers are on the losing side. Now, our product prices are quite low, but we are still grateful that we have something to cook.

We have a clean environment, which is one of our important characteristics. We have a rich forest, because most of our areas here are still virgin forests with large trunks. Barangay Dibut is proud to firmly stand for the trees, despite whatever calamity we face, because these are God's treasures.

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[2] Dibut and Dikapinisan are *barangays*, roughly translated as "villages" or "wards", while Diotorin is a smaller *sitio*, or locality, within the larger barangay of Dibayabay.

The reason why we do not get jobs is because of the lack of education. A percentage of [the children] need to graduate to be able to work with machines. But we cannot finish school because of the lack of income.

4 METHODOLOGY

4.1 Interpretive Framework

The ontological framing we use in this study is of the people, material resources, practices, and the networks of relationships between them that interact to implement repair as a sociotechnical system, and as infrastructure. We examine this infrastructure not as an external entity that imposes and controls actors' decisions and practices, but rather as constructed dynamically by people's activities around repair, which in turn set up patterns that guide further actions. There is not one monolithic "repair system" but many, which overlap and abut each other. Moreover, these repair systems are constantly being re-created, while what we present in this paper is merely a snapshot, which may make some fleeting associations appear solid.

4.2 Sampling Rationale

4.2.1 Sites. Our engagement with these communities began as a collaboration with the existing Village Basestation (VBTS) Project by Barela, et. al. [4]. VBTS is focused on deploying community-managed cellular network infrastructure in seven sites in rural Aurora. The VBTS Project prompted our discussions around repair, providing a motivation to study and mobilize or improve existing local repair infrastructure to support the sustainability of VBTS. For our IRB-approved study, we chose three coastal sites of the seven which we expected to have the greatest needs in terms of repair infrastructure as they are the most isolated (detailed in Section 3). We conducted observations and interviews in these sites and also in Baler, when it became clear as a central location repeatedly referenced by local repair actors.

4.2.2 People. Our primary goal was to discover the existing local repair infrastructure in the coves by meeting and interviewing people who do technology repair for cove residents about their practices. We started by interviewing key informants with various leadership roles in each cove community about their repair practices as users of technology, regardless of whether they considered themselves repairers. The VBTS Project's prior experience and engagement with these small communities was that local leaders would know almost every resident; these leaders included, for example, the Barangay Captain [3], the school principal, teachers, pastors, the Dumagat Chieftain, and local technical maintenance officers for VBTS. Based on the precedents and engagement patterns set by our partners, and seeking not to disturb these relationships to their detriment, we used the same working relationships to seed our recruitment process. We also interviewed others who seemed eager to talk with us whenever possible to increase sample diversity.

From there, we used snowball sampling by asking participants who they knew with technical skills, or who they would go to for help with repairing broken devices. We followed these referrals when possible, including to Baler. An underlying assumption was that local residents would know each other well enough that asking around would reveal those with technical expertise, although we understand that this assumption could have caused us to miss repair practices as a private hobby, for example among homemakers without named employment. We also assumed that technical or repair people within a given locale would be more likely to know of each other based on similar domain knowledge, context, and activities, again biasing our findings towards those with publicly visible technical jobs who are typically men in these contexts. We realize additionally that elected

[3] head of the local government

officers may have been biased by political alliances in their referrals, though we expected the combination of other seed interviewees to balance this potential bias. As the communities are small and we reached saturation for referrals, we believe we found the members of the cove communities who practiced repair on behalf of others in a publicly visible fashion.

4.3 Data Collection

We conducted 24 semi-structured interviews with 32 people in the three cove sites and 6 interviews with 8 people in Baler over a period of six weeks starting in May 2018. The interviews in Baler were all with repairers (1 woman and 7 men) and took place in repair shops in their normal work setting. Those in the coves took place in the entryways or receiving areas of interviewees' homes, and our sample included both repairers and non-repairers (8 women and 24 men). We also include notes from field observations of the VBTS project sites between January and August 2018. All names used in this paper are pseudonyms.

The semi-structured interviews included questions about electronic devices or appliances owned, stories of broken or repaired items, own repair expertise, other repairers inside and outside the community, technical education or work if relevant, and sources of parts and tools. If participants had no experiences with device repair to draw upon, we asked about repair of other technologies, especially those involving electricity. Questions were added and modified as the study progressed based on emerging themes in our data as in grounded theory, which were identified through memoing and post-interview debriefs.

Four researchers from a Filipino research university and three researchers from a US-based institution performed data collection. All interviews were conducted in Filipino by one or more Filipino researchers, except for one interview in Baler that was conducted in English at the participant's insistence. All interviews were audio recorded and were transcribed and translated to English by native Filipino speakers. Interviews were augmented with notes taken during collection.

The Filipino researchers are local to the Philippines and knowledgeable about regional cultural context but not local to Aurora. The US authors are neither from the Philippines nor fluent in Filipino, and they relied on the Filipino authors for linguistic and cultural understanding through all stages of the research.

4.4 Data Analysis

Data analysis began with post-interview debriefs among the research team. After the last interview, we coded the interview transcripts using a combination of open codes (e.g., "Disposal/Waste", "Desire for Cell Phone Repair") and initial research questions as codes (e.g., "What breaks and how often?"). Coding was conducted primarily by US authors with only basic Filipino comprehension, mostly on the English translations. Coded data was synthesized from the perspectives articulated in the Interpretive Framework. Our first theme, remoteness, was identified as central to an initial research question, "What are the challenges to repair in the coves?" Our second theme, trust, was identified as central to another research question: "How does repair happen in the coves?".

5 A CHALLENGING REPAIR ECOSYSTEM

We now describe the repair ecosystem in the coves: the devices present, how they break down based on the particular challenges of the environment and context, and how repairers and device owners make repairs in the remote coves and in Baler.

5.1 Relating Remoteness and Technological Marginality

To repair a device, four material ingredients must be brought together: a damaged device, any needed spare parts, a person with repair skills and knowledge, and tools for doing the repair. In the coves we find an emergent repair infrastructure built atop existing material and human flows arising from informal social networks and interpersonal relationships. However, we also observe processes by which devices readily drop out of these flows to become waste.

In the following sections we describe the environmental and contextual challenges that contribute to the cove communities' effective marginality and exclusion from a technological "center." We identify the following major challenges to technology function in these communities: (1) limited overall access to devices, (2) harsh environmental conditions for electronics, and (3) limited information flows. Further, we discuss the consequences for repair of these challenges and their intersection with geographical disconnectedness and broader infrastructural (including technological) marginality.

5.1.1 Limited Device Ecosystem. A limited device ecosystem in the coves results in low availability of technology and experience with technology for end users, as well as low availability of parts for repairers upon breakdown.

The three sites follow similar patterns of household device ownership; most households own at least one basic cell phone, an electric fan, and a television usually paired with a satellite TV receiver and dish. However, the TVs are often very low quality and of widely different models without interchangeable parts, as one Dibut repairer noted. Households typically do not keep computers, though high school or college students staying in Baler may own and use them there. Boat owners may have a solar panel and battery on their boats for lighting at night, and a few wealthier families have a solar set at home for lighting during the frequent grid outages.

School teachers often have personal laptops, and a few laptops and desktop computers can typically be found at the local elementary or high school. However, most school teachers neither reside in nor have family in the coves, and return home via Baler once per week when possible. At the time of field work, school computer labs in all three barangays were in states of long-term disrepair, with only a few usable units and typically not enough to support classroom activities.

5.1.2 Environmental Challenges to Electronics. Many specific environmental challenges shorten the lifespan of electronics in these communities and increase the need for repair or replacement.

First, the infamous "sea breeze," or *umido* (also translated as "humidity"), describes the tendency for coastal air containing moisture and high salt to corrode exposed metals, leaving a hardened layer of white crystals that cannot be removed. Both repair technicians and laypeople, particularly in the education sector, talked about the harms of the sea breeze to both electrical infrastructure and devices. The Diotorin Elementary principal described a stopgap measure to protect the school computers from the moist air by wrapping them in clothing before leaving school.

Frequent severe storms, also called "calamities," were reported to lead to TV damage, possibly due to power surges or water entry leading to shorts and corrosion. Many houses in the coves, designed for a tropical climate, maximize airflow by having open walls or windows with wooden bars instead of glass, potentially exacerbating water entry. Both mechanisms can result in serious damage to electronics. During field work, the researchers came to expect one or more power outages per week. Furthermore, the outages limit the usage of devices that consume electricity, especially those without batteries such as desktop computers.

5.1.3 Stalled Information Flows. The software update and security exploit ecosystems as they exist today force us to think of some computing devices as perpetually in need of repair in the form of updates and patches, to protect against new and opportunistic ways for the device to be broken.

Among the few computers present in the communities, we were told of many software-related issues due to an update ecosystem that assumes stable Internet connectivity. Dikapinisan Elementary's six computers were unusable at the time of field work because the antivirus was not up-to-date: *"that's why it hangs but isn't broken."* Due to the lack of Internet access in Dikapinisan,

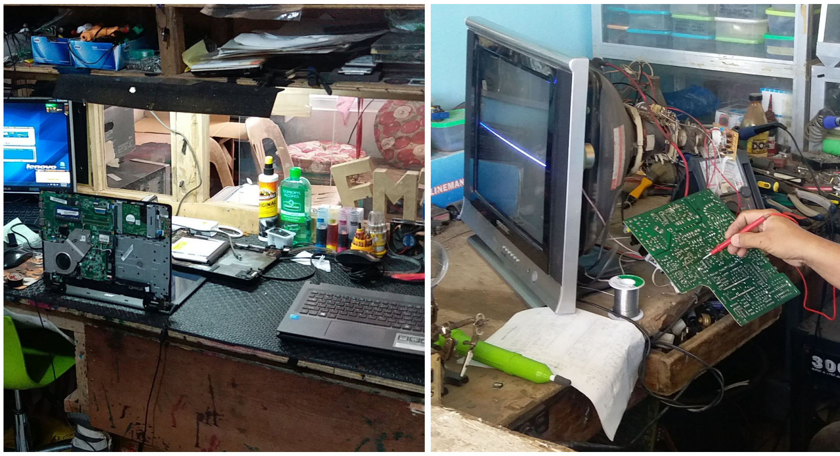

Fig. 2. In the closest urban center, Baler, a laptop is being debugged in one shop (left), and a TV is being repaired in another (right).

an update would require bringing the computer to Baler by boat. Computer repairers in Baler confirmed that the most common problem brought in from the coves was due to teachers' laptops with viruses (e.g., spread over USB) in need of reformatting. Sneakernets [18], the use of physical media like USB sticks for network connectivity, are one mechanism for distributing updates in these situations [10], but we did not notice any such practices in the coves.

5.2 A Patchwork Repair Infrastructure

5.2.1 Remote Rural Repair: A Desire for Trusted Expertise. Initially surprised to find no repair shops in these areas despite the frequency of breakage, we asked participants about local resources for device repair and their own practices. The majority responded that there were no local electronics experts, and the typical path was to travel to a shop in Baler if repair was needed. However, replacing rather than repairing devices was the most common practice, often followed by "stocking" broken items in storage without a clear purpose in mind. A repeated sentiment was that repairing their devices in Baler did not make sense financially due to the high costs of labor, replacement parts, and boat travel (around PHP 100 or USD 2 per way), as well as risks such as sailing during bad weather and the uncertainty of how long the repair would revive the device before it broke again.

Upon insisting on local repair, we were told of a few professional repairers linked to the community through familial or friendship ties, who occasionally visit the coves bringing spare parts and tools with them. However, they are only transiently available, for perhaps a week or two once a year. They will often spend the whole week of their visit fixing a large backlog of broken TVs, leaving many devices unfixed.

In one special case, the unusually well-connected, wealthy Dibut school principal is able to call on her sibling for repair, which sometimes has broader community benefits. As she described: *"I don't let unskilled people fix stuff. My sibling, who is an electrician [of the town hall of San Luis], goes here... If there's something broken. I let him sit on [my] boat... [He comes] whenever I say. Last week, he was here twice. [. . .] I had him install our e-classroom."*

We were referred to one local expert repairer, Teodoro, who had worked in Manila for 6 years repairing TVs and other electronics before settling down in Dibut as a farmer. With his limited personal set of tools, he does what he can as a favor to his neighbors for only partial fees (the cost of parts plus PHP 100, or whatever they can pay). However, he faces substantial challenges getting access to critical parts, more expensive tools, and information needed for repairs. This is in part due to his social exclusion from networks for part-sharing among repairers who know each other in Baler. In his words, *"[People] seldom ask me for repair because I do not have a source for parts. I would have to source it outside. And when I do source it outside, they do not give me parts [in Baler]... They reserve the parts for their own repairs."* Instead he must buy parts in Manila, a full day's travel away at considerable expense (around PHP 750, or USD 15). Despite his known expertise, resource limitations prevent Dibut residents from relying on him fully for their repair needs.

Underlying these responses, we note a dominant understanding of repair work as expertise rather than say, general technological literacy. Trust in a repairer's expertise, whether based on credentials or experience, emerges as a requirement for repair work to happen, regardless of its availability locally. As a substitute, people rely on their network of personal relationships to recruit trusted experts to meet their repair needs.

A different form of trust, embedded in interpersonal ties, is mobilized to enable the bridging of geographical distances, the use of alternative supply chains, and the identification of a pool of reliable repairers. However, in this case a lack of such ties between the coves and repairers with supply chains in Baler results in an emergent exclusion and social marginality for remote cove residents. Baler's potential as a hub for repair for the coves remains unrealized and hampered by exclusionary practices.

Countering exclusion with self-reliance, among Diotorin residents we found hints of a quiet culture of individual tinkering and DIY for fixing simple appliances. At the same time, respondents emphasized that they were not experts and would not volunteer to repair for others, asking them to place trust in their ability. One group of men said, *"The usual practice here is if no one comes yet to do repairs, try to do it yourself if you can... "* Jobert, another self-described tinkerer, explained, *[I] only [repair] for myself. Sometimes, [others] ask me to repair. I repair [their things] if possible. I only repair the easy ones like broken flashlights. If I can solder it, I do it. [...] Actually, I tell others that I don't know how to repair. [...] I don't brag [...] [T]here are other people who know more than me.*

We note that in Filipino culture the concept *masyadong pabida* refers to the rude act of brazenly volunteering or "putting oneself out there" too much without being asked or communally acknowledged. As researchers we consider that this humility may be a polite hesitance to suggest they might be better than others in their community, and potentially masks skills and capabilities that remain invisible.

5.2.2 Urban Repair: Ever Increasing Centralization of Repair Work. Even in Baler, itself considered a provincial town by its residents, repair is challenged by its distance from high-resourced urban centers such as Manila. However, repair shops exist and regularly overcome these challenges.

These shops are full of broken and spare machines; scavenging from irreparable devices and sharing of rare parts between personally connected repairers are common. As computer repairer Bienvenido explained, *"You can just find [CPU wire] here nearby where those are also repairing... You should have many friends so you can just help one another. If, for example, they are the ones in need, then they will come to me. Also if I am the one who needs anything. It's a give and take for us, technicians."*

Independent estimates from three different shops of the percentage of recycled components they use, for both computer and general electronics repair, were 70%, 80%, and 80-100%. We note that hardware repurposing and sharing practices here are similar to the Indian concept of *jugaad*, "an arrangement or a work-around which has to be used because of lack of resources," documented among Mumbai mobile phone repairers [40].

Even so, from Baler as well as from the coves, we see patterns of movement to areas of greater centrality in search of more trusted expertise and material resources, mobilizing social relationships between people and institutions. For example, one computer repair shop sends difficult board-level repairs to a trusted "master technician" with more tools and expertise in the proprietors' more urban hometown, Baguio City.

While consumer devices in need of repair flow readily from rural to increasingly urban areas, repairers and their expertise do not readily flow in the other direction. When we asked Baler repairers whether they would ever consider traveling to the coves, all said no for reasons including expense and the difficulty of successful repair: *"It's far. Hassle. Unnecessary expenses." "Just a waste of time when you didn't finish anything."* With enough work available locally from residents of Baler and all surrounding areas, it does not make financial sense for repairers to leave their well-stocked workshops. As a result, broken devices must move towards urban centers for repair, while training, specialized tools, and parts move by individual effort in the other direction.

5.3 Repair Despite Remoteness

Despite the time consuming, energy intensive, and costly nature of transport between urban areas and the coves, we found that residents' need for centralized resources and infrastructure such as paid work, education, and governance drives daily or weekly traffic to and from Baler, however lengthy or difficult. This regular individual effort forms an active transport network for people and goods between the coves and Baler. Designed to be resilient to interruption, it works to bridge the seams between many different urban and rural infrastructures, dynamically patching them together. At the same time, the coves' dependence reinforces Baler's centrality and the coves' marginality.

5.3.1 Robust Rural-Urban Human Networks Enable Repair. Many cove residents' mobile lifestyles, involving living in more than one place, enable the flow of materials across urban-rural infrastructural seams. Like many migrant workers across the Philippines, people from the coves hired for outside work often stay in larger towns for days or weeks at regular intervals. Christian Pastor Eduardo of Dibut explained, *"Most of us here stay in Baler, San Luis, some even in Manila to work."* Many farmers and fishermen also make regular trips to Baler to sell their goods, leading to daily boat traffic to and from the coves. Small objects like cell phones and letters hitchhike on this traffic.

People seeking specific resources such as access to education or certification infrastructures must also split their lives across multiple places. Nearly every Diotorin or Dibut parent we met with a high school age child (starting from Grade 7) had sent them to board in Baler due to the lack of a local high school. Maintaining the connections between students in Baler and their families involves frequent travel and regular visits, even during monsoon season when the sea can be too rough to travel for days or weeks. As a Dibut mother said, *"If the weather in the sea is bad, we walk."* From Dibut, the closest of the coves to Baler, travel by foot through the densely forested and mountainous terrain takes a full day.

For individual repair needs, a cove resident would typically bring their device to Baler, incurring the monetary costs and physical risks of travel. As described by local maintenance officer Carlos in Dikapinisan: *"we bring [devices] to Baler…For example, if my TV is broken, then I'm the one who will bring it to Baler… we ride boats for public commuting…[They go] almost everyday."* On the boat ride, Dibut electrician George described, *"[An appliance] is packaged and stored in plastic so it won't get wet and damaged."*

5.4 Waste: Broken Devices Stuck in Purgatory

In Aurora we encountered a variety of processes for the creation, disposal, and recovery of e-waste from broken devices. On balance these processes lead to an accumulation of waste in the

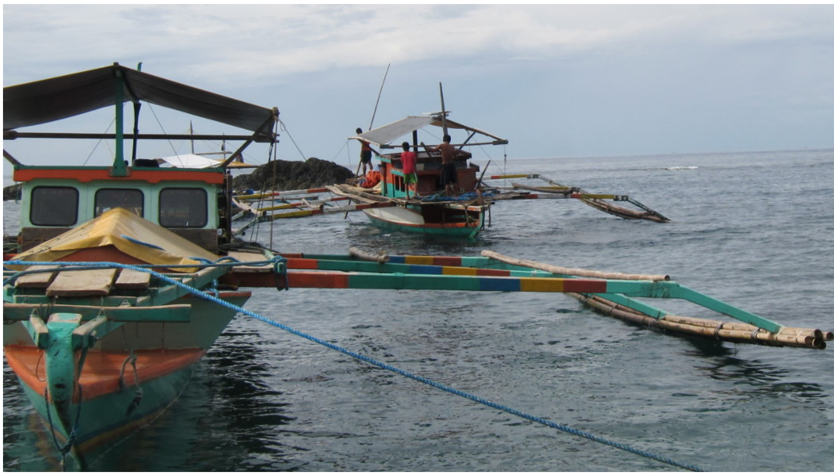

Fig. 3. Two typical boats preparing to leave Diotorin. The vessels moving between the cove sites are generally small and open air, making it difficult to keep belongings dry when seas are rough.

communities, due in part to the difficulty of repair and of waste transport to facilities or specialists for reclamation or disposal. Stocks of broken and deteriorating devices remain that would have been quickly repaired, recycled, or disposed of in urban contexts.

5.4.1 Becoming Waste. Waste can be defined both by the lack of use of a device and the state of the equipment itself. Items become waste in a number of ways, such as upgrading to new devices, giving up on restoring their usability, or exposure to the elements eventually leading to irreparable damage. Repairing a broken object allows the owner to restore value to it and avoid waste. Even if the device is not repaired, leaving it at a repair shop, reselling it for parts, or extracting raw materials and selling them return value to the ecosystem. In sustainable design literature, this efficient life-cycling of devices is referred to as the "circular economy" [32].

However, as we have observed, the intersection of cove residents' geographical remoteness, low income, and infrastructural marginality can increase the costs and risks of repair beyond what is seen as worthwhile. Furthermore, in some cases device owners forgo repair because they were already planning an upgrade, for example in favor of flat-screen over CRT TVs.

Though such equipment also incurs some transportation cost and risk, it avoids other risks. Many see repair as a fragile solution not expected to last more than a few months, especially when applied to what participants called cheap, "disposable," or "China" appliances. Community members' low incomes often lead to the purchase of cheaper devices that are *expected to fail* and are treated as such. During an interview at the public basketball court in Dikapinisan, a participant pointed out a phone that had been casually discarded as trash. *"You can find [a broken phone] loitering around here, sometimes. There's one there."* These dynamics reveal as part of the decision to repair a balance between trust in a new device to work as compared to trust in the repair process (or expert) to restore long-term function to a device.

The culture of replacement that emerges from this balance results in a net positive flow of devices to the cove communities. For most people, who do not want or know how to reclaim materials from their devices, there is apparently no value proposition for their immediate removal as long as storage space is plentiful. Old devices commonly remain "stocked," sometimes in open air near a dwelling, for long periods of time (see Figure 4). As an example, the researchers noted one front yard in Diotorin containing three TVs, one functional, and arranged for communal viewing and two sitting nonfunctional beside.

Unfortunately, without attention, devices will eventually degrade, losing most residual value. This process of storage and degradation has also been noted in other rural environments with other types of equipment [12], and it means that even functional but unused devices need some minimal maintenance lest they transition to waste.

5.4.2 Waste Recovery. Opportunities for device scrapping do exist in the coves, but they are infrequent and rewards are low for making the effort. Two Dibut residents told us of a big recycling boat that comes once a year for 5 days at a time to collect plastic, metal, bottles, broken TVs, and used appliances to melt down for copper in exchange for goods such as plastic basins and cheap jewelry. However, many interviewees do not find it worthwhile or do not know to take advantage of this trade-in.

One transient expert repairer who visits Diotorin once or twice yearly also *"buys damaged TVs, then gets the good parts"* to bring back to his workshop in Manila, but cannot take more than he can extract and carry on his own. Dibut's local expert Teodoro also collects copper from the backs of broken CRTs and sells it to a junk shop in Baler for PHP 150 per kilo, amounting to only around PHP 30-50 (USD 0.6-1) per TV, less than the cost of the boat ride. However, he does this opportunistically with his own TVs and abandoned irreparable devices. These reclamation efforts, while helpful, are insufficient to meaningfully impact the amount of waste given the large volume and quasi-disposable nature of IT infrastructure brought into the communities.

6 TRUST AND REMOTENESS

The prior section introduced how repair happens materially in the remote coves and in semi-urban Baler. In this section we deepen our analysis of how various forms of trust are mobilized to overcome the challenges faced by increasingly remote repairers. Repair infrastructure is built on networks of trust, including personal relationships, obligations, reputation (of both people and components), institutional certification, and warranties. Those with repair expertise, which we define as the knowledge and latent ability of a person to repair, depend on the trust of clients who authorize repair. Repairers must trust other repairers to teach or learn from them and share resources such as tools and parts that are often hard to acquire new. They must also place trust in the sociotechnical systems that produce spare parts and other tools by relying on them; they dynamically build the repair infrastructure itself by choosing who and what to trust. These decisions, influenced by geographical remoteness and infrastructural marginality, shape who is entrusted with and can gain expertise in repair, and ultimately where repair can occur.

6.1 Networks of Trust to Get and Share Supplies.

In more remote environments with scant parts, networks of both interpersonal and system-trust among repairers and suppliers crucially facilitate the flow of spare parts and repair knowledge.

As noted in section 5, the primary sources of replacement parts in Baler are scavenging from other broken devices and the sharing of hard-to-find parts within professional or friendly repairer networks. Even when parts are purchased new or acquired across long distances from urban centers, networks and relationships of trust are crucial to the movement of resources. Every repair shop we encountered in Baler buys tools and replacement parts from Manila, with the exception of one repairer couple, Beo and Maria Clara, who source parts from Baguio (a city closer than Manila) where a family member ships them from particular trusted suppliers via a daily passenger bus.

Since quality and prices of parts can vary widely, sources and business relationships create competitive advantages. For example, during an interview with a college student employee at a hardware and repair shop, the owner overheard us asking where they source spare parts in Manila, which prompted him to stop our interview. He considered these details *"business secrets,"* not to be shared. Computer repairer Jose Maria prefers the twofold more expensive electronics market in Greenhills over the cheaper one in Quiapo (both in Manila) for motherboards because of the 6 month warranty as opposed to 1 month: *"It takes a month to deliver the package, so after that, if it breaks, the warranty is over."* The difference Jose Maria highlights is not in the price or material value of a specific part, but in the contractually enforceable trust in the seller via the warranty.

The common practice of sourcing parts and goods from distant metropoles instead of local retailers, even from Manila over closer cities, reflects popular beliefs about electronics from more urban locations having higher quality. They are perceived as more trustworthy, perhaps due to less exposure of the systems that produced them to perceived risks such as counterfeiting, cheapness, or even just age associated with distribution time. Computer repairer Beo explained: *"[A] lot of people here would rather go to Cabanatuan which is the nearest city here, or to Manila or to Baguio, to buy whatever tech things they need. Because it's really more of a trust thing, because they feel like if you buy it from this retailer here [in Baler], 'Oh that's fake," or "You're not that rich because you bought it here."*

Likewise, networks of interpersonal trust between repairers exclude those who are not already familiar as friends or established as repairers. Teodoro from Dibut travels to Manila for parts because he does not have social connections to repairers in Baler. These practices again reinforce the marginality of more remote areas by increasing their central dependence.

6.2 Trust of Customers in Repairers

We also note the importance of the trust placed in repairers by clients who give them their devices to repair, which may manifest as system-trust in the repairer's qualifications or reputation as well as interpersonal trust if personal connections are leveraged or built up over time. Without this active trusting by the customer via giving up their objects to be unmade and remade, repairers would not have opportunities to practice repair and gain experience. A repairer in Baler described the trust required to hand over a computer to a shop: *"Mostly it's a trust thing here in the province. Because you would invest on a 20,000 peso [around USD 400] laptop and you earn a meager living. And then you will bring it to someone who will just swap out the parts and tell you it's dead."* He also mentioned that especially in the case of computers, strict data privacy was crucial to maintaining the trust of clients, who included both local government officials and political dissidents: *"Your doggy pictures and the top secret data that they have, it's the same thing here in the shop."*

Formal accreditation, reputation or recommendations via other repairers or former clients, and even simply the existence of a repair shop as an established place of business (not to be taken for granted) all serve as sources of trust, manifesting some definition of "expertise" or "professionalism" for people seeking repair. We note that all of these are much easier to acquire in typical urban contexts with repair businesses and training institutions than in geographically isolated areas with low population and relatively few devices.

6.3 Expertise and Training as Trust Relations, Mediated by *Aktwal*

Repairers in both the coves and Baler were clear that the best way to gain expertise and become more trusted with repair was through what they called "*aktwal*," not through formal education. The Filipino word *aktwal* (from the English "actual") refers to learning by manipulating a real system. The concept encompasses not just the passive observation of an "actual" system, but the active hands-on practice of "actual" repair or other technical work on real broken systems. Such experiences typically had to be found outside of the context of formal education, for example during practical apprenticeships or other paid work.

Although seminars, schools, or degrees can provide important knowledge, one can learn to repair without them. Five of eight repairers we talked to in Baler had started undergraduate degrees related to electronics or computers, but only three had graduated, and two had finished degrees in unrelated fields such as Nursing. As Beo said, *"Being highly unregulated here in the Philippines, we are able to go into this business without even showing any requirement for us to be in the repair business."* Beo's wife and business partner, Maria Clara, now the primary repairer in their shop, learned repair through Beo and self-study: *"The first year, 80 percent of my knowledge came from my husband, so 20 [was] mine. Then after 3 years... when he went back to Baguio and studied; that was really the time that I dug into my knowledge. Google is my best friend."*

In contrast, training or apprenticeships with experts is highly valued by repairers, as seen in other repair sites across the world [29]. Trainees can get access to the *aktwal* experiences they need to gain expertise by effectively borrowing the trust that customers have in the experts they learn from. One student repairer we met at a shop in Baler was pre-training before his degree-mandatory "on the job training" (OJT) in Manila to finish at the Aurora State College of Technology (ASCOT),[4] showing institutional recognition of *aktwal*. Beo and Maria Clara explained that taking inexperienced OJTs fresh out of school was seen as a public service obligation for established shops: *"They (ASCOT) give out requests for us to take in some of their students." "They don't know how to really repair a computer, even a basic one with the CPU, because that's the basic thing that you should know in repairing."* We again note that these training environments are easier to find in urban centers, perpetuating the centralization and concentration of repair knowledge.

6.4 Trust and the Marginalization of Local Repairers

6.4.1 Distrusting Repairers "From Here". We noted a strong self-bias against trusting the expertise of electronics repairers in remote contexts. A Diotorin electrical lineman cited an expected lack of exposure or familiarity with equipment: *"If they are from here, they are hard to trust with things like [solar panels]... We rarely use solar panels here."* Again we see that the limited availability of technology associated with geographical remoteness, low resources, and infrastructural marginality results in a practical disadvantage for obtaining "aktwal" experience and expertise. Cove residents do not expect those "from here" to have repair skills, especially for less common technology, unless it is known that they had formal training or practical experience from outside. This may be a reason for most local repairers' extreme humility about their own skills, like the tinkerers from Diotorin in section 5, and may contribute to the bias that there are no repair skills in the coves.

6.4.2 Accessing Trusted Repairers from Outside. In contrast, a large amount of trust is placed in the small group of transient visiting expert repairers who carry tools, parts, and expertise into the communities in response to familial or friendship obligations, leveraged by cove residents to achieve repair. These infrequent visitors make themselves available to a wide group of acquaintances, but overall demand is too high to meet.

Joshua, a repair shop owner in Manila, visits family in Diotorin once or twice yearly on holidays. A local government leader described, *"Since he is really handy in fixing things, before he arrives the people ready the things they want to have fixed... Probably since he is knowledgeable in electronics, he already knows what commonly breaks and brings the parts needed for those repairs. [...] Usually he stays for a week...Probably [he repairs] a lot [of devices] because his week's stay is not enough to have everything fixed."*

Local repairers' strong trust in these visitors stands in stark contrast to their own humility. As Diotorin electrician Romeo commented, *"He is skilled and experienced like a master. [...] I know him because we are friends. [...] I trust him because he already mastered this."* While the occasional

[4] A public technical college in Baler.

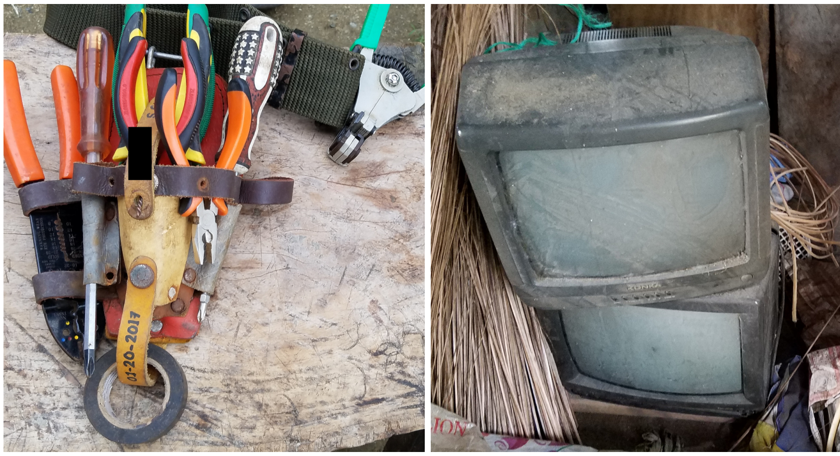

Fig. 4. A set of local repair tools (left) and "stocked" nonfunctional TVs in Dibut (right)

presence of these experts can present learning opportunities for interested local repairers, the visits are also too short and intermittent to substitute for long-term apprenticeship or *aktwal*.

7 "TRAINING GROUNDS:" A CASE OF ROBUST RURAL REPAIR

Despite the challenges, we found robust local infrastructures for electrical line repair (for home wiring and public grid lines) in all three communities. Examining the factors leading to this success, we develop the concept of *training grounds* and how they create the conditions for successful and sustainable rural repair.

Electrical lines were installed in all three sites between 2006 and 2010, connecting them to grid power. Tools and parts are usually available locally, and numerous residents in each cove have experience with these repairs. We met nine resident "electricians" or "linemen" in the coves who were readily able to repair public electrical lines serving their community and home installations.

We find that training grounds promote a healthy repair ecosystem by supporting the sustained growth and maintenance of a local repair community. We identify four factors, of which three are crucial to repair and define the training grounds, while the fourth supports and enables the others:

Training Grounds

(1) Material resources for repair, such as tools and parts, must be readily available to both experienced repairers and trainees.
(2) Trainees need access to practicing experts or expertise to acquire new information and skills.
(3) Opportunities to practice "*aktwal*" repair as a learner or apprentice are required to gain experiential repair knowledge.
(4) Locally accessible institutions for formal education and certification play an important role in enabling access to all three aspects of training grounds.

In the context of rural electrical repair in Aurora, AURELCO and the Technical Education and Skills Development Center (TESDA) in Baler provide relatively accessible institutional support for repair in the surrounding rural communities. Such institutions counteract the typical centralization of repair by extending the global network of trust, knowledge, and resources for repair to increasingly remote areas in a sustained way, as shown in the following cases.

1. Availability of Tools and Parts: TESDA is known to give tools to trainees upon graduation that they might not otherwise be able to afford. A group of Diotorin residents explained of a young man who had left his community for college: *"He does a lot [of repair]. His tools are complete . . . He gets to keep them after graduation. They're his." "Where do you find someone who can buy his own tools?"*

The Dikapinisan barangay electrician, Francisco, has a kit of specialized tools on hand for line work: *"[The 'shotgun stick'] made of fiberglass that we use to grab onto the power line. So we don't get electrocuted. [I also use the] safety belt. Plus the step belt, to use going up the post. Pliers, electrical tools."* Transport infrastructure is available for going at a moment's notice up the mountain to where the electrical lines come from barangay Dibayabay and return within a day: *"They're going to pick us up somewhere in the other town. We're just going to walk to where the boat is waiting for us."*

The provincial electrical coop AURELCO also ensures a regular flow of tools and parts by sending personnel monthly (when possible) to check the physical infrastructure and collect payments. Teodoro, the expert repairer in Dibut, told us that *"when [AURELCO personnel] come here to perform repair [then I am able to ask for some spare supplies for electrical installations]."* As a result, Teodoro was once able to perform an emergency repair at the school upon the principal's request. She relates: *" I saw that the line was hanging close to the ground. I called [Teodoro]. . . The children might get electrocuted. So he removed it."* This critical repair could have taken much longer without local supplies and a trusted repairer available to be mobilized at a moment's notice.

The institutionally managed flow of repair resources can be seen as effort or care that works to patch seams between disconnected rural and urban infrastructures, similar to the NGO logistics in Jack & Jackson [22]. However, forms of care like the provision of tools to trainees enable and empower local actors much more than they are a top-down form of control.

2. Experts to Learn From: By working together, electrical line technicians transfer knowledge and skills outside of the process of official accreditation. Via these working relationships that foster interpersonal trust, some of the system-trust associated with credentials can be informally passed from accredited to non-accredited repairers. For example, Teodoro from Dibut described that *"I tag along and observe while AURELCO does maintenance,"* which contributed to his ability to perform the school repair above. Carlos from Dikapinisan, while not certified himself, also learned his skills as an electrician's "helper" in Baler and would in turn teach his helpers while working: *"Sometimes [an assistant] will cover the live wire with electric tape... I teach them."* Over time, these processes of knowledge transfer can allow other community members to place their trust in a local repairer's reputation over their credentials.

3. Opportunities and Funding for Practice: Technicians are able to practice their craft often to gain experience, learn from a mentor, and earn money that they could be making in other work. As in Baler, though the repairers were positive about any formal education they had, they were clear that most of their learning was through experience and placed the highest value on "aktwal."

Due to the difficulty of sending personnel from AURELCO, local technicians get an opportunity to work whenever people build new houses, wiring gets damaged, or lines are disconnected due to lack of payment. As Romeo from Diotorin described, *"Here, if people are not able to pay [AURELCO], their electricity will be cut off. When they pay, the engineer does not come here anymore and just teaches me what I have to do for them to get their light back. The labor fee is 85 [pesos] for connecting the line, and they [pay] me."* Romeo's informal financial relationship with the electric company provides funding for repair work in addition to experience.

A further incentive to repair is that electrical line repair is seen as easier than farming, with income that is guaranteed when due by AURELCO or the local government. The promise of good pay leads to more sustained effort towards accreditation and learning. Technicians are also empowered to provide private home services to relatives and friends for free, while charging for other labor.

4. Accessible Formal Education and Institutional Certification: Formal degrees or accreditation, while not materially necessary for repair, can reduce uncertainty in a repairer's expertise for new customers or employers by acting as a symbol of system-trust that they can place instead in the accrediting institution and process. It can help local repairers manage risk in case things go wrong and can help them find work outside a local social network that trusts them.

Seven of the nine linemen had participated in formal training, two of them at TESDA. TESDA, a government institution whose mandate is to develop the skills of the local labor force, issues certifications that act as credentials for employment. AURELCO also provides training seminars and issues line repair certifications. Leon of Dikapinisan explained, *"I am a certified electrician of AURELCO [though] I am not a maintenance personnel. [If something breaks] I have the license to fix it; I can do work throughout Aurora even though I am not [employed by] AURELCO anymore."*

At the same time, the strict requirement of such certifications in order to take any action can be a barrier repair, especially if trustworthy experts can still be excluded due to externalities. Teodoro, who considers himself too old to go through the effort of certification, explained his hesitancy to work on public lines except in an emergency: *"It is difficult to attempt repair [if one is not authorized]. If something goes wrong, I will be blamed."* However, he and other technicians still frequently do work on electrical lines without official accreditation within their barangay, suggesting that well-reasoned exceptions are made for trusted community members based on reputation.

7.1 From Individual Tinkering to *Bayanihan*

Motivated by the repair goals inspired by the VBTS Project, we briefly explore some possible strategies for operationalizing our understanding of training grounds and how institutions can provide resources and infrastructure to support local repair in our remote contexts.

For example, a community-oriented repair and learning space or group could be established to transform the practice of repair from individual tinkering to a form of *bayanihan* (or *atag*, as it is known locally in Aurora), a Filipino concept roughly meaning "cooperative work in care of the community." *Atag* is regularly contributed by adults in all of these communities to help maintain shared infrastructure such as public buildings and school yards. Coordinated activities such as collecting e-waste from homes and helping to restock repair tools or supplies when in Baler could be incorporated as service activities towards care. We liken such an institution in spirit to a makerspace [5], hackerspace [17], or repair cafe [32], similar spaces focused on bringing together community resources and expertise for goals such as learning about technology and sustainable living [43]. However, we focus on activities that might be appropriate to our context.

The space could stock specific components, tools, and manuals for disassembling, understanding, fixing, or ruggedizing common devices such as mobile phones, the repair of which many cove residents identified as a severe unfulfilled need. It could also provide training and teaching, as makerspaces commonly do as a core part of their mission [7]. This training, perhaps combined with device collection and repair by students, could allow local repairers to get the experience and practice (*aktwal*) they need to learn repair skills.

There would be many challenges to overcome in such a project, for example a potential lack of government or institutional support from an AURELCO or TESDA (though such support would be welcome), and a pragmatic commitment that the communal space also help support people's livelihoods. However, as researchers and designers we recognize a need to think about possibilities for sustainable community structures that can enhance technological self-reliance and autonomy from regional power relationships in the long term.

8 DISCUSSION: IMPLICATIONS FOR HCI AND ICTD

The difficulties of sustainable device cycling for people in the cove communities highlight the residuality of these communities as consumers and repairers of technology. Despite the body of literature demonstrating that local electronics repair capability does arise in rural areas, we must also acknowledge the reality that the successful emergence of this infrastructure depends on many factors such as environmental, institutional, and resource-based conditions, and should be explicitly supported rather than taken for granted. We believe this paper provides important contributions for technologists focused on rural areas that experience infrastructural marginality and remoteness.

A need for occasional or extended self-reliance is fundamental to the rural experience. ICTD and HCI4D projects must address that most resources, be they technical (such as datacenters) or social (such as universities and other institutions), may be remote from their rural users. We suggest that focusing on the community and their own abilities and resources, as in Asset-Based Community Development [37], is one way to address this reality. In the prior section we discuss what a local community-based institution supporting repair might look like in this context. Another could be co-locating new repair-related resources within in the community itself, explicitly designing (and co-designing) them for the difficulties present in these areas. Wyche et al. [51] provides one example of this, postulating a phone optimized for ruggedness rather than features due to the difficulties of operating in the users' environment. From a government or policy perspective, we also suggest that some form of municipal transportation infrastructure specifically targeting technology reclamation, recycling, or repair could be effective for reducing the large amount of devices being consumed and wasting in "purgatory," both in these remote contexts and elsewhere around the world.

Bringing a system perspective to processes in the technology life cycle like repair allows us to think about a broader ecosystem around use, breakdown, and repair of devices that can be considered even in areas like our field sites without consistent or formal repair infrastructure. Rather than limiting our knowledge of rural repair to practices and infrastructure in central areas with repair shops, we seek to understand the seamful patchwork of intermittent and overlapping infrastructures that extends to more remote rural areas—what resources are accessible, where, and when, and what causes seams to appear. To do this, we must better understand the lives of people in these areas, including their knowledge, skills, relationship with urban people and places, systems of trust, options for communication, and more.

We note the importance of networks of both interpersonal and system-trust for recruiting resources in rural areas with less institutional infrastructure and centralized resource provision, particularly for collaborative technical work like repair. Long-term, stable engagement in communities, for example through local institutions, are crucial for establishing *training grounds*, which can provide a foundation for trust in repair processes and people. While trust has long been acknowledged as crucial in ICTD interventions [34, 39], this paper suggests that we be aware of the myriad forms trust relations can take in different contexts and its role in shaping collaborative networks.

Finally, we join the call from the wider research community encouraging researchers and practitioners to consider the processes of recycling, disposal, and wasting as part of their designs [21, 35]. The dominant technology design culture of frequent obsolescence and replacement, even made cheap to arguably increase access to low-income populations, can be particularly unsustainable in remote places. Designers must acknowledge that their devices will eventually be discarded, and create sustainable devices or mechanisms to support their repair or reclamation.

9 CONCLUSION

This paper characterized a seamful patchwork of repair infrastructure for electronic devices that exists in Dibut, Diotorin, and Dikapinisan, geographically isolated cove communities in Aurora, Philippines. Despite frequent breakage due to a harsh environment for electronics, there are no local repair shops, and local device repair is uncommon due to the difficulty of mustering the material resources, tools, and expertise needed for repair. Confronted with their communities' remoteness and marginality with respect to many forms of public infrastructure, cove residents largely take a disposable view of their equipment, often buying cheaper ICTs with the expectation of their inevitable failure, and leading to extensive local e-waste. However, device owners occasionally do travel long distances to bring broken devices to repair shops in the nearby peri-urban center of Baler, following a typical pattern of rural-urban flows echoed by Baler's repair shops sourcing expertise and parts from more urban Manila.

We found device repair infrastructure in the cove settings to be more informal, intermittently available, and largely mobilized by individuals based on personal relationships. Both interpersonal and system-trust and their mediators crucially enable repair. Networks of trust between repairers, their clients, certifying or training institutions, suppliers, and fellow repairers facilitate movement of material resources and expertise, but also reinforce the coves' marginality. Under these circumstances, local people successfully maintain a healthy and robust ecosystem for rural electrical line repair. From observations of this ecosystem we developed the concept of *training grounds* to sustain local communities of repair experts. Finally, we outline a number of ways these concepts can inform future efforts to make repair a more accessible option for people living in isolated rural areas.

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