Maintaining Computers and Maintaining Computer Science

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Abstract

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Every technical intervention is surrounded by a rich set of social relations which both maintain and are themselves maintained by the technical artifacts involved. My dissertation explores the social relations and technical cultures maintained by our work on computing for "good" or for "development" or for "impact" using three cases. First, a community networking collective in Argentina; second, an international collaboration to manage vaccine cold chain equipment; third, a UW CSE capstone course. I detail how we use seemingly mundane computing artifacts to stabilize and contest specific social structures, including the computer science discipline itself. Finally, I argue that the generic formulation of "CS4Good" is inadequate to the challenges facing computer science today, and that instead computer science needs to embrace sociotechnical analysis with a historicist sensibility.[1]

[1] "Historicist sensbility" I borrow from Soden et al. [140].

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[W]e should see social situations less as problems to be solved and more as people and institutions to be nurtured

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Kentaro Toyama in *Geek Heresy*

ACKNOWLEDGMENTS

The narrative in chapter 3 follows a strategy of drawing global interconnections. In the same spirit, I will indulge in drawing out some of my personal interconnections that allowed this dissertation to come about.

First, this work was assisted along the way by my co-authors Esther Jang, Michael Lithgow, Nico Pace, and Lucy Pei. The data collection and writing that forms the empirical basis for this dissertation were planned and executed with their collaboration.

I would not have found my way to this PhD program without Bernardine Dias and Judith Schachter at CMU, who introduced me to ICTD and qualitative research methods. Their initial guidance was supported by my collaboration with Minnar Xie and Marjorie Carlson.

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Naveena Karusala and Chris Geeng have been my best friends throughout our five years in the PhD program, and their feedback has shaped much of my writing. Naveena has been along for every twist in my PhD journey as my housemate and academic "sibling." I would have certainly left the PhD program if not for the support of my housemates and the many other students who created a strong community in our department: Nicasia Beebe-Wang, Saadia Gabriel, Christine Chen, Esther Jang, Matthew Johnson, Erin Wilson, William Agnew, Brian Hou, Alex Okeson, Tal August, Sofia Serrano, Leah Perlmutter, Gabe Erion, Ivan Evtimov, Peter West, Manaswi Saha, Laura Vonessen, Taylor Cunnington, Eunice Jun, Morelle Arian, Camille Cobb, Yasaman Sefidgar, Amanda Baughan, Amal Nanavati, Tyler Baxter, Levi Cai, Stefania Druga, Soubhik Deb, Dorna Abdolazimi, Audrey Seo, Kentrell Owens, Miranda Wei—again, I cannot list everyone. Many of these colleagues supported my research directly by giving feedback on drafts and research plans. The students of the ICTD research group deserve special mention: Trevor Perrier, Fahad Pervaiz, Waylon Brunette, Samia Ibtasam, Spencer Sevilla, Sam Castle, Clarice Larson (not a student), Galen Weld, Matt Ziegler, Sudheesh Singanamalla, Innocent Obi Jr, Emmanuel Azuh Mensah, Lisa Orii, and Nussara Tieanklin.

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Nic Bidwell helped me recognize the depth of my interconnections when she offered some valuable criticism of the version of chapter 2 published in CSCW 2021. I had tried to distance my work from hers to establish the novelty of the contribution, but she rightly argued that in fact her prior conversations with my interlocutors about the same topics meant that we were all taking part in knowledge-construction together. Latour writes that researchers should expect to be catching up to their informants, whose self-analysis is likely already one analytical step ahead of the researcher [87]. My most important debt, therefore, is to my many interviewees, whose words I have cut up, refracted, subjected to unanticipated theoretical dialogue, and glued back together. If any of you are reading this, I should apologize in advance because, though I have tried conscientiously to represent your ideas accurately, perhaps your words will feel foreign inserted into the context of these pages.

Working on cold chain equipment software, my spirits were supported by the students I got to collaborate with, including Aashna Sheth, Sanjana Sridhar, Jenny Cho, Suliman Osman, Sahar Osman, Corbin Phipps, Dhreeti Rathore, and Elijah Greisz.

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Finally, I'd like to thank my parents who raised me to be a reader, which is the foundation for most of this dissertation

Chapter 1

INTRODUCTION

Capital, run amok, produces social relations that are opaque to those who inhabit them

Benjamin Peters in *Your Computer is on Fire*

Human-Computer Interaction literature over the last decade has grown attentive to the maintenance and repair of computers, a welcome corrective to the overwhelming focus on novelty and creation [76]. Researchers in this area usually turn their gaze "out there," to the practices of technicians conducting repairs formally or informally [75, 81]. They (we) travel to repair shops and markets and collectives around the world and consistently find the influence of "the social" on the maintenance practices under study [84].

At the same time, the critical computing literature has explored the role of technologists, geeks, and computer scientists in shaping global changes not only through their technical artifacts but through their narratives, discourse, social structures, and power relations [105, 78].

In order to analyze the impacts of computing for development, or more broadly for a generic "social impact," this thesis combines these approaches to explore one core question: what social structures are maintained through technical labor on ICTD projects? We will be getting into lots of details in the following chapters, but let this question be your guide.

This analytical approach comes from science and technology studies (STS). Latour, for example, writes that face-to-face human interactions are fleeting, so an explanation of "the social" should look to material objects that stabilize our social worlds.

> So, when social scientists appeal to 'social ties' they should always mean some-

> thing that has great trouble spreading in time and space, that has no inertia and is to be ceaselessly renegotiated. It's precisely because it's so difficult to maintain asymmetries, to durably entrench power relations, to enforce inequalities, that so much work is being constantly devoted in shifting the weak and fast-decaying ties to other types of links. [87, p.66]

In the three cases described here, we will see that it is not quite as simple as durable objects bringing solidity to otherwise flimsy human interactions. Instead, the computers and their software are quite fragile, prone to stop working and in need of careful attention. And yet, broken devices, prototype software, and software with defects are mobilized to support many social relations, sometimes *because* of their defects.

My research question puts the emphasis on one direction of influence: how our social world is stabilized by our technical world. But of course there is no clean separation between the technical and the social: human relationships and technics reproduce each other. In the pages that follow we will also see a lot of the other direction of influence, "the social shaping of technology" [95]. I've chosen to focus my research question on the stabilization of social structures because too often discussions of "social factors" in technology development describe the technical artifacts as almost dormant: inactive, acted upon but not influential themselves. Sometimes, this is a rhetorical move toward innocence.

Chapter 2 explores maintenance of computing equipment and community ties in community networks. The global community networking movement promotes locally-managed network infrastructure as a strategy for affordable Internet connectivity. This chapter investigates a group of collectively managed WiFi Internet networks in Argentina and the technologists who design the networking hardware and software. Members of these community networks collaborate on maintenance and repair and practice new forms of collective work. Drawing on Actor-Network Theory, we show that the networking technologies play a role in the social relations of their maintenance and that they are intentionally configured to do so. For technology designers and deployers, we suggest a path beyond designing for easy repair: since every breakdown is an opportunity to learn, we should design for accessible repair experiences that enable effective collaborative learning.

Chapter 3 is an essay on the history of the Cold Chain Equipment Manager (CCEM), a software tool decidedly "for development" with some University of Washington (UW) involvement. I weave together the violence in sourcing of computing minerals, the Ugandan government's partnership with foreign donors, and the role of cold chain equipment software. Unlike the other two empirical studies, the contribution of this chapter is one of narrative. Though the narrative is developed with the help of a few conversations with the key players and my own experience as a software developer on CCIS, its main value is not in the facts introduced to the public record but in the connections made between pieces of the history usually considered independently. The emphasis is thus on interrelation and mutual influence.

Chapter 4 contributes to the conversation about undergraduate students' conceptions of computing and career pathways. I present a qualitative study of undergraduate involvement on a software research project in ICTD. This chapter analyzes interviews with nine students who worked on the project in a capstone course and/or as volunteer research assistants. It contributes (1) a new angle on students' conceptions of computing and the ICTD subfield, which reveals that interest in "social impact" motivates their involvement in ICTD, in contrast to a perceived default computing career path at large tech companies; and (2) an articulation of *deferring social impact*, which describes student researchers' intentions to eventually find the social impact they desire despite following that default career path.

In the conclusion, I zoom out from the details of specific projects to discuss the implications of computer scientists' turn toward CS4Good, based on the analytical perspective developed through the three cases.

Chapter 2

"THE NETWORK IS AN EXCUSE": HARDWARE MAINTENANCE SUPPORTING COMMUNITY

2.1 Introduction

A growing movement of ICT users and designers promotes community-run telecommunications networks as a way to address connectivity challenges [149] and support local self-determination [20]. Belli defines community networks (CNs) as "collaborative networks, developed in a bottom-up fashion by groups of individuals that conceive, deploy and manage the new network infrastructure as a common good" [20].

Our setting is a group of CNs in Córdoba, Argentina that collaborate with our research partner, the AlterMundi Civil Association, a prominent community networking organization. AlterMundi promotes community development through the creation of networking technology, such as the open-hardware LibreRouter [45]. For AlterMundi, CNs are a step towards the "right to co-create the Internet": the right not just to access telecommunications, but to build one's own infrastructure and to control one's own online interactions [44]. Indeed, a persistent challenge expressed by our interviewees is how best to broaden engagement by CN members in the design, creation, and maintenance of networking technology.

The Human-Computer Interaction (HCI) community has begun to explore how technicians around the world learn to repair electronics [82, 10, 84] and the role technical artifacts play in community building [38, 104]. Laypeople contribute to repair of these CNs, and their participation is shaped in part by material aspects of the networking technologies.

Early work on CN maintenance suggests improving fault diagnosis to facilitate novice repair and identifies a need for educational approaches to supporting CN repair [141]. Indeed, simply designing devices to minimize repair fails to ensure that devices are readily repairable in their context of use [127]. In this case, the networking technologies are designed and configured by members of the CNs and of AlterMundi to nurture an accessible repair community of practice, suggesting one such "educational approach." Using the fact that every breakdown is an opportunity to learn, the CNs try to support broad participation in repair. We contribute to the new, small body of scholarship on the sociality of repair and maintenance of community networks in the Global South, a set of writing with shared interest in demonstrating the complexity of the connections between the materiality of CN hardware and participation in CNs [84, 25, 43].

For implementers of new CNs and for organizations supporting CNs, we observe that a primary challenge is building and nurturing a community of learners. To better understand how material objects mediate cooperative work, we use Actor-Network Theory to analyze how community-run networking technology encourages and affords different kinds of community engagement. The purpose of this case study is to document how networking technology can be used to address a community network's need to building a novice community of practice based on repair and maintenance of network hardware.

This study was conducted and written up with my coauthors Esther Jang, Michael Lithgow, and Nicolás Pace and was originally published in CSCW [59].

2.2 Related work

2.2.1 Community ICTs and Community Networks

Community network literature generally focuses on costs and impacts of newly deployed information and communication technologies (ICTs) [68, 142]. Such perspectives overlook questions related to the development process itself, including links between appropriate technologies, cultural contexts and technology designs, as well as questions of long-term sustainability [6, 8, 57, 100]. Numerous researchers have advocated for more interdisciplinary and contextually grounded approaches to community ICT research [64, 77, 101, 102, 130, 157, 152]; however, little interdisciplinary research addresses both ICT artifact design and "the subtle interaction between the ICT artifact and the context" [157].

2.2.2 Actor-Network Theory

Actor Network Theory (ANT) is a framework for interpretation that understands the social world as the unstable product of a network of alliances, interactions, and controversies among actors—human and non-human [87]. In the interest of explaining social ties, ANT looks at how actors act on each other and how certain relations are made durable by non-human actors. This makes ANT an attractive framework for studying telecommunications networks since it helps us consider the materiality of technical infrastructures in tandem with human action [138, 143].

ANT has proven helpful in examining the creation of community ICT networks beyond simple explanations of success and failure based on measurements of impacts [135, 71]. Further, it is useful in revealing dissonance between results stimulated by external development decisions and the needs of local communities [17, 125], and has been embraced by some researchers as a framework to overcome simplistic understandings of how to bridge the digital divide [128].

Though wireless mesh networks include many parts, we treat networking technology as a single actor, *not* as an actor-network. We use the term "network" in three ways: in the ANT jargon *actor-network*, to refer to the *networking hardware* that makes up a wireless mesh network, and to refer to a *whole community network* (CN): the hardware, the people who identify as members of the network, and the relationships between them. For example, Quintana Libre is a CN. The network in the second sense is an actor that shapes and is shaped by the relations and associations that comprise the community network in the third sense.

2.2.3 Communities of Practice

Lave and Wenger's now-classic theory of *communities of practice* is a social theory of learning that identifies knowledge and knowing as participating competently in valued enterprises.

A "community created over time by the sustained pursuit of a shared enterprise" in which practices have been adjusted to "reflect both the pursuit of [the enterprise] and the attendant social relations" is a *community of practice* [159, p.45]. For Lave and Wenger, the ultimate goal of learning is the *social production of meaning*, which is continually negotiated through the dual processes of *participation* and *reification*: participation is direct interaction between people, and reification is the production of artifacts (e.g. tools, documentation, methods, lesson plans) to organize participation. But, this is not a strict human/non-human dichotomy, and thus it is a natural pairing for ANT; Wenger writes, "the duality of participation and reification suggests precisely that, in terms of meaning, people and things cannot be defined independently of each other" [159, p.70].

We use this case study to argue that lay members of a CN can participate in a community of practice focused on learning to maintain networking hardware (with some expert support). In this chapter, such a community of practice includes (1) a broad group of members with little to no prior experience with telecommunications technology maintenance, and (2) collaboration between lay members on the technicalities of maintenance. We posit that nurturing a novice community of practice can anticipate breakdown and facilitate repair.

2.2.4 Repair and Design

Amid HCI's focus on creation and design, repair and maintenance scholars have centered repair as a crucial part of technology use, since everything breaks eventually. This turn is what Jackson refers to as "broken world thinking." Writing on the sociality of repair has elaborated the many connections between repair work and repairers' social worlds. For instance, Houston and Jackson argue that repairers rely on both local (walking distance) and global (online) knowledge networks [76], and Jang et al. point out how repairers depend on relationships with parts suppliers, emphasizing the role of trust in those relationships [84]. This approach has borne critical analyses of divisions in who does which maintenance work. For example, De Wilde describes how women are expected to do cleaning work [39], and Bidwell describes how women are expect not to climb CN towers [24]. Similarly, Crooks describes how in the absence of structured support for classroom technology, the troubleshooting of iPads in an LA public school fell to unpaid student labor [36].

The literature about digital device repair commonly finds it important because of sustainability issues [82, 80, 83], an important perspective given the proliferation of electronic waste and the exploitative labor practices of mining metals used in computers. Houston's work that interprets digital device repair as care expands our ability to appreciate the labor of repair through attention to repairers' personal and emotional investment, and it calls on ICTD scholars to attend to the ethico-political commitments of their/our work [76, 75]. Recent work by Rifat et al. dexterously engages both the e-waste and care considerations [126]. In this chapter, we further extend this appreciation of repair by focusing on the social relations repair supports.

To make that argument more precisely, we lean on de Laet and Mol's work, translating their arguments about the Zimbabwe Bush Pump to the world of telecommunications [38]. They write that the Bush Pump's need for maintenance "*constitutes* its community."

> *After all, if pumps are to be successfully maintained, some degree of organization and division of responsibility are needed; the community needs to assume joint ownership and so affirm itself* as *a community. And so with a Bush Pump – or any other standard pump – the community acquires a piece of equipment that it subsequently enrols in its efforts to organize and form itself.*

In a direct parallel, Section 2.4.1 documents social relations made durable by the maintenance needs of the networking technology.

Throughout maintenance and repair literature, particularly in HCI, there is a general admonishment to "design for repair," but it is not yet well understood *how* we might design for repair. Rosner and Ames developed a crucial critique that "breakdown and repair are not processes that designers can effectively script ahead of time" [127]. They point to failures to repair the XO laptops of the One Laptop Per Child program as evidence that the design of a device itself, or even a device and its attendant documentation, is insufficient to ensure that it will be maintained. Among complicating factors they identify are *repair infrastructure* and user *expertise* (as we will see, both are aspects of local context which AlterMundi nurtures through their design processes and collaborations with CNs).

If repair cannot be baked into a device, technology designers interested in repair must direct their efforts to the contexts of use and maintenance. Houston and Jackson responded to this critique with a call for device manufacturers to "intervene in the aftermarket," [75] echoing Jackson et al.'s earlier call for manufacturers to develop connections to local "repair worlds" [81] Jang et al. gave a more detailed suggestion for how such "aftermarket" interventions could work by schematizing a "repair ecosystem" [84]. So far there is no documentation in the literature of a digital device manufacturers' or designers' attempts to engage with local repair communities. This chapter describes how the AlterMundi technologists relate to a novice repair community of practice, presenting initial evidence of how such connections can work.

Our focus on unpaid novice repair contrasts with the usual focus on paid experts (e.g. Orr's original study at Xerox or the cell phone repairers of Dhaka [10, 114]). This raises some natural questions which we leave to future work: how can device manufacturers connect to professional repair worlds? and to what extent are AlterMundi's strategies particular to the unpaid novice repair context?

2.3 Methods

2.3.1 Collaboration and Topic Selection

This research was conducted as a partnership between AlterMundi and academics from the U.S. and Canada. We decided to collaborate based on our shared interest in documenting how successful CNs work in order to support the community networking movement. this chapter is just one academic expression of that goal.

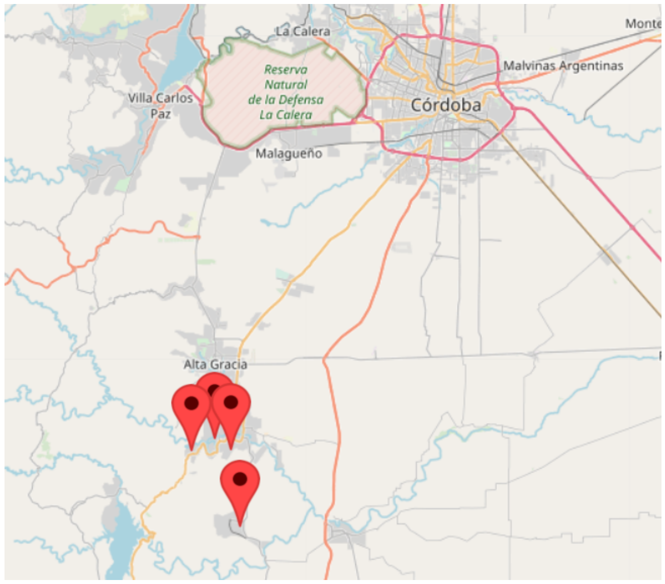


Figure 2.1: Research sites in Córdoba province, Argentina (from OpenStreetMap).

2.3.2 Sampling Rationale

We first chose to investigate the Quintana Libre (the CN in José de la Quintana) network because of its relatively large number of members and network nodes, around 70 households. We then expanded our data collection to three of the other four CNs created in partnership with AlterMundi in Córdoba province, Argentina: La Bolsa Libre, La Serranita Libre, and Anisacate Libre (marked in Figure 2.1). Each CN is named after the town where it is located.

We identified interviewees through AlterMundi, recruiting CN participants in as wide a variety of roles as possible. We interviewed technologists who design networking equipment (4), people with official responsibilities in their networks (4) (e.g. collecting money), people trying to restart non-operational networks (4), people responsible for network hardware they mounted on their homes (12), and enthusiastic network users (15). In total we conducted 13 interviews with 15 people: 5 women and 10 men. Table 2.1 provides more detail.

2.3.3 Conducting Interviews

Interviews were semi-structured. Topics included how CNs are maintained, financed, used, designed, and governed. Though Nicolás Pace is a co-author on this chapter, we interviewed him as part of this study in his capacity as a technology designer, community animator, and member of AlterMundi.

All authors conducted the interviews together. Interviews were conducted in a mix of Spanish and English, with Nicolás Pace translating. The English portion of the interviews was transcribed for analysis. Interviews lasted roughly 45-90 minutes. Participants are identified by their real names, at their request. Data collection for this study was approved by the Athabasca University Ethics Review Board.

2.3.4 Data Analysis

We present a snapshot of a few specific CNs at one point in time, centering our analysis on the wireless mesh networks themselves to reveal how networking technology mediates others' courses of action. In Latour's 2005 re-articulation of ANT *mediation* is a key concept, referring to an actor's mobilization to act in response to being acted upon [87]. For example, when a swarm of wasps builds a nest inside a router, the router mediates the wasps' action by *stopping* the flow of data packets moving through it.

The first author analyzed the interview transcripts. The interview with Nicolás Pace was coded first with an open coding, and then these codes were synthesized into a small set of high-level codes reflecting this ANT-based interest in understanding the role of the networking technology as an active participant in CN sociality. Specifically, the coding scheme focuses on courses of action mediated by networking technology and the actions of the technology mediated by others. This set of codes was then used to code the full set of transcripts.

Name	**Gen.**	**Affiliations**	**Roles**
Gio	M	AlterMundi (AM)	AM tech developer, visiting
Nicolás Pace	M	AM	AM tech developer, long-term visitor
Martin	M	Anisacate Libre	Network member
Walter	M	Anisacate Libre	Network member
Alajandro	M	La Bolsa Libre	Network member
Natalia	F	La Bolsa Libre	Network founding member
Marcos	M	Quintana Libre, AM	AM tech developer, resident
Florencia	F	Quintana Libre, AM	Network *referente*
Jessica	F	Quintana Libre, AM	AM & network founding member
Nicolás Echániz	M	Quintana Libre, AM	AM & network founding member
Daniel	M	Quintana Libre, AM	Network founding member, early admin
Virginia	F	Quintana Libre, AM	Network founding member, early admin
Manel	M	Quintana Libre	Involved network member
Soledad	F	(Quintana Libre)	Potential new network member
Leandro	M	La Serranita Libre	Network founding member

Table 2.1: Interviewees by gender, CN/AlterMundi affiliations, and CN involvement. "Early admin" role refers to procuring initial bandwidth and managing finances for the Quintana Libre network, respectively; these roles have since been distributed among others.

2.3.5 Validity & Limitations

Since we have only interviewed a subset of CN members, we necessarily present a partial view of experiences in the CNs. Our sampling strategy—seeking a diversity of roles—was our attempt to make the most of limited time to conduct interviews. Relationships between CNs and those who are not involved is a ripe area for future work. In particular, people who have left CNs would provide a valuable complementary perspective.

Our analysis employed multiple rounds of coding as part of a process of rereading transcripts and revisiting audio recordings to ensure the account is faithful to our interviewees' perspectives. Following ANT, in the analysis we try to understand how research subjects construct meaning, since this is an integral aspect of understanding how actor-networks emerge and are sustained.

As an additional check on the validity of our results, the bulk of the analysis was conducted without Nicolás Pace. He read through early drafts and corrected any points in conflict with his understanding as a very involved member of AlterMundi. These corrections were minor (but important).

After writing a draft, we met with participants again to assess the validity of our interpretations (a form of member check). We invited all of our participants and conducted a small group discussion online with the few who were available to meet. We described both our descriptive findings and our interpretations, and we discussed two main questions: whether the interpretations fit their understanding and what feedback they have about how we are representing their communities. The response was quite positive, with enthusiastic support for the interpretations we were least certain about, and we learned more detail about how these issues are continuing to play out.

2.4 Findings

2.4.1 Relationships Constitute the Community of Practice

> *It's a social relation thing. That's the most important part of the network. It's not Internet... The network is an excuse. That's what I understand... and why I am part of it. For sure, there are more points of view, but that's what I think.*
> —Manel

For some interviewees, the CNs are an excuse to build community relationships. The networks bring together people of different backgrounds who have different goals for the CNs by prompting and reinforcing a variety of relationships, which in turn constitute the groups as communities.

The CNs are communities of *practice*; we identify their practices as participating in the relationships discussed here. To the extent that these are repeated practices and named relationships, they reify meanings that people bring to them, such as the importance of Internet connectivity or the productive challenge of collaboration. To participate *competently* in the community of practice is to plan, talk about, and do maintenance with others.

A number of concrete community strategies emerged.

Workshops. Quintana Libre runs workshops to introduce new people into the network. At the workshops, participants together assemble new roof-mounted nodes that manage the mesh networking protocol (while standard commercial routers installed inside users' homes are used as WiFi hotspots). Previously, AlterMundi's recommended way of assembling a node was to purchase a specific commercially available router, open up the case and weatherproof it, and install a new antenna. That model of router they used is no longer produced.

AlterMundi has designed and manufactured an alternative—the LibreRouter—which, among other differences, does not require weatherproofing. However, Florencia told us that this means the future of the workshops is uncertain.

> *For every [workshop] there is a coordinator, and all the people that want to build their own routers build their routers, their nodes. Now, with the LibreRouter, that you don't need to build it, now we need to think. What collective dynamic do we build around the joining action so those people that will join understand what [a community network is], acquire the knowledge to manage it, and also assume the commitment to sustain it?*

Florencia identified that some characteristics of their group (e.g., shared understanding and commitment to sustaining the network) are reproduced by these workshops. Without the need for assembling routers, she seeks a way to replace their valuable social functions.

La Bolsa Libre holds workshops too, and Alajandro sees them as playing an important social role: to "reinforce the importance of being together," which he sees as political, "a way of resist[ing] this right-wing struggle." Though these workshops also teach technical skills, it's the social pedagogy of learning to build community and solve problems collaboratively that Alajandro emphasizes.

Collaborative maintenance. Among our interviewees, novices doing maintenance are usually supported by someone else, such as neighbors who have done a similar task, or an expert in another town. Jessica explained how these mentoring relationships can begin at workshops or other CN meetings.

> *[In the workshops,] sometimes, [people have] organized collaborations like, "Oh, so you live in that house that I can see from my window. Well, if you will manage your node this Saturday, when I can go there and help you." So, they meet each other, they help each other, just because they live in the [same area].*

The collaborative work of maintaining the network brings people together and forms social ties. Those ties, in turn, support maintenance. Martin, a member of La Bolsa Libre, maintained a node connecting to the neighboring town of Anisacate, and would work with Juan (a pseudonym), who managed the other end, to solve hardware problems. Martin told us that when there was a major connection problem, he and Juan did not have the right relationship to be able to communicate and perform a repair.

> *This link that was broken—it was providing internet to Anisacate—has never been fixed, and it's something– It might be something simple, but there was no communication that helped. . . . It's not about having the number or to be able to call someone; it's the bond that makes the communication possible.*

However, Martin clarified that it's not just that the human relationship was unable to support the relationship between the routers—the technical link failing also weakened the social bond.

> *[W]hen we have the link, we talk to [Juan] almost every week. Like, we have a fluent relationship with, like, a friendship, you know. When the link went down, we stopped talking. So the network in a way was facilitating a social relationship. The other way around too, but the network was making that happen.*

Studying the Cuban CN SNET, Dye et al. also observe that maintaining connections between nodes depends on social relationships—she describes how a pair of users were disconnected from the CN because the owner of the node they connected to was uninterested in supporting the technical link and was able to exclude them due to their lack of "social influence" [43]. We discuss inclusion/exclusion in our case in more detail in section 2.4.4.

In La Bolsa Libre, the backhaul antenna connects to another antenna on a mountain a few kilometers away.[1] A few months before our interviews, a storm had knocked the mountaintop antenna out of alignment. Since then, the CN has been disconnected. In our interview with Alajandro, we discussed plans to realign the antenna. The research team was initially eager to join in the repair to contribute positively to the network as participant-observers; however, upon learning that the La Bolsa Libre community had already organized themselves to conduct the repair, Nicolás Pace told us not to join.

> *If you have too much technical knowledge, you can affect negatively the community. If we [the research team] go—if you come with me and we go on Friday to the mountain—we would be preventing for them [the members of the network] to go to the mountain and deal with it. So. And they were already organizing. . . . It's a healthy mechanism.*

According to Nicolás Pace, repair is an opportunity for learning: realigning this antenna is not just a social activity, but a challenge with pedagogical value. CN members *learning* to repair was understood to contribute to long-term network operation as much as, if not more than, the repair itself. If we intervened to simplify the process, we would be denying them a chance to exercise their technical problem solving capacities and expand their experience.

Assemblies and reunions. In order to coordinate the repair of the mountaintop antenna, members of the La Bolsa Libre network planned a reunion event—a barbecue—for the upcoming weekend. Having not met in a while, the group would use the CN as an excuse to

[1] A *backhaul* connection is a link between a local network and the greater Internet. Another long-range wireless link connects the mountaintop antenna to the Internet via the University of Córdoba, which allows use of their excess bandwidth.

strengthen important social bonds. By organizing the barbecue around the CN, La Bolsa Libre's members actively constitute themselves as a community despite their network's current dysfunction.

This finding also echoes a comment from one of Dye's participants in their investigation of the Cuban CN SNET: discussing the in-person meetups of the CN members, Alejandro (Male, 65) says "The most important thing about SNET is the relationship between all users" [43].

Quintana Libre members hold regular assemblies to make collective decisions about the network, such as managing membership and collecting money for repairs and upgrades. Jessica explained:

> Jessica: *You have to ask for help if you can't solve [your problem] yourself. [For] people who... don't feel [the] confidence to say, "I have a problem," ... we decided in [the] assembly... that people have to come a new [assembly] and a new workshop of the meeting to ask for... reentry.*
>
> Nicolás Pace: *They have to be resocialized.*

Like the La Bolsa Libre barbecue, these regular meetings help to constitute Quintana Libre as a community. Further, they are used to maintain norms and expectations, to "resocialize." Resocialization through assemblies is used to re-establish, in Wenger's terms, *mutuality of engagement* in response to people not *participating competently.*

2.4.2 Motivations are the foundation of relationships: What people want

Investigating some of the same community networks, Bidwell identified an important distinction between "members whose families had lived locally for generations and newcomers who moved to the area during its gentrification in the past decade" [24]. These two groups often give different meanings to the network. She writes, "Newcomers more often related the CN to political commitments... In contrast, members whose families had lived locally for generations...tended to relate the CNs to affordable connectivity." In our study, interviewees value the CNs for many reasons; e.g., communicating with loved ones, activism and community independence, or professional/economic use. From these, we identify affordable connectivity and political vision as two parallel modes in which desires about the CNs are produced.

Affordable internet. When Daniel moved to José de La Quintana, he was CEO of a telecommunications company. He wanted Internet service at his house and was working outside with a gardener when a representative from the local Internet Service Provider (ISP) came by. The representative described the new infrastructure the ISP would have to install to reach Daniel's house and quoted a price triple what Daniel knew it actually costs. At that moment, the gardener interjected, "Why don't you go to see these hippies? They have Internet that's free and super-fast." From there, Daniel quickly became heavily involved in Quintana Libre.

Like Daniel, most of our interviewees want a CN because they want connectivity and local alternatives are generally slower or much more expensive. In Quintana Libre, the monthly fee for using the network is ARS 100, about USD 1.5, significantly less than commercial Internet costs. The other CNs are similar. Members of Quintana Libre who cannot afford that price can instead support the network with their labor. Jessica, a co-founder of AlterMundi, described the economic situation:

> *[I]t's not a high-income place. But anyway, people usually have some kind of cellphone data connectivity which may be not permanent. Like they pay for it daily.*

The desire for affordable connectivity is distinct from the collective vision discussed next, but these are not mutually exclusive: many interviewees express both desires.

Collective problem solving as political vision. AlterMundi operates on principles that support and encourage open source technology and local community effort to combat digital exclusion [13]. They view local collective responses to problems—whether global, local or regional—as the most strategic for community survival.[2] CNs fit into this vision as both a solution to the problem of communications and as a catalyst for building community relationships, expanding capacities for collective problem solving in general. Nicolás Pace explained:

> *A dream is to create this empathic territory where communities will start helping each other. Because it's not [AlterMundi's] call to help everyone. Our call is to prepare a fertile ground for everyone to be able to do it. . . . We [all] directly or indirectly made the communities be vulnerable and be unsustainable and be in danger because of climate change and be dependent on global consumerism. . . If the communities grow in this empathy, there will be more hands involved in the process of making this [problem solving] happen.*

Further, Nicolás Echániz, a co-founder of AlterMundi, described the organization's goals as being in competition with individualist and capitalist models of service. "[T]he social economic organization here [in Argentina] is an individual capitalist [structure], so that's I think also a problem [for us]." In contrast, he recounted the relative ease of organizing in a Cuban community he visited to discuss potential CNs, due to robust existing practices of collective action there.

> *[T]he first meeting [about a CN] was already 70 people from every organization. . . . It's a completely different landscape. . . social organization. . . . They had to set up. . . one kilometer run of electricity poles and cable, and it was. . . organized or led by the [state-run] company, but the people dug the holes and brought out the poles and fed the workers [at] each house in that kilometer during 10 days. . . . It was not like, "Oh, this was something new." It's common sense. . . . They were doing this to bring electricity to one house.*

---

[2] CNs are similarly motivated in other parts of the world, e.g. the "vision-based organizing" of the Equitable Internet Initiative [139].

Just as prior experience facilitated the Cuban CN's inception, many of our interviewees hope that experience with CNs will develop capacities for starting other communal projects. Manel, a member of Quintana Libre, identified this inspirational power of CNs: "the relevance of these community networks is that they open a future that is not the official one."

This vision of broad participation in collective work is aspirational; in Córdoba, AlterMundi encountered barriers to collective action rooted in local histories. Argentina has a tradition of local service cooperatives for providing utilities (water, gas, electricity, etc.), which are democratically managed but with delegated responsibility. Nicolás Echániz explained:

> *The difference [compared to community networks] is that the workers are workers—are hired. People don't go fixing the electrical and water network... I think that for us having this mindset in Argentina about community services, cooperative services, has to do with people understanding quite easily the idea of having a community network. But then, when you start explaining "but you won't be calling the guys from the cooperative to come fix your node. You will fix it yourself," that is a step forward.*

In the service cooperative model, the community of practice would be a small group of trained professionals. But in AlterMundi's CN model, it includes a wide range of local novices in addition to some experts. The focus on broad participation illustrates that this vision is about a desire to be in community; this is the community that the CNs are an excuse for.

To achieve broad participation, CN members hold one another personally responsible for maintaining "their node" at their own residence, with support from others.[3] Manel explained this method of fostering responsibility:

> *Someone can come and just tell me, "I don't find the problem [with the node];*

[3] Because these networks use a mesh architecture, they are primarily composed of a router with one or more antennas mounted on each member's home. A family living together could have one node that is theirs to care for; in other communities with denser populations, the ratio of people to nodes might be higher.

> *I've [tried] this." . . . If they have done nothing, then no one will pay attention to that request. If they tried and they failed, someone will come and will help.*

In other words, people should first try to fix their hardware with their own knowledge, and then ask for help; this practice is a mechanism by which people are held responsible for their piece of the communal infrastructure, a *relation of mutual accountability*, in Wenger's terms.[4]

2.4.3 Network hardware as actor: What the network wants

The CNs face some trouble: despite the sociopolitical vision that many members share, non-participation lurks around every corner. Networking technology offers some affordances for collaborating with those who do not necessarily share that vision. In particular, it can (1) recruit and excite new people, (2) motivate people to take care of it, and (3) permit multiple readings of why the CNs are valuable.

If networking hardware is the central object of concern, ANT encourages us to ask (1) what/whose actions does the network mediate? and (2) what are the network's actions, and who mediates them? Networking hardware *connects* users' devices and other Internet-connected devices. It *supports* people in communicating with their friends and family. It *allows* children to spend all afternoon on YouTube. Sometimes, it *stops* connecting people to the Internet. And in these situations, it *needs* to be repaired. It also *needs* to be installed, to be upgraded, to be designed.

Soledad, a friend of a Quintana Libre member, visits her friend's house regularly to connect to the Internet. She was sitting on a chair outside her friend's house with her laptop, when, as she tells it:

> *One of the neighbors passed by—he's building his house—and he stopped with his truck, shocked, and asked [me], 'you have Internet* here*?' And [I] shared with*

[4]Manel actually rejects the term "responsibility" here because it might suggest coercion: "There are none responsible. . . Everything is voluntary."

> *him what the network is.*

In this sense, networking hardware *recruits* people into getting involved, raising curiosity and starting conversations: first with Soledad (who is planning to become a member herself), and then with the neighbor. Similarly, Martin related that the network gave him an excuse to talk to neighbors he sees only rarely.

> *[T]here are other neighbors behind me, around 50 meters, and I was just talking to them. . . . The topic allowed me to get in touch with a neighbor I see not too often because they work in Córdoba. Because I have my antenna here, it was easy to get to [discussing] that.*

Martin used the physical presence of the antenna to start a conversation about the CN. Thus, it is not just the idea of the CN but the material network hardware that is used to recruit. Indeed, we used the conversation-starting ability of antennae in our data collection: we conducted most interviews in the interviewees' homes, and, during or after the interview, we would often go to see their antenna.

La Bolsa Libre had been disconnected from the Internet for months, but Alajandro described their ongoing desire to repair their backhaul antenna on the mountain.

> *[F]ive and a half of the families are on vacation. So it's very, very difficult to [get] all together and have a reunion and go to [the] mountain to do the work. . . I think this Sunday we have a reunion. And then I think we will go to the mountain. . . and do that thing.*

Despite, or perhaps because of, the antenna's prolonged state of disrepair, the networking hardware still "*seduce[s]* people into taking care of it," to use a phrase of de Laet and Mol's (emphasis added) [38]. The network does not act alone; rather, it is made to act. The seductive power of the technology is produced jointly by people's desires for connectivity and for a communal project, the storm's chaotic ability to de-align antennae, and the decision to use that particular link for backhaul.

Finally, the networking hardware facilitates participation by people who interpret it differently. Manel describes the main difference in how people understand the CNs, echoing Alajandro's view (from 2.4.1) that the workshops are political.

> *People don't usually understand what it means to be social, the communal part. So, they came [to join the network] because they know it's... cheaper... It's harder [to get connectivity] because they are in a rural area. There are many motivations. But [to] understand what it means—that's why the workshops are there, so [that] people understand that it's not a service.*

The workshops are used actively by Quintana Libre to inculcate in new members the community-minded ethos and emphasis on broad participation. But even for some core members of the CNs, connectivity is the goal. Daniel has been a member of Quintana Libre and AlterMundi since their beginnings; here, he explains his focus on connectivity.

> *Having or not having Internet is more or less autonomy; it doesn't matter where the Internet come[s] from. ... It's not that the community network will give autonomy to the community; Internet gives them autonomy.*

Thus, it is possible for those who understand the CNs as primarily for connectivity to collaborate with those driven by the sociopolitical vision for the CNs. Crabu and Magaudda, in their study of the Ninux.org CN, found that, "often participants' involvement began on a mere technical level, but soon started intersecting with political views and practices rooted in leftist and in part anti-capitalist movements," suggesting a similar flexibility [35].

The hardware, the focal point of the CNs, is a flexible object in that it can permit these multiple interpretations. Despite their disagreement on the meaning of the network, Manel and Daniel could have a productive discussion about the direction in which the antenna of a new node should point, and they share goals such as including more people in the CN. Collaborating on technical issues is a common ground for all involved; this facilitates *mutual engagement*—one of Wenger's three dimensions of practice as the property of a community.

2.4.4 Social and technical protocol: The question of power

Anyone can join the CNs if they are within range of a wireless signal, and novices will get help if they are ready to take some responsibility for their node, as indicated by Manel in section 2.4.2. In practice, however, failing to carry out one or any of these expectations alone has not proven grounds for exclusion. There also needed to be technical failure. Jessica and Nicholàs Eshániz described the sole case of eventual exclusion that we came across, and how the person had installed a connection to the Quintana Libre routers without officially joining the CN.

> Nicolás Echániz: *This guy has a client device pointed at our node, which is open.*
> Jessica: *He... made that helped by our neighbors.*
> Nicolás Echániz: *Yeah, he was helped by our neighbor here*
> ...
> Jessica: *And [the priest] talked to me, and he asked [to] be part of the network, and I told him, "Okay, you have to come to the meeting," ... and I think that it was too much for his Lefebvrism.*
> Nicolás Pace: *He would have to face all the members of the community.*

While the community member had expressed interest in joining and had found a way to connect to the CN without permission, he did not attend any meetings. Eventually, his hardware broke down.

> Jessica: *We didn't disconnect him, but when... his node was*
> Nicolás Echániz: *Hit by a lightning or something.*
> Jessica: *Yes. Nobody wanted to help, so he [was] disconnect[ed], because–*
> Nicolás Pace: *And the network didn't pay for a replacement, [though usually] the network pays for replacement hardware.*

In this telling, the action of the lightning and networking technology are foregrounded: it is the technical breakdown which occasions his disconnection from the CN. Simultaneously, we see other actors - the other CN members - who did not want to help and decided not to pay for replacement hardware. The priest's (lack of) participation failed to produce in the other CN members the desire to help repair, and thus he was unable to take advantage of the collaborative mechanisms that others rely on to keep their hardware functional.

Jessica identified four levels of participation in the Cordoba networks: (1) core and ongoing active participation, (2) people who participate when asked, (3) people who only participate occasionally in small ways (4) as described above, people who contribute no labor. Jessica's four levels of involvement directly parallel Wenger's four levels of involvement in a community of practice: (1) core, (2) active, (3) peripheral, and (4) outsider [160, p.57]. So-called outsiders violate the relations of mutual accountability that shape the joint enterprise of the community of practice. In fact, this standard of "being responsible to others by not making their lives more difficult" has been identified as a relationship of mutual accountability in prior work [159, p.81]. Jessica used the term "leech" to describe the nonreciprocating community member, a term which legitimizes the others' unwillingness to help the "leech"—this is a discursive component to CN inclusion.

Non-payment of ongoing costs for covering CN operations and non-performance of volunteer services did not prompt disconnection from the CN. Instead, the regulating mechanism for CN inclusion was a combination of technical network function and the willingness of CN members to assist with maintenance. In the case described above, when the "leech's" node needed repair, no one came to help with the repair because he was not participating in the CN. Broken social protocol combined with technical failure ended the relationship.

We observed two kinds of protocol at work defining network operability. The technical operation of a digital network requires each node to comply with the LibreMesh standards. Inclusion in the event of technical failure—when LibreMesh standards fail to be met—requires compliance with social protocol. Recruiting help when your node breaks requires accepting the terms of mutual accountability on which network functionality depends. Network functionality encompasses both kinds of protocol agreement: technically, between nodes and socially through collective assistance in the event of breakdown beyond a node owner's capacity to repair. This limitation in capacity is important. If the node owner described above had been able to repair his own node after the lightning strike, there is every indication that he would have been allowed to stay connected. The social protocol is rooted in reciprocity. Since breakdowns are inevitable, the end result is that those who refuse to engage lose their ability to connect (technically) to the CN. In this case, breakdown of hardware is used not as a learning opportunity, but rather to manage the social boundaries of the CN.

This could have an impact on CN members incapable of meeting accountability standards for reasons other than selfishness—for example, physical and mental disability, infirmity due to age or other ailment, lack of time due to parenting obligations, etc. Bidwell in her study of CNs in Indonesia found that "expectations for cooperation affect different parts of local society differently," revealing that women and elders did not receive the help they required to be connected, despite assertions that those with access would "always help" those without [25]. Though our study did not reveal any similar cases, the possibility of future exclusion remains.

Another dimension of power in CN operations is knowledge, which is directly related to both the social and technological protocol for CN inclusion. The figure of the *leader* or the *geek* is viewed as problematic by many of CN members we spoke to. "Geeks" are people who have more technical knowledge and experience giving them a higher capacity for debugging and repairing network problems, but as a result they can take on too much responsibility. A CN can end up depending on geeks too much, and their efforts could dampen broad participation. The admins of the Cuban CN SNET, for instance, have a role as an obligatory passage point: other users are strictly dependent on their technical labor to remain connected [43]. Some members of AlterMundi, for instance, were concerned (based on experience with other technology projects) that a CN could become dependent on a single geek and then collapse if/when that person decides to move on. Marcos, a software developer with AlterMundi, explained that he tries not to help with too many technical issues in the network so that others with less expertise can expand their technical capacities by volunteering to repair.

> Esther: *So, for example, if you know, everyone is saying on the WhatsApp group that there's a problem. Then do you go?*
> Marcos: *No. I read it. I wait for the people to react, and for them to solve it. Many times the problem has nothing to do with the network itself. [Instead,] with the electricity, someone has unplugged the router. Or something like that.*

Marcos's expertise is important when there is a bug in the LibreMesh software, but most issues do not reach that level of difficulty. This contrasts with the issue Bidwell identified in the Indonesian CN where those with more technical expertise said they would always help, but did not [25]. Instead, Marcos's decision to selectively not help others with maintenance is pedagogical, designed to foster broad participation. Stepping in to solve problems too often works against the kinds of collective learning and capacity building required for long term CN sustainability where expertise is more evenly distributed among community members.

In contrast to these problematized roles, members of the CNs have developed a formal, positive role for people to assume which they call the *referente*. A referente is a CN member who others can go to for help, usually with technical tasks, but their role extends beyond the technical to the social by working with community members as educators to help realize the political vision for the networks. Often, these are laypeople—technical novices who, through experience with the CN, have just enough knowledge to be useful to others. Florencia, a referente for Quintana Libre, sees growing the group of referentes as crucial for sustaining the network.

> *Through these and other experiences, we are convinced that the challenge is educate those leaders [referentes]. . . The people need to have this technical knowledge, need to have political vision, education, that can be available at the disposal of the communities and a bridge for the communities to hold [and] sustain the network.*

While the "geek" image suggests highly-specialized technical expertise among a small set of enthusiasts, *referente* is a role more accessible to many community network members that includes some knowledge of the telecommunications technologies involved. "Geek" is a word of warning, a critique of knowledge hierarchy. *Referentes* are a strategy for resisting concentration of knowledge.

Martin, a software engineer and member of the Anisacate CN, has a slightly different view of the referente, one imbuing the role with a certain authority. Martin wanted to update the routers in their network. However, he hadn't (yet) made the change, explaining, "I don't want to challenge the referente." In this instance, an expert prioritized the social value of referentes to the CN over a quick technical solution. Thus, despite an envisioned non-hierarchical relationship between referentes and other CN members, they, like "leaders" or "geeks," shape how and when others contribute.

In summary, CN inclusion in these cases depends on three kinds of regulatory conditions: technical agreement between nodes, collective repair, and ongoing resistance to concentration of technical knowledge. The normal assistance CN members provide each other to reestablish connection in the event of failure depends on informal standards of reciprocity, and a perceived lack of reciprocity is as significant as technical failure in determining inclusion/exclusion. These informal standards of reciprocity on which this is based, as observed by Bidwell in Indonesia, can also obscure power imbalances within a community, which is an ongoing concern for the CNs.

2.5 Designing for a Repair Community of Practice

2.5.1 Design Decisions

> *The LibreRouter is a distillation of principles, values, techniques, and practices, as a whole, not only the device, but the whole proposal. Like, the way we offer the LibreRouter tries to put together. . . a set of tools that allow the communities to explore the community network territory by themselves, having the capacity to reach out if they need help.* —Nicolás Pace

AlterMundi (re)designs their technologies to change *how* the networks need maintenance so that lay people can become more involved in the social relations of maintenance. This section documents technical choices intended to make the community of practice more accessible to novices, thus inscribing AlterMundi's political vision discussed in 2.4.2 into the networking hardware and software. AlterMundi designs for a repair community of practice by (1) helping novices learn to maintain networking hardware, (2) promoting mutuality of engagement in the community of practice (section 2.5.2), and (3) flattening the learning curve for network maintenance (section 2.5.3).

AlterMundi has tried to make the networks they support easier for laypeople to understand. By representing information about the network in accessible ways, users can develop better mental models of how the network functions.

Traditionally, network administration is done via a command-line console or desktop user interface. Experience with the command-line is a sign of software expertise, and these consoles are almost always accessed on a laptop or desktop computer, which many cannot afford. AlterMundi has built a mobile application, LiMe App, that makes many tasks normally done on a command-line possible from a smartphone via a graphical interface. AlterMundi developer Gio notes that they made one task, the `traceroute`, more legible in the LiMe App by replacing Internet Protocol addresses (IPs) with Spanish names for network nodes.

> *When I do, for example, a traceroute, for me was very comfortable to just see the IPs. But [for] the community it's not... So the feature request was "please, in the traceroute, show the names, the actual names of the nodes, so we don't have to go in the map and look for the IP address."*

This user-driven feature demonstrates an advantage of broad participation in CN development: an engaged group of lay repairers can help improve interfaces for networking technology. Bidwell describes the co-design of the LiMe App in more detail, and argues that it is part of a commoning practice [23]. Concisely and accessibly representing network state directly supports repair. By sharing screenshots of the LiMe App in WhatsApp groups, laypeople communicate network state and recruit debugging help via a smartphones.

To support repairs to the LibreRouter hardware, one of two internal boards is designed with a simple circuit layout so that repairers can comprehend it visually; the other replaceable board concentrates the most complicated components. Similarly, the hardware is made easier to inspect with an abundance of General-Purpose Input/Output (GPIO) pins.

For users who want to get more deeply involved in tinkering with the network, the LibreRouter firmware and LibreMesh software are open source and written in Lua,[5] selected because it is an easy language to learn even if it is not the favorite tool of AlterMundi's software developers. The software and hardware are both documented thoroughly online (albeit for a somewhat technical audience), with some of AlterMundi's non-expert members on the documentation team. We have not collected data on whether these attempts to make the technology more hackable are being appreciated by users.

Experimenting and tinkering are important for developing practical technical experience. Whether it's a new phone experimentally thrown in the river [81] or an old computer gleefully destroyed [48, p.9], hardware designated for experimentation is made educationally useful since learners can use it without fear of destroying something valuable. Spare parts are useful for more than just successfully completing repairs, the primary use identified in earlier work [84, 75]. Nicolás Pace described the importance of having extra devices to work with.

> *Because we don't have the resources available, like the equipment, or the money to purchase the equipment, . . . our capacity to learn, to experiment, to tinker, to break [is reduced]. . . if you can break something, it's like you feel much more confident that you can try things out. And if it breaks, you put another one.*

To make the LibreRouter and its parts readily available, thought has gone into the supply chains for various components. Part of the motivation for concentrating the most complicated parts of the router on a single small board is that it is small enough to ship inexpensively (compared to shipping costs for the whole router). Since the design is all open source, even that circuit board could be manufactured by any organization with an electronics laboratory. Likewise, AlterMundi's parabolic antenna design is carefully configured for manufacturability

[5]`https://lua.org`

by a common blacksmith. Molding metal into a true parabola is challenging, but their approximation of a parabola is easy to manufacture while retaining functionality.

2.5.2 Designing to Shape Social Relations

In two of the CNs we visited, participants discussed using a captive portal (a web page to which a WiFi router redirects users when they connect) to set expectations for how people should participate in the network. They envision captive portals as one way to teach newcomers that a CN is not a commercial service, but a community project. Natalia explicitly connected teaching with setting the expectation that users contribute to the network.

> *For someone that is not part of the network, they need to learn. They can use the network, but they should learn. So if the billboard—the page—should appear not only when they connect... they should be disconnected every 30 minutes maybe, and they need to connect again and to see a video again... It's like reinforcement learning. You as a teacher, you say something, and you do it again, and you do it again, and you do it again. And that way, if you're like this, then you will [get] fed up and you will go.*

Natalia wants a captive portal not only to educate people about the CN's social mission, but to ensure that most network resources go to those who become CN members. In making this proposal for a captive portal, Natalia is engaging in design. As imagined, the captive portal would contextualize and interrupt access to the Internet, thus serving as both a rhetorical tool and technical form of gatekeeping. Through interacting with this portal, new users would have to negotiate what the CN means to them—in the theory of communities of practice, such *negotiation of meaning* is a foundation for *mutual engagement* between network users [159, p.73]. Since maintenance is a core part of being a member of the CN, encouraging people to join is also about expanding the repair community of practice.

Another example of social design is the remote support plaftorm in development by AlterMundi to facilitate collaborative problem solving among CNs globally, and between

CNs and distant technical experts. Nicolás Pace articulated part of AlterMundi's learning philosophy for us, arguing for the importance of peer-to-peer education.

> *When networks teach each other, they are the same level. They are not like the hacker over there and we the common people. And that creates a lot of bridges that make the learning process much easier. It can happen with materials and it can happen with training too.*

This potential online community of local CN maintainers could help repairers learn in a manner similar to the webfora that Ahmed *et al.* found in Dhaka, Bangladesh[10]—perhaps with more collaboration.

On a local level, this online community has been created. WhatsApp groups for each CN were formed early on to promote collaboration, and they are used for debugging (described above). As town-wide chat groups, these have strengthened social bonds. In Quintana, creation of the CN group led to organization of unrelated activities and creation of additional local groups. Though creating WhatsApp groups is not design in the usual sense, we include it here since it was a technical reconfiguration intended to mediate the networking technology's need for maintenance, similar to the remote support platform.

2.5.3 Designing for Repair

Fixing or replacing components on circuit boards is an advanced, yet relatively common, repair practice. Jackson et al. describe repairers in Dhaka fixing broken connections on motherboards, a task complicated by the density of components on the board [82]. To simplify repair for novices, as described above, AlterMundi divided the LibreRouter circuit board into two boards. A smaller, denser, replaceable board holds the CPU and the most complicated components, while the larger one is designed for easier access and analysis. The modular design principle is further used to make components that are likely to fail replaceable. Gio described components inside the LibreRouter.

> *In the middle there is this gas arrestor that protects from electricity discharge, . . . and eventually those gas arrestors may burn. . . . [Y]ou can see here they are mounted in a way that it is very easy to replace them.*

With replaceable gas arrestors, fixing a fault caused by electrical discharge is no longer a lengthy procedure that demands significant expertise, but rather a simpler task that a novice (with the right spare parts) could be coached through. Modular hardware design (á la the Fairphone) has been recognized as supporting repair. In Wyche et al.'s study of rural Kenyan mobile phone repair, participants lament the non-modular design of the circuits in cheap phones compared to the multiple separate circuits of brand-name phones [162].

In addition to modularity, the pins on the LibreRouter's larger board are physically arranged for easy soldering. The board's solder points are exposed on one side, with pins spaced for easy access.

These design decisions shape the LibreRouter, like those described above that shape the LiMe App, the antennas, the potential captive portal, elRepo.io, and the remote CN support platform. Across all of them, we see technologists making decisions intended to not to minimize repair but to change the maintenance of the networking hardware, whether to make it easier (as with replaceable gas arrestors), more accessible (changing the names on the traceroute), or to encourage those who use the network to participate in running the CN (as with the captive portal).

2.6 Conclusion

ANT suggests that social realities emerge from within networks of actors and objects [87]. Uniquely, ANT views non-human creatures and non-living objects as potential actors in the formation of social reality. CN operability and sustainability in this case create particular kinds of demands and relations—for example, demands on "geeks" to incorporate design decisions that facilitate collaborative problem solving and that walk the delicate line between revealing overwhelming detail and obscuring necessary information.

The repair community of practice is maintained intentionally through workshops, assemblies, barbecues, and more that sustain relationships between CN members. This community of practice simultaneously maintains the networking hardware and is reproduced through the hardware's need for maintenance, which is its *raison d'être*. Norms around collaborative repair allow the group to function like other communities of practice: relations of mutual accountability structure cooperation on a joint enterprise [159]. When AlterMundi redesigns the networking technology to make repair more accessible, the vision of broad participation in collective work in inscribed into the hardware and software. And as AlterMundi's technical work reshapes the manner in which the technology needs repair, the networking technology in turn lends durability to the repair community of practice.

Protocol of inclusion and exclusion rooted in technical and social frameworks present opportunities for power relations extant in communities to influence network functionality in differentiated ways. In this case, the only evidence of exclusion found suggested the dual significance of both technical and social protocol in regulating network access. A failure to meet standards of reciprocity in this case resulted in an unwillingness on anyone's part to repair a node. And yet, had only one member offered to repair, exclusion would not have happened. Such informal standards could present opportunities for abuse as has been found in other studies, and is suggests future longitudinal research on community network sustainability.

This study highlights the complexity of the relationships involved in repair, with a particular interest in the role of the networking technology as an actor. Due to this complexity, supporting repair requires a deep understanding of the social relations at play. In that direction, our analytic approach may be valuable for technology designers. Building on this study, one could ask (thinking with ANT) "what role does this technology currently play in the social context of its maintenance?" and (thinking with Lave and Wenger) "what sort of repair community of practice should this technology be designed to support?"

Jang et al. outlined a map for fostering a robust repair ecosystem, depending on availability of tools and parts, experts to learn from, opportunities and funding for practice, and accessible formal education and institutional certification [84]. In this case, we find a robust repair ecosystem without formal education or certification; instead, CN assemblies and expectations of personal responsibility help establish the protocol of reciprocity required to maintain network functionality.

We identify some specific ways in which technical artifacts can support a novice community of practice of repair and maintenance, including: (1) making technologies more understandable by novices, (2) fostering social relationships that support learning, (3) reducing the need for "geek-only" repairs, (4) making advanced repairs more accessible, and (5) making devices, parts, and repair tools abundant and affordable. Design decisions that addressed each of these points were significant in this case and can serve as guide and inspiration, but they must be understood as part of AlterMundi's broader engagement in the repair community of practice.

Chapter 3

THE COLD CHAIN EQUIPMENT MANAGER: AN ICTD PARABLE

Sunday, February 13, 11pm. My advisor, Richard Anderson, emails one of our colleagues, Marie,[1] in the Ugandan Ministry of Health a set of instructions for patching a Microsoft Access application built for 32-bit computers to work on her 64-bit machine. Marie is a cold chain technician—the "cold chain" is the sequence of refrigerators and/or freezers that vaccines pass through in their logistical lifetime—and the application in question is the Cold Chain Equipment Manager (CCEM). CCEM is used by government health officials to keep track of this refrigeration equipment. Richard's instructions are a postscript to an email primarily about scheduling a meeting.

> Ps – Blake[2] mentioned that you are having difficulties with CCEM – in that it would run on a new laptop.
>
> The issue is that there is a change that is needed for visual basic to run on 64-bit machines.
>
> The steps to do this:

```
Open CCEM
Hold down the key Alt-F11  (this accesses the visual basic code).
```

> Now you need to change the word 'Declare' to 'Declare PtrSafe' in all files, by doing a global replace. My notes give the following steps:

[1] A pseudonym

[2] A pseudonym

```
Edit Replace
Current Project
'Declare' to 'Declare PtrSafe'
Replace All
```

This should report that 51 replacements have been done. That should be everything you need to do. Happy to provide additional assistance.

Richard

It's morning in Uganda, and Marie replies within half an hour that Alt+F11 doesn't work on her Lenovo computer. To execute the find and replace on her computer, Marie will need to click "Okay" through 109 error messages and use Alt+Fn+F11 instead of Alt+F11.

This chapter elaborates a history of CCEM, centered on this simple email exchange. I chose this exchange without knowing what connections my investigation would reveal, simply because I was struck by the fact that Marie is still using CCEM in 2022, long after support for the tool has ended. In other published accounts of CCEM, nuanced historical context is left out—a standard pattern in reporting on ICTD projects when the focus is on the software. This chapter is not an evaluation of CCEM; rather, its contribution is to contextualize CCEM in a historical narrative, thus giving readers interested in the project a richer understanding.

The maintenance burden of CCEM is impressively small, which works well in the context of an underfunded healthcare system. But Xiaowei Wang calls us to examine how Ugandan healthcare infrastructure challenges are produced, writing, "The promise of software and technology is that they help solve the problems we face right now, without addressing how those problems began—problems including the uneven distribution of basic resources like food" [158]. This chapter pushes back against the current of solutionism by drawing connections between CCEM and potential causes of Uganda's healthcare infrastructure challenges. But this is not an exposé of CCEM; there is no scandal here, but I want to refute assumptions of the innocence of ICTD work. As CCEM is in many ways a pretty regular ICTD project, the analysis shows how ICTD projects can get entangled in dynamics that reproduce the problems they try to solve.

This investigation is guided by the same central question as the thesis overall: what relationships are maintained by our work on computing for development?

3.1 64-bit machines

All mainstream computers are built to execute assembly instructions from the x86 instruction set. Instructions manipulate values in memory many bits at a time. Each architecture (corresponding to a particular x86 specification) has a default "word" size, which is the number of bits of memory that an instruction operates on by default. The word size is also the number of bits used to reference a specific location (which is itself eight bits, or one byte) in memory. So in a 32-bit architecture, a location in memory might be specified in binary as the following.

```
11111111 00000000 00000000 10001011
```

Converting this binary value to decimal, it would refer to the 4,278,190,219-th byte of memory. Since there are are 32 bits available, the total number of memory locations that are nameable is limited to 2^32, which is 4,294,967,296, or approximately four gigabytes. The implication of this is that a computer with a 32-bit architecture cannot make use of more than 4 GB of RAM (Random Access Memory). A 64-bit architecture, in contrast, has a 64-bit words like the following.

```
11111111 11111111 00000000 00000000 00000000 00000000 00101100 10001011
```

With 64 bits, the total number of memory locations expands to 2^64, which is $2^32 \cdot 2^32$, or $18,446,744,073,709,551,616$, around 18 exabytes. If that sounds like a ridiculously large amount of RAM today, consider that four gigabytes also sounded huge when the first 32-bit microprocessors were released.

CCEM wasn't working on Marie's laptop because it was built for a 32-bit computer but hers uses a 64-bit architecture: the code was expecting to use references to memory (pointers) with half as many bits as her processor was expecting. This is a well-known issue, and the programming language CCEM was developed in, Visual Basic, has a way to work around it: the `PtrSafe` keyword from Richard's instructions.

When we refer to RAM colloquially, usually we are referring to Dynamic Random Access Memory, DRAM. (Its counterpart, Static RAM, is used internally in processors). Amid the dot-com bubble, DRAM manufacturers were increasing their memory density (i.e. how many bits they can squeeze into a device), and CPU manufacturers started planning for a shift from 32-bit to 64-bit machines. AMD released their 64-bit version of the x86 instruction set, x86-64, in 1999. The first processors to implement it, also from AMD, were not released until 2003. It would be years more before everyday PC users got their hands on machines with more than 4 GB of RAM—even today many devices are sold with 4 GB of RAM or less—but CPU manufacturers were responding to the consumer demand for increased RAM and the innovations in DRAM development.

The basic memory unit of DRAM is the transistor-capacitor cell, in which a capacitor (like a battery) can store a charge, or not, representing one bit. 3.1 gives a schema of this building block. This was the basic design proposed by Robert H. Dennar in 1966, and that core pattern has been basically unchanged since [41]. Capacitors store a charge, and the more charge stored in the capacitor, the higher the voltage across it. This is expressed by the formula $Q = CV$, where Q is the stored charge, in coulombs, V is the voltage across the capacitor, in volts, and C is the "capacitance" of the capacitor, in farads. Depending on the geometry of the capacitor and the materials used, the capacitance C changes: with higher capacitance designs, a greater charge can be stored at the same voltage. To squeeze more and more transistor-capacitor cells into a DRAM chip, each one should operate at a lower voltage while storing a sufficient charge. Thus, increasing capacitance has been a key goal of innovations in DRAM development.

In the period from the late 90s through early 00s, one source of big improvements in

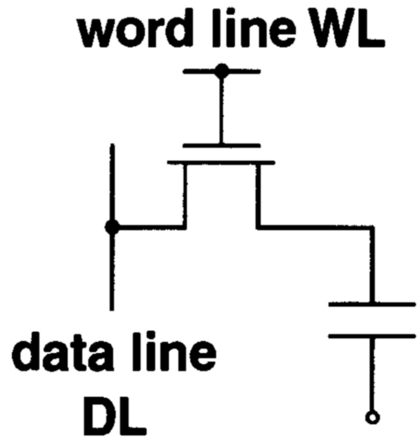


Figure 3.1: The transistor, where the word line and data line meet, acts as a switch controlling whether the capacitor on the right is connected to the data line. For the write operation, the switch is turned on by applying a high voltage to the word line to connect the switch, then a voltage (high or low) is applied to the data line and stored in the capacitor. The circle in the bottom-right below the capacitor represents a connection to "ground", defined as zero voltage [79].

DRAM capacitance came from the use of the new material tantalum oxide, Ta_2O_5. Tantalum oxide was specifically useful for DRAM "because of its high dielectric constant ($\sim$ 35), high refractive index and chemical and thermal stability with the promise of compatibility with microelectronics processing" [51]. The "dielectric constant" mentioned here is directly proportional to the resulting capacitance. In comparison, one of the common materials at the time was silicon oxide, SiO_2, which has a dielectric constant around four.

Though DRAM manufacturers tend not to announce publicly the materials they use, patents can give us a sense of where their attention lies. For example, one of the top DRAM manufacturers, Micron, was submitting patents on the use of tantalum oxide in DRAM with priority dates as late as 2006 [90, 54, 56, 55].[3] Today, tantalum oxide is less common in DRAM, but other compounds using tantalum continue to be used in capacitors both in

[3]Companies often file multiple patents in one "family" as different parts of a single invention. The priority date of a patent is the date of the first patent in the family, which the patent office considers as the "effective filing date."

DRAM and elsewhere in computers [145].

Tantalum is primarily found in the mineral coltan, a combination of columbite (made of niobium, previously called columbium) and tantalite (made of tantalum). Niobium has also proved to be a useful capacitor material: it has properties similar to tantalum, as one would expect given that they occupy the same column of the periodic table. It is estimated (with some imprecision) that the DRC holds the majority of the world's coltan deposits (one estimate is 64%[62]). In the same time period, from 1998 to 2003, Uganda was waging a war (with their ally Rwanda) in the East of the DRC, escalating from their 1996-1997 military involvement there. A 2001 United Nations report on the war found that Uganda and Rwanda were profiting massively from their extraction of natural resources from the area, including coltan [34].

> The Panel, on the basis of the data, accounts and documents received and analysed, came to the conclusion that the systems of illegal exploitation established by Ugandans and Rwandans differ from each other. In the case of Uganda, individuals, mainly top army commanders, using their hold over their collaborators and some officials in rebel movements, are exploiting the resources of The Democratic Republic of the Congo. However, this is known by the political establishment in Kampala.

Not only did individual Uganda officers profit off of the war, so too did the Ugandan government, by way of export taxes.

> The re-exportation economy implies that natural resources imported from the The Democratic Republic of the Congo are repackaged or sealed as Ugandan natural resources or products and re-exported. That is the case for some gold, diamonds, coltan and coffee exported by Uganda. The re-exportation economy has had a tremendous impact on the financing of the war

In the panel's analysis, income from the export of natural resources was used to finance the military further, and on all sides the conflict was "mainly about access, control and trade of five key mineral resources: coltan, diamonds, copper, cobalt and gold", so they argued that the conflict should be seen as a lucrative business venture.[4]

> The conflict in the Democratic Republic of the Congo, because of its lucrative nature, has created a "win-win" situation for all belligerents. Adversaries and enemies are at times partners in business (Maï-Maï and Rwandans and Congolese rebels), prisoners of Hutu origin are mine workers of RPA, enemies get weapons from the same dealers and use the same intermediaries. Business has superseded security concerns. The only loser in this huge business venture is the Congolese people.

The story of the rise of personal computers, including innovations enabling denser DRAM chips, is incomplete without an account of coltan mining. It should be noted that, at the time, Australia produced the most tantalum of any country, though in the coming years tantalum production would shift to mainly the DRC and Rwanda [154, 153][5]

3.2 Foreign aid

To put CCEM in the context of Ugandan history, the reader needs a little background on foreign aid in the country.

In 1891 the Imperial British East Africa Company (IBEAC) signed a treaty with king Mwanga II of Buganda putting the kingdom under IBEAC's protection. In 1894, IBEAC transferred control to the British Empire. Violence and resource extraction in Uganda have a long history, as does innovation. Richard Reid, a current British professor of African history, argues that there are substantial continuities between precolonial and postcolonial violence.

> [I]n some respects precolonial mechanisms for conflict resolution were undermined [through colonization], much of the violence itself was actually precolonial in ori-

[4]Copper, cobalt, and gold are all also important minerals in the manufacture of computers.

[5]Though that war ended in 2003, violence, extortion, and coercion of miners in the DRC. is ongoing. These resources continue to be exported via Uganda, Rwanda, and Burundi.

> gin – most obviously that involving the hegemonic southern kingdoms, especially Buganda. Cultures of violence and militarism long pre-dated the formal creation of Uganda, and the fault lines which opened up in the years following Uganda's independence in 1962 were in fact of considerable antiquity. And so, too, were the histories of cultural interchange and reciprocal inspiration, and the economic networks which bound together diverse communities to mutual advantage. If war was old, then socio-economic connectivity was just as deep-rooted [124].

In particular, the Baganda were collaborators with the British and the Kingdom of Buganda remains powerful in the country today.

In 1944, as World War II approached an end, the Allied Powers established the International Monetary Fund and the World Bank through the Bretton Woods agreement, putting the US dollar at the center of the international financial system. The initial focus of the international financial institutions was to support European reconstruction in the wake of the war, but it would soon expand. In 1949, President Truman announced in his inaugural address a foreign policy toward the Third World that would morph into the international development of today. "For the first time in history humanity possesses the knowledge and the skill to relieve the suffering of these people" [147]. Through "greater production" and "democratic fair dealing," the U.S. would save the Third World. The early development discourse is unabashed in its paternalism. Consider the following excerpt from a UN report on the "Measures for the Economic Development of Underdeveloped Countries."

> There is a sense in which rapid economic progress is impossible without painful adjustments. Ancient philosophies have to be scrapped; old social institutions have to disintegrate; bonds of caste, creed, and race have to burst; and large numbers of persons who cannot keep up with progress have to have their expectations of a comfortable life frustrated. Very few communities are willing to pay the full price of economic progress [151][6]

[6]This UN report and Truman's inaugural address are quoted in Arturo Escobar's *Encountering Devel-*

But the international aid was not motivated simply by paternalism: aid to the Third World was used by both the Soviet Union and the Western powers through the 1980s as a tool to win allies in the Cold War. In 1967, for example, President Nixon said, "Let us remember that the main purpose of aid is not to help other nations but to help ourselves"[].

Uganda achieved independence from the British in 1962, after which Buganda king Edward Mutesa II took power. Rule of the country was contested until approximately 1994, with many conflicts throughout. Milton Obote and Idi Amin were the primary heads of state through 1986, when current president Museveni took power following the Bush War. The current constitution (the fourth in Uganda's history) was instituted in 1995.

On his 1986 ascension to power, Museveni's government "envisioned a shift to a pro-people, broad-based, humane, accountable and moral government and state" but quickly ran into budget shortfalls and chose to accept aid from the World Bank and International Monetary Fund, along with the neoliberal conditions they required [161, p.11]. This included first "the implementation of Structural Adjustment Programmes (SAPs) in the late 1980s, and then liberalisations, privatisations, 'de-regulation' and public sector reform in the 1990s."

Broadly, Museveni went along with the economic reforms of the international financial institutions while resisting their requests for multi-party democracy. In response to this and to Uganda's military partnership with the US (Al Jazeera, cited in Reid), Uganda received great praise as a "success story" and a "donor darling." (In this quick history I am conflating Uganda's various donors, both other nations (bi-lateral) and international financial institutions (multi-lateral). In the late 2000s this will also come to include the Bill and Melinda Gates Foundation.) Following the dissolution of the Soviet Union in 1991, "the geopolitical momentum and rationale of the international development apparatus was lost with the end of the Cold War, pressuring donors to demonstrate results to maintain moral and economic support at home. Combined, these factors led to a massive increase of foreign aid and actors to Uganda from the mid-1990s by donors wanting to be part of and contribute

---

opment. [46].

to the success story" [161, p.45].

The 2001 UN report on the Second Congo War argued that foreign aid had an important role in enabling Uganda's occupation of the DRC.

> The apparent strength of the Ugandan economy has given more confidence to investors and bilateral and multilateral donors who, by maintaining their level of cooperation and assistance to Uganda, gave the Government room to spend more on security matters while other sectors, such as education, health and governance, are being taken care of by the bilateral and multilateral aid.

In fact, not only did the donors turn a blind eye to the war profiteering, they lauded the positive impacts on the government's budget.

> In the case of Uganda and its exploitation of the natural resources of the Democratic Republic of the Congo, the World Bank never questioned the increasing exports of resources and in one instance a staff member even defended it. During the Panel's visit to Uganda, the representative of the Bank dismissed any involvement of Uganda in the exploitation of those resources. The Bank not only encouraged Uganda and Rwanda indirectly by defending their case, but equally gave the impression of rewarding them by proposing these countries for the Highly Indebted Poor Countries debt relief initiative [34].

The biggest conflict between donors and Museveni would come in 2005, when two factors came together. Museveni planned to amend the 1995 constitution to remove the limitation on presidents only serving two terms, so that he could legally run in the 1996 elections. This brought long-term tensions between the donors' interest in multi-party democracy and Museveni's insistence on single-party rule to a head. At the same time, internal corruption reached a critical point.

> The 2005 World Bank (WB) survey estimated that up to $300 million were lost per year through corruption and procurement practices. With increasing corrup-

> tion, donors threatened to cut aid, pointing out that a Corruption Perception Index (CPI) score below four was unacceptable (Ambassador Stig Barling, in Masumbuko 2005). Uganda's CPI remained below three, and even declined after 2009, yet aid inflows continued and even increased from 2005, despite the threat (Asiimwe 2016). The donors' failure to execute their threat led to questions about the underlying rationale behind, and interests of, giving aid [18].

Despite their disagreements, the bi-lateral and multi-lateral donors financial support for Museveni's government remains quite stable, as ample international aid continues to flow to the government [7].

3.3 The cold chain

> *Is the cold chain just a network of cooling equipment? Is it just a team of workers trained to order and distribute? Is it simply the technology of processing and packaging? The cold chain is all of these things, bound together in a managerial system whose objectives and whose procedures are clear to everyone involved.*
>
> —John Lloyd [93]

The origins of the immunization cold supply chain lie in the WHO's 1966 campaign to eradicate smallpox. In order to successfully vaccinate sufficient numbers of people globally, existing medical systems were not robust enough so a connected but parallel health logistics system was created. John Lloyd, who worked previously on polio vaccination within the WHO Expanded Programme on Immunization, explained the beginning of this division.

> Smallpox eradication established stepped vaccine distribution systems based on existing health services infrastructures but separate from the routine distribution of medicines. Recognizing the managerial weaknesses of medicine distribution at that time, WHO helped build the capacity of countries by developing the technologies, systems, and guidance towards a vaccine 'cold chain' to distribute

> vaccines routinely. [...] Integration with medicines and other hospital supplies was rejected because the necessary control over stock management, transport priorities, maintenance and monitoring of storage temperatures could not be achieved at that time [92].

The fragmentation between immunization and non-immunization logistics remains a pressing problem today, as global health funding is hyper-focused on immunization at the expense of treating other diseases. Over the last 30 years, argues sociologist Linsey McGoey, private voluntary charitable contributions have expanded from 30% of the WHO budget to 70-80%, and these voluntary contributions are massively focused on communicable diseases (60% vs. 4%) [98, p.224]. Perhaps communicable diseases are really the primary health concern? No.

> The failure to combat obesity, cancer, and heart disease epidemics in poor nations has been one of the most glaring mistakes of global development efforts in recent years, a point reiterated time and again by global health scholars David Stuckler and Martin McKee. They have pointed out that, 'overall there is little or no correlation between global health funding and the [global] disease burden, suggesting factors other than need are driving the global health agenda. This inconsistency comes in spite of donors' commitments to align aid flows with national health needs.' [98, p.224]

We do not know for certain what motivates the emphasis on tackling communicable diseases. Writing for the Lancet in 1997, Cairncross et al. argue that donor morale and the ease of measuring impact on a specific disease are one of the main reasons for the shift toward "vertical" health initiatives.

> Indeed, some observers find the situation [of poorly funded health systems] so bleak, especially in Africa, that vertical programmes are hailed as the only way to produce success stories and so maintain the enthusiasm of donors and governments for investment in public health [30].

Even among communicable diseases, there is substantial imbalance in funding. After the eradication of smallpox, polio has been the largest focus of immunization efforts in poor nations, at the direction of foreign donors. Donald Henderson, who led the WHO campaign against smallpox, said in a 2013 conversation with McGoey that "A number of villagers, say, 'What is polio? We've never seen it – why are we worried about it?' ... They say, or children are dying of measles," and "Because of this very intensive effort on polio they stopped administering the other vaccines" [98].

There may also be an element of donor self-interest behind the emphasis on specific communicable diseases—recall Nixon's assertion that foreign aid is ultimately about the interests of the donor. In the same vein, Richard Heeks argued in 2009 that Western technologists should engage in international development through technical interventions (ICT4D) on the basis of "enlightened self-interest," among other reasons. He writes, "the problems of the poor today can – through migration, terrorism, disease epidemics – become the problems of those at the top of the pyramid tomorrow" [69]. This line of reasoning can support foreign intervention to strengthen the cold chain across the so-called developing world: if we stop smallpox in Uganda, that helps keep it away from the First World.

The development of the cold chain as a supply chain *specifically* for vaccines is the product of specific historical circumstances in which aid is the predominant mode of global healthcare funding.

3.4 Panama City (2006–2007)

> *From a software standpoint, the application [CCEM] is not that sophisticated. The significance of the application is the extent of public health knowledge that has been built into it, and the degree that it captures the process that cold chain planners use in managing a vaccine cold chain.*
>
> —Richard Anderson, John Lloyd, and Sophie Newland

Sophie Newland transferred to the cold chain equipment team in the Program for Appropriate Technologies in Health (PATH) around the same time that the first 64-bit processors for personal computers were on the market, in 2003-2004. It wasn't until 2006—after the 64-bit version of Windows XP was released, but before 64-bit PCs were mainstream—that work on the Cold Chain Equipment Manager (CCEM) began. A few key events happened in 2006 under the auspices of TechNet21, a biannual conference of immunization professionals led by UNICEF and the WHO.

First, on the last day of May, the UNICEF Regional Office for Latin America & the Caribbean (UNICEF-TACRO) and PATH held a workshop in Panama City on Central and South American immunization programs. In attendance were many of the key players in the development of CCEM: John Lloyd (now at PATH), Sophie Newland, and Paulo Froes (UNICEF-TACRO). On the second day of the workshop, UNICEF consultant Fernando Perez presented on the recent cold chain equipment inventory conducted in Peru. A medical doctor, Fernando had developed an application that analyzes the collected data about the cold chain and "permits forecasting of equipment needs due to replacement and planning for new vaccine introduction." The workshop report describes the "high level of enthusiasm for this system" and notes some important issues.

- It is important to establish a system for updating the inventory rather than having to repeat the assessment survey periodically.
- [. . .]
- Local technological expertise is essential to maintaining and modifying the software [150].

As we will discuss, these remain major challenges for cold chain software.

In September, John Lloyd raised the possibility of an English translation of Fernando's tool on the TechNet21 email forum.

> [. . .] The only software that handles inventory data by store and compares capacity to demand is the Peru MOH software (FoxPro) that is written and maintained

Figure 3.2: The banner image from the 2006 report of the TechNet21 meeting in Mexico City.

> by Fernando Peres in Peru (fperez77@gmail.com) in Spanish only. How much interest would there be if an english version of the software, the inventory team manual/forms could be produced? Press your reply button to vote![91]

Some respondents pressed their reply buttons, such as Dereje Ayalew of WHO Ethiopia, who affirmed "I would like to contribute towards the development of this tool, which I am very much interested" [19].

Five months later, John, Paulo, and Fernando reunited at the full TechNet21 conference in Mexico City where Fernando presented again on Peru's inventory and his software. The report from the conclusion of the conference describes the cold chain inventory needs that Fernando's tool helps address.

> The principle characteristics of an inventory system designed to meet current needs includes:
>
> - Clear and tested SOPs for data collection and routine maintenance of the database.
> - Ability to forecast the impact that the introduction of new vaccines would have on existing storage capacity

- Forecast of new equipment needs and the related budget needs over several years, taking into account replacement and changes in program strategy

- Guidance on the selection of new equipment based on past performance and capacity needs [99].

It was from this meeting that John Lloyd's proposal for a new tool started to become a reality, following the inspiration from Fernando's tool. After the meeting, PATH was able to repurpose funding from their USAID HealthTech grant to support initial work on the new Cold Chain Equipment Manager, bringing Sophie Newland onto the team [110].[7]

Dexter Bersonda was working in Manila at the time for the WHO Western Pacific Regional Office (WHO WPRO). Paulo knew Dexter from Paulo's time as the Philippines county director at WHO WPRO, and he brought Dexter in to write the new software. Dexter flew in to Panama in February of 2007 where he started working on a prototype of the new system based on a database schema described by Paulo [22].

Dexter and Paulo decided to use MS Access to build CCEM, which the CCEM team would come to be regard as the "wrong" way to build the tool. (However, I will discuss below the benefits of choosing MS Access.) They chose MS Access instead of the platform Fernando Perez used, (Visual) FoxPro. In terms of features of the competing platforms, the difference was minor: both support developing applications with a programming language and relational database management system. But, it would turn out to be a good choice.

[7]The USAID grant in question is HealthTech IV: Cooperative Agreement #GPH-A-00-01-00005-00.

An aside on FoxPro

The decision to avoid FoxPro was a timely one. Microsoft had acquired FoxPro in 1992, the year they releases MS Access. On March 13, 2007, just after development of the CCEM prototype, Microsoft announced that they were discontinuing support for FoxPro. This seemed to spell the end of the platform and prompted the Spanish-language FoxPro community to start a petition, MásFoxPro, requesting further development of the tool, or, failing that, the release FoxPro as an open source tool.

Microsoft responded with more detailed reasoning behind their decision, and agreed to make the tool open source. Microsoft had just released Windows Vista, supporting both 32-bit and 64-bit architectures, and they cited the transition to a 64-bit architecture as one technical challenge in continuing with the FoxPro product.

> For Microsoft to continue to evolve the FoxPro base, we would need to look at creating a 64-bit development environment and that would involve an almost complete rewrite of the core product [53].

The FoxPro source code was published on Microsoft's CodePlex website. CodePlex was shut down in 2017 following Microsoft's acquisition of competitor GitHub [67], and the FoxPro source code now appears to be unavailable (though the binaries are still available on GitHub[a]). Though Microsoft's decision mostly ended further improvements to FoxPro, a small community of dedicated FoxPro users continued to use and maintain plugins for it.

[a] `https://github.com/VFPX/VFP9SP2Hotfix3`

After Dexter's week of prototype development, Sophie and John flew back to Panama City, and together with Paulo, the four of them worked out the requirements for CCEM. Sophie described the scope of the project they laid out there.

> I think, one of the biggest problems with CCEM—and it's going right back to that Panama City three days—is I sat in a room with two dreamers, technical

> dreamers, and our software– our programmer. . . but he didn't push back. I mean, he's one guy and he's a junior, and I didn't know enough. We developed not just an equipment inventory tool. We developed a modeling tool. And it took that programmer, whose name is Dexter, a lot of time to try to capture what was being asked.

Following the lead of Fernando's tool and the goals discussed in the Mexico City meeting, CCEM was planned to achieve a few high-level sets of goals: to store and organize the results of national cold chain equipment inventories, to compare the existing state of cold chain equipment to a set of requirements, and to make recommendations for equipment allocation and procurement in the event of various possible changes to the cold chain. To Sophie, in hindsight, the large scope of functionality defined in that Panama City meeting would be the cause of later difficulties completing the project.

After that meeting, Dexter stayed in Panama for a few more weeks, working into March on version 1.0 of CCEM which implemented the database relations the group had specified. The team quickly got to work trying to use the new tool to support a national cold chain inventory. The team was looking for a country to pilot in, and PATH had a country office in Uganda, but some negotiations were required to settle on a pilot country, as Sophie described to me.

> I think we had to get the invitation and we wanted the invitation from the WHO country office. So, you know, I think there was a bit of romancing going on in to get ourselves sort of matched with Uganda [110].

The team piloted CCEM in July of 2007 at a three-day workshop in Uganda. Participants in the workshop requested a set of changes, which Dexter implemented. For Sophie, the breadth of participation in the workshop is crucial, since, along with the involvement of Dexter and Paulo, it meant that CCEM was not PATH's tool, but a collaborative effort.

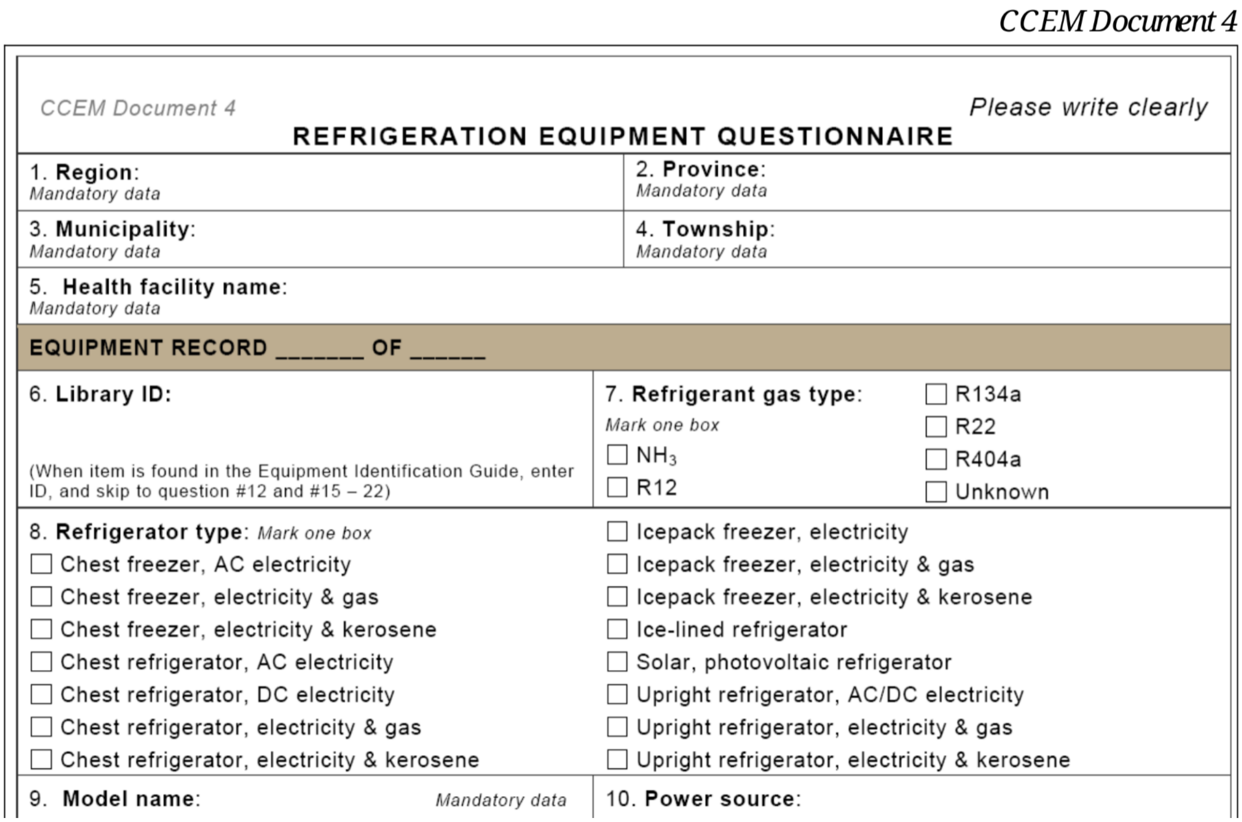
> At that three day workshop we had the WHO IST [Inter-Country Support Team]

> officer, we had the WHO country officer for EPI [Expanded Program on Immunization], so it was not ever PATH alone doing this. And also we had all, we had ten people from EPI in that room.

Here, Sophie is pushing back against what she describes as "an unfair criticism of CCEM," that it "was another tool that was sort of thought up sort of in the Western world" [110]. She argues that, though John and Sophie, as PATH employees, were central players in organizing the project, it should not be seen as theirs alone, but rather the product of global interconnections, particularly via WHO and UNICEF. Crucially, logisticians from the Kenya, Uganda, and Malawi governments did a lot of work to refine the requirements for the tool, as Sophie explained.

> [The Malawian logistician] Mr. Moussa Valle added some great additions and minor corrections to CCEM and data collection forms. He deserves credit alongside UNEPI [Uganda National Expanded Program on Immunisation] for CCEM. His additions were on things like adding data elements to support planning icepacks for immunization campaigns and routine immunization activities, and his insistence that we add data on # gas canisters, as it was a big problem for EPI [Expanded Program on Immunisation] cold chain planning from his perspective, even when many of us thought this was too detailed. People often think John Lloyd is the source of an overly complicated CCEM dataset and 50+ automatic reports, but I think it was more to do with Uganda and Malawi EPI cold chain managers knowing what they needed/wanted, the Devil is always in the Details. [111]

For a country to conduct a cold chain equipment inventory compatible with CCEM, they had to organize their data according to the CCEM schema. To enable this, the CCEM team produced a set of paper forms which could be manually digitized for use in CCEM. Figure 3.3 shows an example of the form for a single refrigerator from CCEM 1.0.


CCEM Document 4

CCEM Document 4 — *Please write clearly*

REFRIGERATION EQUIPMENT QUESTIONNAIRE

1. **Region**: *Mandatory data*	2. **Province**: *Mandatory data*
3. **Municipality**: *Mandatory data*	4. **Township**: *Mandatory data*
5. **Health facility name**: *Mandatory data*	

EQUIPMENT RECORD _______ OF ______

6. **Library ID:**

(When item is found in the Equipment Identification Guide, enter ID, and skip to question #12 and #15 – 22)

7. **Refrigerant gas type**: *Mark one box*
☐ NH_3
☐ R12
☐ R134a
☐ R22
☐ R404a
☐ Unknown

8. **Refrigerator type**: *Mark one box*
☐ Chest freezer, AC electricity
☐ Chest freezer, electricity & gas
☐ Chest freezer, electricity & kerosene
☐ Chest refrigerator, AC electricity
☐ Chest refrigerator, DC electricity
☐ Chest refrigerator, electricity & gas
☐ Chest refrigerator, electricity & kerosene
☐ Icepack freezer, electricity
☐ Icepack freezer, electricity & gas
☐ Icepack freezer, electricity & kerosene
☐ Ice-lined refrigerator
☐ Solar, photovoltaic refrigerator
☐ Upright refrigerator, AC/DC electricity
☐ Upright refrigerator, electricity & gas
☐ Upright refrigerator, electricity & kerosene

9. **Model name**: *Mandatory data*

10. **Power source**:

Figure 3.3: The CCEM 1.0 manual, released in March, 2008, includes seven questionnaires, one for each of the following categories: health facilities; refrigerators; cold boxes, vaccine carriers, and ice packs; spare parts and tools; voltage regulator/stabilizers; generators; and cold rooms.

The paper forms created an easy way for potential users of CCEM to understand the expectations of CCEM without touching a computer. Sophie describes their ability to interest.

> Those paper based forms were always sent places and people wanted to see them and they wanted to adopt them. And it just always felt like it was the entrance to people being interested in CCEM [110].

Beyond this "ambassador" role, the forms served an important data standardization role.

> People would always want us to send them copies of the paper based form. And then I also think it was the beginning of. . . a data standard conversation. So that was sort of a physical visual example of what we what we, what we proposed is a data standard.

Though, in the years since, many countries have used CCEM to conduct national inventories, the data standard it defines never became universal. Years later, Fahad Pervaiz, Richard Anderson, and Sophie Newland would attempt to develop a consensus data standard inspired by CCEM [118].

When Uganda's Ministry of Health conducted a national cold chain equipment inventory in September of 2007, they used CCEM. When Dexter and John flew to Uganda, the government team had already completed their inventory and entered the data into CCEM. From there, Dexter and John taught the Ministry of Health logisticians to use the forecasting component of the tool, and with that tool they developed a cold chain plan.

Sophie argues that the additional complexity of the forecasting component was a poor investment of effort because, while forecasting is important, doing the forecasting within CCEM did not add much value. Rather, "Everybody wants their hands on the data, and they want to do the analysis themselves, and they wanted to do it in Excel" [110].

Dexter acknowledges that the Ugandan Ministry of Health may have been the only users of the forecasting tool, but he thinks it is needed in cold chain software. It is, I think, a point of pride for him to have developed a powerful tool that can support advanced analysis.

And he is right that it is a valuable tool: Marie (the Ugandan cold chain technician from the beginning of our story) still wants to use CCEM's forecasting tool in 2022. But that part of the story is in 2022, and we're still in 2007.

3.5 "Proper" software engineering (2008–2011)

CCEM's advanced analysis tools were used to produce the Ugandan cold chain equipment plan in 2007, but CCEM would not see much use until 2011. In part, this reflects the "model project" issue that Scott sensitizes us to: development projects routinely demonstrate strong results when supported by intensive direct support like Dexter and John provided, but then struggle to demonstrate results with reduced support [134]. Returning to Panama City in the summer of 2008, the team held a workshop to demonstrate the tool to an international group, who requested further features. In addition to the feature requests, Sophie described that, "while CCEM worked well for Paulo, John, and me there were errors that could come up due to new users and computers, and after this workshop the idea of CCEM 2.0 was started" [111]. The PATH team decided to get an improved version 2.0 before conducting future deployments, and they contracted the Seattle-based iLink to develop an updated version with their new requirements.

In September of 2009, UW CSE professor Richard Anderson went on sabbatical and started working with PATH. PATH suggested half a dozen projects to him, one of which was CCEM. At first his interest in the project was quite low, since it was an MS Access application where the "right" approach was, in his opinion (and Dexter's), to build a web application that could receive updates to the inventory over the internet. A web application, however, would introduce additional technical complexity. With Richard's involvement, PATH embarked on an attempt to address the many bugs in CCEM by following standard software engineering practices, including creation of an issue tracker on BugZilla.

In May of 2009, PATH hired a software engineer to test the version of CCEM developed by iLink, who identified issues which PATH found concerning.

> Feedback received from the consultant, in combination with findings by PATH staff, clarified that CCEM 2.0 had not undergone sufficient rigorous testing and was not sufficiently stable for wide release as a cold chain inventory management and planning tool [121].

Between the ambitious scope, limited funding for software development, and feature requests from a immunization experts across many countries, Dexter describes feeling some frustration from managers at PATH about the pace of the project.

> I had the impression that. . . some of the higher ups [at PATH] were not impressed or were unhappy with the way we were developing, because as they said. . . , we didn't have the whole plan in the beginning.

At the time, linear software development models (e.g. waterfall) were still dominant; agile (a cyclic model) was gaining acceptance, but was not as ubiquitous as today [120]. PATH managers, influenced by the Enterprise Architecture approach to software development expected that software requirements should be fully specified before building a tool [107], and their contracting model reflects this: they hired contractors for short periods to build a specified set of features for CCEM, but without precise specification of the requirements, progress was challenging. Dexter told me:

> I mean, we have all these software engineers telling us that we should have the model right from the beginning and have all the analysis, all the requirements from the beginning. That's very ideal. But from my experience, it rarely happens that you have all the requirements from the beginning and the entire model from the beginning. So what usually happens is as we go along, things keep changing and modifications keep getting added, and that's something we can't avoid [22].

Dexter's attitude reflects the common wisdom in software engineering today: software requirements always change, often because initial versions of a tool reveal new needs; software

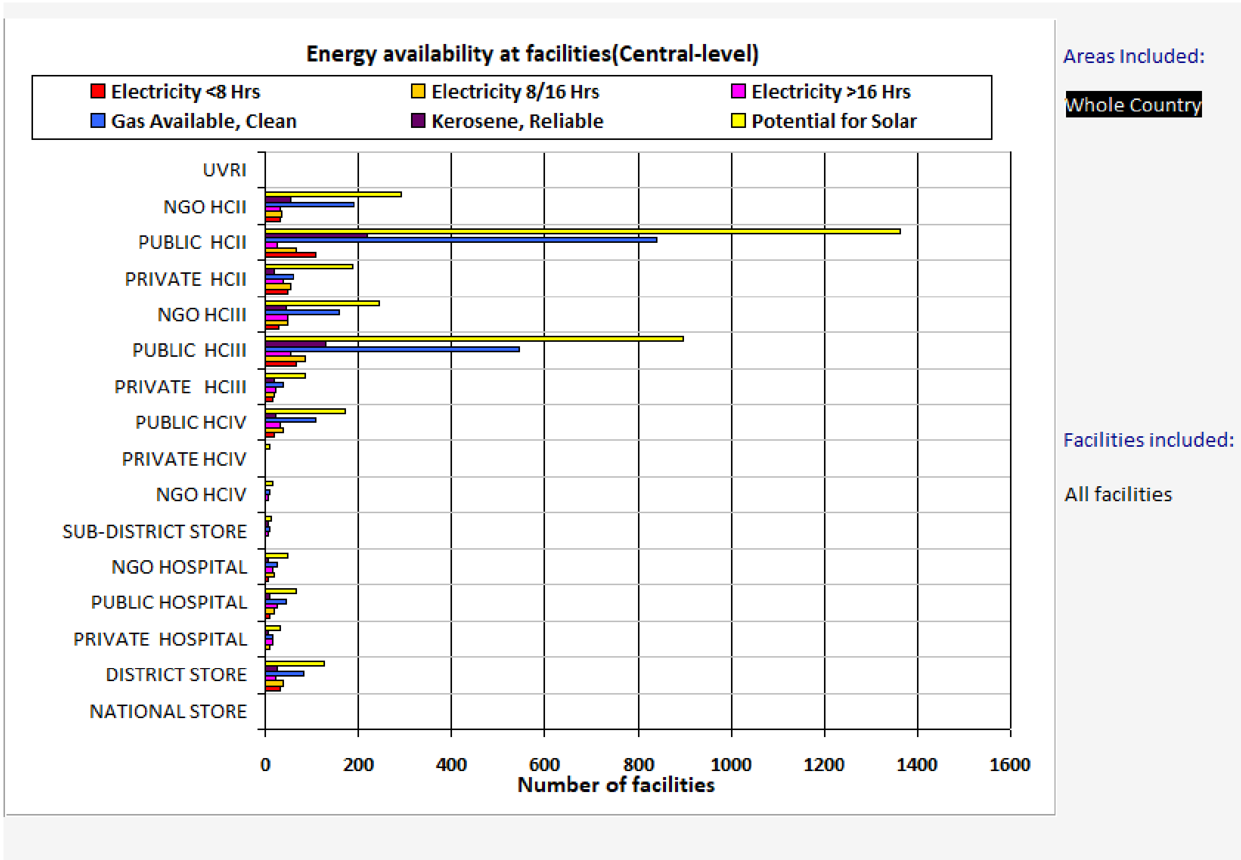


Figure 3.4: Screenshot of data visualization from CCEM 2.1 provided by Richard Anderson.

always needs maintenance as operating environments change (e.g., the switch to 64-bit architecture); and the ability to dream up new functionality always outstrips the funding available to support software development and maintenance.

In August of 2009, PATH hired consultants to work on CCEM 2.1. They produced a list of 173 changes (106 of them "critical") needed for the new version [111]. CCEM 2.1 was released in December, 2009 [122]. After this, 16 issues (three of them "critical") were identified in CCEM 2.1, with the goal of fixing them in a future version.

In late 2010 and 2011, CCEM 2.1 was deployed in Kenya, Uganda, and Zimbabwe, and

Malawi [123].[8] Until that point CCEM had been funded by a patchwork of sources, including the WHO, the Clinton Health Access Initiative, and the Rockefeller Foundation, but the key piece of funding that supported the PATH employees was the USAID HealthTech grant repurposed at the beginning of the project. This grant ended in September of 2011, which marked the end of primary software development on the tool.

3.6 Aspirations unachieved

At this point, a couple of key issues were evident in CCEM. First, one of the issues brought up in the first Panama City workshop in 2006 about Paulo's FoxPro tool persisted: due to the MS Access architecture, the system had no internet-accessible interface, and only one user could update data at a time. This meant that the system was more suited to one-time national campaigns to update the data than to continual distributed updates. Matt Morio, a current PATH officer working on cold chain equipment software, put it starkly.

> Updating a cold chain inventory can be two to four hundred thousand dollars, when you're going out, sending people to every site, and paying per diems and transportation. And all that adds up, and as soon as it's ready, it's outdated [103].

Second, recall the other issue brought up in that 2006 workshop. The workshop report wrote presciently: "Local technological expertise is essential to maintaining and modifying the software" [150]. Because PATH used a series of contractors for much of the development work of CCEM, there was only one engineer who maintained any long-term knowledge of the codebase: Dexter Bersonda.

The District Health Information System 2 (DHIS2) was released in 2008, aiming to be an open source national health information system. The tool was developed initially by researchers at the University of Oslo, and continued development and maintenance has been

[8]CCEM was also deployed in Nicaragua at some earlier point, but the documentation on this is scarce.

decentralized among a number of HISPs (Societies for Health Information Systems Programmes) around the world. DHIS2 was not well-known at the time, but today is used in 73 countries. Sophie described her experience collaborating with the DHIS2 team in the Ghana Ministry of Health, in contrast to her experience with CCEM deployments.

> When we were there, we got to work with a [DHIS2] team within the Ministry of Health, HMIS Team, and they were pretty strong. So just the image of having eight or nine really strong program developers sitting in the Ministry of Health managing their overall larger national health information system, running on [DHIS2], and have them be able to customize reports and visualizations and troubleshoot problems. That just sounds fantastic rather than all problems... having to go to the UW or Philippines or India or wherever your programmers are sitting. It just it seems like a much more sustainable image. And then your computers and your tablets and your data plans serve more than just the cold chain team [110].

So, rather than supporting foreign technology experts, investments should be made in engineering capacity in the countries where CCEM is used.

Third, as Sophie alluded to there, CCEM continued the pattern of fragmentation between immunization services and the rest of the healthcare system. John, CCEM's senior advisor, argued in 2017 that integration with general health supply chains should be the goal of future cold chain developments [92]. My sources are not unanimous on this point, since Dexter questions the technical feasibility of integrating the advanced forecasting functionality into DHIS2 or other systems.

Sophie and Richard contracted HISP India via PATH to integrate CCEM with DHIS2's newly released Tracker feature, which supports distributed updates to the database over the internet. This seemed like a move to address inventory updates, health system fragmentation, and potentially also local capacity building all at once by leveraging the substantial software engineering investments into DHIS2. They submitted an application to Gavi, the vaccine alliance, for a grant to support further integration of CCEM into DHIS2, but it was rejected. Richard returned to UW, and the DHIS2 integration was not pursued further. Sophie passionately expressed her disappointment with this conclusion to CCEM's software development.

> I feel really frustrated that that gift [CCEM] wasn't recognized and accepted and and then taken to the next level. But anyway, that's probably what I would describe as one of the biggest disappointments in my professional career.

3.7 Those who cannot remember the past... (2019-2022)

My involvement in this story comes in via a recent collaboration between Richard and PATH on a new piece of cold chain equipment software, the Cold Chain Information System (CCIS). Like CCEM, CCIS is designed to support national cold chain equipment inventories. CCIS is a web application, like Dexter and Richard always dreamt of, and it uses ODK-X (Open Data Kit X) to receive distributed updates over the internet. Of special note is that, with ODK-X, cold chain technicians can make updates on their phones in regions without internet access, and these are then synced to the central database when they get connectivity.

CCIS continues CCEM's tradition of close collaboration with the Ugandan Ministry of Health—today CCIS is deployed nationally in Uganda, and no other deployments are planned yet. It is in this context that Marie and Richard had reason to talk about CCEM and for Richard to help Marie patch her copy of CCEM for use on her 64-bit machine.

CCIS also continues CCEM's tradition as a tool not integrated with other healthcare supply chain software. One of our partners in the Ugandan Ministry of Health commented once that the visualization web dashboard we developed was not nearly as polished as the polio dashboard they use. The continued hyper-focus on eradicating specific diseases like polio means that engineering effort goes into software with narrow vertical scope, while more general tools struggle to get funding.

CCIS is supported by grants from Gavi and the WHO to PATH. The Gavi grants (the bulk of the funding) are "subgrants" of a grant to the Ugandan Ministry of Health. So far, with CCIS there have been no local Ugandan engineers involved in the software development. PATH has allocated limited funding has supported UW students and staff under Richard to build CCIS, but no local developers have been included. This problem is not unique to cold chain software; rather, it is well-known among scholars of development. Louis et al., for example, take particular issue with this pattern.

> [T]echnical assistance on aid projects often uses foreign advisors, who may come at a higher price than locals, and this also restricts the number of locals trained to implement and ultimately take ownership of projects. In this way, [Official Development Assistance] can suppress local human resource capacity building [94].

We can contrast the maintenance communities of practice for CCEM, CCIS, and the LibreRouter. Where AlterMundi has developed a small group of maintainers in each community network by introducing interested local people to the project through workshops and other events, the cold chain software has invested in just a few technical experts. Dexter has (perhaps remarkably) remained involved in supporting CCEM deployments from 2007 through 2017, and Richard continues to do some maintenance work like sharing the 64-bit patch, but there is no enduring social organization of the technical work. At the time of writing, there is an attempt to bring African engineers into the development of CCIS, but it remains just a potentiality.

3.8 Supporting Museveni?

Both CCEM and CCIS support data-driven governance, intended to rationalize allocation and procurement decisions. From a more skeptical angle, software for data-driven governance might be seen as enhancing bureaucratic state power [52], solidifying the ruling group's (Museveni's party's) grip on power.

PATH described one purpose of CCEM in their report to USAID at the conclusion of the HealthTech grant in 2011 (emphasis added).

> CCEM assists EPI managers with analysis of their national cold chain equipment inventory and assists development of justifiable equipment lists and budgets to *motivate donors* to support important new cold chain equipment investments [123].

When governments analyze a national cold chain inventory with CCEM, they usually produce a plan for future cold chain equipment, and they usually use that in order to go to foreign donors to ask for funding or cold chain equipment [22]. What social structure does this funding support?

The report on the Second Congo War claimed that foreign donors "gave the Government room to spend more on security matters while other sectors, such as education, health and governance, are being taken care of by the bilateral and multilateral aid," and that foreign donors (indirectly) enabled the government to reinvest the profits of war into further war-making [34]. The stabilization of Museveni's party's (the NRM) patronage network by foreign donors has continued through at least 2016, according to Rubongoya.

> Rubongoya argues that this dialectic has produced a 'political settlement' which fostered particular processes of state making and wealth accumulation and brought about the contemporary power structures and the corresponding clientelist political system, characterised by allocations of rents and patronage within the ruling coalition. Powerful foreign actors have been central to the emergence of the ruling coalition and to its persistence, not least because they provided crucial resources to the NRM, including funds for electoral campaigns. Interacting with Uganda's long-standing political culture, neoliberal policies have enabled the NRM to pursue and achieve its core objective: power consolidation and regime maintenance [161, p.22].[9]

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[9]This quote is from the editors of *Uganda: The Dynamics of Neoliberal Transformation*, succinctly

In the same vein, Ugandan academic and activist Stella Nyanzi pulls no punches when she decries the "organs that uphold the gun-based system of patronage that entrench this reign of terror and family rule" [108].

Both the funds which software-backed cold chain equipment inventories help secure as well as the funds provided for government use of cold chain equipment software can be distributed by NRM patrons to their clients. We should be careful, however, of oversimplifying this dynamic as simply anti-democratic corruption (though it is that). Scherz writes that Kiganda[10] patron-client relationships come with some accountability: that giving material aid obliges the patron to continue to support their clients in the future. Scherz describes an expectation that wealthier people will seek out clients to support materially, which offers a way for people to make claims of the powerful.

Muwanga et al. make a similar argument, that while the patronage system is about "countering 'people power' with cash," it does at least redistribute money to the poor.

> During campaign time, rather than rely on his lieutenants, Museveni has taken to handing out the cash himself. As well as helping him to directly endear himself to the public, some observers believe it actually helps to reduce financial malfeasance and corruption, with money for poverty reduction finally reaching the poor. [106]

The "observers" Muwanga references include a beneficiary who "engag[es] in the collection of scrap metal and run[s] a small retail shop."

If we interpret the Ugandan government's use of cold chain equipment inventory data to request support from donors in this context, we can see it as a way of making claims on the resources of wealthy countries and private donors. This stands in contrast to the Western focus on sustainable development in which the word "sustainable" is primarily deployed to support the assumption that the donors will back out of the relationship at some point and does little to support people in making claims to donor funds [132]. Thus, to understand

summarizing Rubongoya's chapter in the same book.

[10]The adjective form of Baganda, the largest ethnic group in Uganda, at just 16% of the population.

the role of CCEM in NRM's patronage, we need to consider patron-client networks[11] role in wealth redistribution alongside their inequality and antidemocratic role.

From 2015-2019, according to the World Bank's data, annual Official Development Assistance to the country measured at 44%-58.1% of Uganda's central government expenses, confirming a strong dependence on aid [146]. Despite the support from foreign aid, Museveni's government faces serious threats. Uganda operates a democracy, though one characterized by single party rule and violence against opposition. Rubongoya writes that the cost of patronage required to win elections is growing, that in the 2011 election and then 2016 election, "the government needed much more money to buy off a relatively wealthier populace due to intraparty fragmentation" [129]. In the 2021 election, government forces placed the leading opposition candidate under house arrest and killed at least 54 in suppressing opposition protests [5]. There are cracks in Museveni's control of the country, but perhaps increased foreign support will continue to stabilize the NRM in future electoral contests.

3.9 Long live CCEM (2017–present)

Though CCEM's last substantial engineering support was around 2011, it has seen substantial use in the intervening years, including deployments the Philippines, Georgia, and, most recently, Tajikistan in 2017. Dexter receives occasionally messages from people around the world using the tool, though he has not been paid to work on it for years.

> If we would have a chance, I would have rewritten CCEM from scratch, maybe in another tool if we have the chance. Because the problem was... the last version we had, I would admit, was very poorly designed. And it is because of the evolving changes in the tool, and the evolving features in a span of several years. So if we already knew... then what we know now, [I] would have done it a bit differently [22].

The last publicly released version of CCEM was 2.1 in 2011, but today Dexter has a wide

[11] I write "networks" because many people are both patrons of some and clients of others.

variety of CCEM versions on his computer, each corresponding to a particular country with specific customizations they've requested. Some of them have been patched to work on 64-bit machines. This longevity is impressive, moreso if you compare it to academic ICTD projects, which regularly see their ends shortly after the papers about them are published [63].

Code, as language made executable, does not degrade the same way physical infrastructure does. Computer hardware does, and code needs to be stored physically somewhere, but someone a hundred years in the future could feasibly run CCEM if they have a running PC from 2022. Paradoxically, perhaps, software always needs maintenance. Besides new features, customizations, and bug fixes, the operating environment (e.g., operating system, drivers, libraries) on users' computers is constantly changing as other software is updated. FoxPro, despite not receiving continued support, can still be downloaded from Github and used today (though the source code seems to no longer be available publicly). What is striking about CCEM is that the *only* maintenance most users need to keep an old version of CCEM working today is Richard's patch to support 64-bit architectures.

CCIS, in contrast, includes a database, multiple web interfaces, and an Android application for data collection. Maintaining a CCIS deployment requires an IT team to manage servers and data access policies. But Marie can use CCEM with almost no support. If CCIS funders don't build any institutions to support the software long-term (like the HISPs for DHIS2), it will stop being used much faster than CCEM. In this regard, developing CCEM as a standalone MS Access tool was an effective choice, despite Dexter and Richard thinking that it should have been a web application from the beginning.

Marie still gets value out of CCEM. Despite all of CCIS's improvements over the earlier tool, it hasn't reproduced all of the functionality. Marie has come to rely on the forecasting tool that Dexter sees as so important. In one meeting we held to get Marie's feedback on CCIS, she emphasized that CCIS should at least offer a tool for comparing current capacity to projected requirements. This is currently being developed for CCIS, but it is a small slice of the many forecasting features in CCEM.

3.10 Conclusion

> *Aggregation is a modernist trope, relied on to raise questions about the reliability of any single truth claim. But it also can affirm the perspective of he who stands outside competing claims, surveying and assessing the evidence to arrive at a final synthesis. An ethnography of Bhopal should not work toward final synthesis. The case should remain unsettled; continuing liability should be assumed.*
>
> —Kim Fortun in *Advocacy after Bhopal*

The expansion of personal computing and the switch to 64-bit computer architecture is tied to war profiteering during Uganda and Rwanda's war in the DRC, and that war helped turn Uganda into the "donor darling" it is today. Museveni's government continues with severe human rights abuses and remains in power thanks to foreign aid, which also funds CCEM and now CCIS. This focus on vaccination and on data-driven governance are the result of donor-driven policies that prioritize measurement over health outcomes. CCEM and CCIS, in turn, are used by the government to attract further foreign aid, which continues to fund US programmers like me while investing insufficiently in human resources in Africa.

Returning to the main question, which relationships are maintained by the technical labor of designing, programming, and patching CCEM? First, the relationship between the core people employed to work on the project (Sophie, Dexter, John, Paulo, Richard, and some of the logisticians, especially in Uganda who became "power users") was created through their shared dreams for the software. The positive terms with which they described each other to me was heartwarming. Second, though it may be just a drop in the bucket, using CCEM requires users to have computers with MS Access. Purchasing Microsoft products supports the Gates Foundation, the second largest funder of Gavi, who funds CCIS. Buying computers to run CCEM (most likely) supports coltan extraction from the DRC. Third, the CCEM (and CCIS) database schema makes durable one specific way of understanding a cold chain, based primarily on John Lloyd's experience. This is only one option among many: attempts to agree on a data standard based on CCEM have promoted healthy debate on various details [118]. Fourth, the desire to produce a piece of software with specific requirements supported short-term relationships between PATH and various software developers, but only managed to build some technical capacity long-term (with Dexter). Finally, the funding of CCEM and the reports it generates support foreign aid to Uganda, simultaneously taking seriously the demand for government provision of services and further supporting NRM's governance based on patron-clientelism.

Tsibolane and Brown argue that ICT4D research needs to embrace postcolonial theory to take critical account of the issues in work opoerating within legacies of colonialism [148]. This is a perspective that unfortunately has had only limited uptake by ICT4D scholars in computer science departments. Since the Ugandan nation was the product of British rule, the whole history here should be understood as part of that colonial legacy, but it is not simply caused by colonialism, as the details here should demonstrate. At the same time, this history does not remain safely in the past—the issues brought up here are playing out today in new configurations.

When reading a story like this it can be tempting to look for heroes or villains, but there are none to be found. Like Haraway argues, there is no innocent existence in the informatics of domination [66, p.157]. Discussing this chapter, my collaborator Lucy Pei riffed on Haraway's notion of non-innocence, "If nothing is innocent, what is the purpose of historical work? To unsettle assumptions, to articulate tensions in how something is remembered or used." What assumptions do I hope to unsettle here? Chief among them is the perspective I often encounter that building cold chain software is a labor of purity or even charity. In a similar vein, when we label software like this "CS4Good" we applaud its goodness rather than taking careful stock of its impact with a historical sensibility [140]. The simplicity of that label belies the complex ethics of all technical interventions, a point we will return to in the conclusion.

Chapter 4

DEFERRING SOCIAL IMPACT: CONCEPTIONS OF ICTD AND COMPUTING CAREERS

4.1 Introduction

[1] Information and Communication Technology for Development (ICTD, ICT4D) is a young interdisciplinary field which features prominently computer scientists and their (our) attempts to "do good" around the world. Heeks defines ICTD as "the application of any entity that processes or communicates digital data in order to deliver some part of the international development agenda in a developing country," although many include social and economic development applications of digital technology in any location [70]. As ICTD scholars, we are reflexively interested in how our subfield reproduces itself. To this end, our overarching research question is the following.

RQ1: How do undergrads understand their involvement in ICTD research?

For this chapter, we choose to write to a general software engineering and computer science education audience to discuss the close interrelation of the students' views of ICTD and their views of computer science careers.

RQ2: How do undergraduates involved in ICTD research reason about their career goals in computer science and engineering?

We address these research questions through a qualitative interview-based study of a multi-year ICTD research project about a data collection and visualization tool for vaccine cold chains.

[1]This paper was previously published in HICSS: [58]

4.2 Background

The capstone course in which the Cold Chain Information System (CCIS) visualization dashboard originated has been taught in different forms in the past. Prior papers by Ruth Anderson et al. describe the pedagogical approach and its motivations in detail [16, 14, 15]. Since the present chapter focuses on students' experiences, readers interested in organizing such courses should refer to this prior work. Here we provide some background on the course and how it was set up, as well as some background on the CCIS project to which the students we interviewed contributed code and other work.

The course began with the instructors pitching a series of ICTD projects to the students who then selected their preferred projects and formed teams around them. One of the projects pitched was the CCIS dashboard project. Professor Anderson, the instructor of the course, told us he selected this project because it was a reasonable scope to prototype in one quarter and because it built on an existing project with strong partnerships, so it could contribute to a future deployment. The project drew substantial interest and a team of five students spent the rest of the quarter developing a working demo of a dashboard that aggregated and visualized information about the conditions of vaccine refrigerators and freezers. The dashboard is intended to display data collected via an Android application developed by others in the research group (the capstone focused on the visualization dashboard, two of the students involved later contributed to the data collection side of the project).

Rather than focusing on familiarity with ICTD as a field, the learning objectives of the capstone focused on teamwork and software engineering, as Professor Anderson explained.

> In a capstone, the central learning outcome... is [for] people to understand what it is to cooperatively develop a software product. And the understanding that people can be have multiple roles in a project and there's more to creating a product than just writing code.

The course's teaching assistant similarly stated that the goals of the course were for students to be able to explain the motivation of their project for an external audience, develop "full-scale" software in teams, and define their own end goals.

Students learned about the global health domain and background on ICTD and vaccines during the first weeks, mainly in order to motivate their engineering work. Instructors met with each team weekly, but did not help directly with programming. At the end of the quarter the students produced a demo (presenting a demo was a learning objective of the course) and were subsequently invited back as volunteer research assistants. Other undergraduates joined the project under Professor Anderson's guidance. The students contributed to a paper on the design of CCIS, including the visualization dashboard, and work on the dashboard is continuing [27].

4.3 Related Work

Our research questions are informed by prior studies of conceptions of CS. The roles, images, and stereotypes of computer scientists have been discussed in a significant body of literature. The early work on conceptions of CS highlighted problematic stereotypes of computing as masculine and anti-social, while recent research has sought to understand students' nuanced conceptions of the field and their place in it. Martin's early work, for instance, asked students to "draw a computer scientist," and their students in introductory courses uniformly drew nerdy men, while a small handful of students doing CS research went firmly against that trend [97]. Similarly, Carter's survey of 836 high school students highlighted a common image of computing as sitting in front of a computer and programming [31]. Another study of 133 students' biographies about computing describes in detail the differences between students who see them selves as "insiders" in CS and as "designers" of computing technology, on the one hand, and those who position themselves as "outsiders" and "users" on the other [133].

More recently, Hewner's study of 37 Georgia Tech students and advisors described three conceptions of CS: the first focuses on theory and mathematics, the second on programming, and the third on interdisciplinarity and "a wide variety of applications." Hewner further argues that the students' conceptions of CS lacked detail and showed confusion about curricular choices [72]. Additional studies have investigated the relationship between students' conceptions of CS and their degree choices [73, 12] or attitudes toward programming [32].

We note the gap that student conceptions of the subfield of ICTD has not yet been explored, though ICTD curricula have [16, 14, 15].

Our study's aim to explore how undergrads understand their involvement in ICTD research also builds upon prior work that has studied service learning and the value of social good in broadening participation in computer science education. Both the ICTD capstone and the undergraduate research work are strategies for deeply involving students in computing for social good through service learning. Prior work in computer science education asserts the value of computing for social good in CS curricula. For instance, Goldweber et al. recommend "motivating computer science students by adding the context of social good to introductory computing assignments" to "exploit the finding that students' desire to have a positive societal impact is a strong determinant regarding their selection of a major" [61]. This claim that computing for social good can make CS more appealing to diverse groups of students has been taken up in the CS education literature [28, 85]. Notably, Sax et al. conclude from a logistic regression of long-term national US survey data that "women's relatively stronger social activist orientation serves as one of the key explanations for the gender gap in computing," which they interpret to mean that "efforts to attract women to computer science will need to highlight the ways in which the field positively impacts communities—locally and globally" [131]. With such significant expectations for the role of computing for social good, it is crucial to understand in detail students' experiences of "CSG-Ed [CS Education for Social Good] endeavors."

Such calls in the literature have been reflected in course offerings for CS undergraduates. ICTD courses are offered at the undergraduate level in a number of CS departments, and CS courses based on a service learning model are also not uncommon. Leidig et al. describe one such CS capstone, emphasizing project management skills (e.g., requirement gathering, project scoping, communicating timelines) as key learning objectives [88, 86]. Buckley et al. describe a software engineering capstone using "socially relevant" projects; they emphasize how effectively the chosen projects motivated their students [28]. The most in-depth way to include computing for social good in CS curricula has been through capstone courses. In a mechanical engineering context, Shekar investigated students' perspectives on and understanding of humanitarian engineering. Based on a feedback survey at the end of their course, Shekar argues that their students expanded their views of the role of engineers [137]. Hislop et al. provide valuable survey data about Humanitarian Free and Open Source projects in software engineering courses across six institutions, finding a positive effect on student learning and motivation/interest [74]. The survey method however does not reveal what students' participation in the course means to them. Building on these arguments, our study addresses the gap in empirical understandings of CSG-Ed courses from the perspective of students, locating ICTD as an example of CSG.

Theoretically, we build on the *career funneling* concept developed by Binder et al. Based on interviews with students at Harvard and Stanford, they define career funneling as the process by which "student cultures and campus structures steer large portions of anxious and uncertain students into high-wealth, high-status occupational sectors," specifically finance, consulting, and "high-tech jobs" [26]. Their analysis revealed several mechanisms by which students learn to value a narrow set of careers: the low knowledge of career possibilities that undergraduates possess when they enter college; the competitive drive at recruitment season when certain industries dominate career fairs and on-campus interviewing; and the internalized and reinforced social pressure to attain a career worthy of one's elite degree. All of these work together to rule out other careers as worthy of pursuit.

In the CS context, Cui identified a career funneling pattern into a small set of "Big Tech" companies, "including but not limited to Google, Facebook, Apple, Microsoft, and Amazon" [37]. Cui argues that the process happens implicitly, as a common-sense default path, rather than as a specific conscious decision [37].

The connection between student conceptions of CS and their subsequent career pathways, especially those around social impact careers, is understudied. Our study refines the theory proposed in these papers and illustrates one way in which the theory plays out in the context of social impact careers and CS undergrads.

4.4 Methods

Overall, our study design—including the choice of interviewees, the interview method, and the data analysis—uses an interpretivist, constructivist approach [117]. The data for this study focuses on interviews with affiliates of the CCIS project. The CCIS project is a useful case to study because it seems successful on a number of factors: students have chosen to continue participating for multiple quarters, they are generally quite enthusiastic about the project, and their contributions are directly enabling deployment of the system nationally in Uganda. We interviewed every student who was working on the CCIS project during Summer 2020, as well as all five students from the 2019 capstone course who worked on the project (nine students total). To supplement this data, we also interviewed the instructor and graduate teaching assistant from the capstone course.

Interviews were conducted by both authors together in Summer 2020. Though this was a full year after the capstone concluded, all five of the students from the capstone continued with the project until at least Fall 2019, with one continuing through Summer 2020. The five capstone students had graduated by the time of our interviews and were on their way to full-time software jobs; the four other research assistants are still UW students. More details on the interviewees is in Table 4.1. Because our data collection is a year removed from the capstone course itself, we report on students' involvement in the CCIS project as a whole, including the significant work that came after the capstone.

Interviews were semi-structured with open-ended questions about their experience, approximately 30-60 minutes. We opened each interview by broadly asking each participant, "Tell us about your involvement in the cold chain project?" Then we followed up by asking how students came to be involved in the project, what they got out of it, the challenges they faced, critiques they may have had of the project, and their thoughts on ICTD and development, which often became discussions about "social good" in computing. We also asked students if they felt their views of CS had changed as a result of being involved in ICTD. The data used in this chapter are a subset of the data for our larger project, an in-depth study of all the stakeholders in the CCIS project, both at the University of Washington (UW) and beyond. We use pseudonyms for all participants.

After fully transcribing interviews, we analyzed the interview transcripts through collaborative open coding based on in-depth discussions about each paragraph of each transcript, focusing on our research questions about conceptions of ICTD and computing careers. For example, codes included, “baseline is working at a tech company,” “shared values with other students,” and “adoption is success.” Quotes are edited to remove repeated words and filler words (e.g., “like”). Through our detailed discussions, we identified patterns in narratives, justifications, assumptions, and word choice across individual codes. We used these patterns to synthesize the argument presented in this chapter, including the development of the concept “deferring social impact.” Our interpretive stance was to treat interviewees’ statements as true accounts of their experience and seek multiple perspectives. Our goal is first to present an empirical account faithful to our participants, and second to reflect on how undergraduates conceptualize CS and ICTD. Throughout this chapter, we use the terms “social good” and “impact” because these are the terms in which students understand their work.

4.4.1 Author positionality

These interviews were particular sorts of conversations conducted over the internet during a global pandemic. Like any conversation, the interviews were indelibly shaped by the relationships between the interviewees and interviewers. We account for the conditions under which our interviews were conducted in pursuit of feminist objectivity. Feminist objectivity asserts that *all* knowledge is situated and advocates for the contextualization of knowledge rather than the denial of its constructedness [65]. The following positionality statement contextualizes our knowledge claims.

Years ago, both authors were exposed to ICTD through a project-based undergraduate computer science course, in a manner similar to our interviewees. Our experiences with ICTD are necessarily part of our interpretation of the data. Philip is also a research assistant on the CCIS project, though he was not involved until after the completion of the capstone course. We were wary that this position may make participants more inclined to present their experiences in a positive light, so Lucy asked direct questions about students' concerns with the project and their work on it. The instructor of the capstone is Philip's PhD advisor. Lucy is based in a separate university and unaffiliated with CCIS. For our analysis, these are valuable complementary positions: Philip's context and relationships to participants ease understanding of the data, while Lucy brings an outsider perspective.

Name	**Pronouns**	**Year in program (as of Fall 2020)**	**Took the capstone?**
Amy	she/her	Graduated	Spring 2019
Shen Wen	she/her	Graduated	Spring 2019
Sam	she/her	Graduated	Spring 2019
Deepak	he/him	Graduated	Spring 2019
Joe	he/him	Graduated	Spring 2019
Priya	she/her	2nd year	No
Ramita	she/her	2nd year	No
Kushal	he/him	2nd year	No
Katie	she/her	5th year Masters'(Electrical Engineering)	No

Table 4.1: Interviewees' pronouns, year in program, and involvement in the 2019 capstone course

4.5 Findings

Our findings first discuss the students' conceptions of CS and ICTD. We find a trend that students believe ICTD work has social impact, in contrast to mainstream CS, which they associate with large tech companies and for-profit motivations. Students also reflected that much of their CS curriculum did not expose them to ICTD or social impact applications of CS. The second section of our findings focuses on the students' anticipated career paths. Most students took or planned to take jobs as programmers at large tech companies. Some students planned to defer the social impact they desire by leaving such jobs later, while others hope to find a way to contribute to social impact within industry. The students who wanted to center social impact in their careers considered going into academia since it seemed the most feasible path to continue to do so. These findings are of interest to software engineering and computing educators since they raise questions about how and why we include computing for social good in our curricula.

4.5.1 Conceptions of ICTD and CS

Our interviews found that students had common conceptions of the field of CS. Students associated CS with gaming, innovation, and industry jobs as programmers, affirming prior findings [31]. They contrasted these with social impact and ICTD. Behind this conception of CS as affiliated with gaming and industry is a critique voiced by some of the students that CS is oriented to profit and service to the wealthy. Some students put it more mildly by noting the difference between technology developed for people who "need" it and products for resource-rich users. The students noted that the path through their undergraduate education does not make social applications of computing an obvious component of CS, and that they had to seek out opportunities to become involved in ICTD, which "opened their eyes" to a broader conception of CS.

Contrasting conceptions of CS and ICTD. When students reflected on how their views of CS were impacted by their involvement in the cold chain project, some students described prior conceptions of CS as associated with gaming, innovation, and automation. For example, Kushal says,

> I remember, you know, just [thinking] like, oh, CS, I can make this game. We can write the cool script and automate things and everything. But I never really thought about [CS] from the perspective of how you can actually make someone

> else's life better by just using the technology that you have available to you.

In characterizing their experiences with ICTD, students explicitly used industry programming jobs as a foil. As Shen Wen says,

> It's not like industry because compared to my previous internship experience [it's] kind of different from this one because for this we kind of work for social good. . . An ordinary computer science path will be after [you] graduated, you will be working like a software developer.

Ramita similarly positioned her experience with the cold chain project in contrast to her past schoolwork and internships.

Our findings reveal a pattern in which students see their conceptions of CS in general as a foil to their understanding of ICTD. Associating CS with games, automation, and software development careers confirms prior work, and the consistency with which students related CS and ICTD as contrary rather than hierarchical or compatible is a novel finding from this study.

Critiquing profit orientation of CS. Some students emphasized that ICTD work does not fit the for-profit orientation they see as dominant in CS. Katie shared her view of the dominant values of CS when she explained how she had come to find ICTD after considering dropping out of engineering.

> I was considering if I should drop out of engineering, because everybody's so into making the next biggest thing to become richer. . . to me it's unimportant, things to make the world better for people who are rich. And I'm like, oh, maybe I should just not do this because I don't think my values align with the work that I'm doing.

Katie is negotiating the tension between her critical analysis of computing and her participation in the field. Joe shared a similar sentiment when we asked about his thoughts on ICTD.

> Well, at least among my peers in UW, a lot of people in UW, when they do computer science, it's always for profit. Money, because all these big tech companies in Seattle give six figure jobs for new grads. It's very tempting to just take it, they're like, "I don't even need to get promoted. I'm already getting 6 figures." Well, when you work for a nonprofit organization or like what we're doing, we're doing it for free. It's not rewarding in a physical sense, like you don't get money. You're putting time to something that's not going to pay you. . . it's very hard for someone to choose getting paid very little. . . So I think this kind of software and helping, building technology for these kind of problems that no one wants to help because you can't profit from it.

Some students acknowledged that working on enterprise projects could still potentially affect some people's lives for the better. But they contrasted the kind of impact that one would have shipping code for a tech giant that serves well-resourced groups with the impact one could have working on ICTD projects for people who "need" the results. Amy elaborated this perspective when sharing her thoughts on ICTD.

> . . . people are doing these projects to make the world better in places that are not just our community. So I'm happy I was able to contribute to something that is not just like cloud storage for people that need more storage and stuff even though that's really cool. But it's also just the different audience and not making an impact in, to every—to lots of people.

The sentiment that certain kinds of computing work may not be needed extended to other default conceptions and synecdoches of CS, such as a lab dedicated to innovations in ubiquitous computing. Priya had associated CS research with that lab in particular.

> So Ubicomp Lab is a massive lab. They're super organized. They have so many undergraduate researchers. But I feel like their work is so high level that it wouldn't really be helping the people who need help.

While not denying the impact that mainstream software development careers can have, students voiced a critique that such careers only served wealthy consumers. Such critique is important for CS educators to understand and grapple with in the pursuit of a robust and diverse experience of CS undergraduate education.

Discovering ICTD. Students noted that this default conception of CS as associated with programming jobs in industry and gaming-oriented innovation was not unsettled by the standard courses and requirements of the CS curriculum. Kushal pointed out that his extracurricular choices to be involved in social impact hackathons helped him to discover the world of ICTD.

> I think it really opened my eyes, opened my eyes to this other side, of CS, that I did not know. But my formal education, I don't think it... exposes us in such a way that we actually think about those things. I guess it was the choices that I made along the way.

Deepak also uses the language of "eye-opening" to describe his experience with ICTD, contrasting it to the "tech bubble" where resource-rich CS students do not have many opportunities to consider how the "rest of the world" functions.

> I feel like people should go through that. Even working with non-profits, they just give you that kind of experience where you get out of the tech bubble a little bit and you're just like, oh, my God. Like the rest of the world doesn't function how we think it functions, which is eye opening to some extent. And it's important to consider even when you're in that tech bubble.

Katie, an electrical engineering major who had considered leaving engineering altogether, only found out about ICTD through the instructor of one of her introductory programming classes, when she had lamented to him the misalignment of her values with what she saw as the dominant values of the field.

> And then he was like, honestly, you are like completely wrong. There is work out there within CS or electrical engineering and engineering in general that work for global good. And he told me about ICTD.

For Katie, the mainstream view of CS/electrical engineering was demotivating, but the possibility of global good work led her to stick with it. Katie's trajectory parallels that of a high school student featured in a recent case study [155]. The high school student initially viewed her activist political identity as incompatible with the values of CS and "unfeeling oppressive corporations." However, like Katie, she saw her activist identity as more compatible with CS after engagement with technology-for-social-good projects.

Students who use programming or gaming to characterize their prior conception of CS align with prior literature. However, the critical position that CS in general is *not* associated with social impact but rather with earning money by serving the wealthy is less documented in prior research. This finding enriches our understanding of why students might leave computer science (or, in Katie's case, electrical engineering). Students who feel this way may provide some explanation for the statistical finding of Sax et al. that social activist values are a strong predictor of not majoring in computer science [131]. future research could try to understand the shape of such values in more detail. Despite the capacity of ICTD to help students with social activist values continue in computing majors, students are not initially aware of the subfield. This aligns with Hewner's broader finding that undergraduates often are unaware of subfields of CS [72].

4.5.2 Deferring social impact

Students told us they would take or had already taken a corporate tech job but had concerns about how they would feel having chosen a path that does not center social impact. Several students were hopeful that their computing work could continue to serve a diverse global audience in the future. These students planned to establish more skills and/or financial resources first. Though the students generally saw corporate jobs as incompatible with social impact, one student asserted that he had continued on the social impact path at such a job where he got to work on pro bono projects. Two students who expressed tension between social impact and industry careers considered going to graduate school since they saw academia as the only way to continue to center social impact in their work. We propose the concept of *deferring social impact* to describe this phenomenon in our data.

Ambivalence about career choice. When we asked students about whether they planned to continue to be involved in ICTD, almost all of the students shared that they planned to work at a large tech company as their first job after graduation. Students felt ambivalence about this career path, expressing concerns about feeling a lack of fulfillment since they believed industry jobs would not allow for the kind of social impact they appreciated about ICTD work. Amy's reflections on her career plans capture this ambivalence.

> I don't know. I'd like to [continue doing ICTD]. At the career fair there seemed like there were some companies that had an option like that [referring to social impact], but most of them were more like not that. If the opportunity arises, I think that'd be really cool. I don't know, I'm just starting my career. So we'll see where it takes me for a little bit. I was a little worried about computer science being not fulfilling and feel[ing] like I'm not, like I wouldn't be giving back. So I think if I start to feel like that, I might try and return, see what's out there.

Amy highlights the central role of the career fair in her decision making, which aligns with the career funneling theory. At the time of our interview, Amy had just graduated and accepted a full-time job offer from a large tech company.

The explanation proposed by the career funneling theory suggests one plausible interpretation of Amy's ambivalence—that she ended up in a Big Tech job not because it was what she was most excited about but because of the structure and norms of job seeking at UW. Similarly, Kushal told us that he wanted to have an industry job even though he also hopes to continue to be involved with ICTD work.

> I think at least part of me would be involved [with ICTD] in some or the other

> way. I do want to go to industry and see what's in the industry. I haven't had my first proper exposure to the industry yet. So I am planning to take a sneak peek and see what's happening out there. But other than that I feel like even if I do go in that direction, I still will at least, a part of me, in some way or the other, would be involved with trying to get the best out of technology for other people.

Kushal's reasoning for seeking a Big Tech job is more explicit, but his belief that one should have a "proper exposure to the industry" indicates that that career path is a default.

The timing of social impact. To manage her concerns about her upcoming job "being not fulfilling," Amy articulated a long-term strategy in which she may try to find other jobs that better match her values, to "see what's out there." In a similar vein, Katie reflected on advice she received about her potential career paths to defer her interest in technology and global health.

> I wonder what the best would be in the end, whether it's more appropriate to go somewhere to learn more technical skills before I jump in [to ICTD]. 'Cause I think some realistic advice that people would give me who are not in this, they're like, just do that when you retire or do it when you're old.

The logic of this advice, Katie elaborated, is that in ICTD (or related fields) it is hard to get paid well and hard to get technical mentorship, so one should first accumulate those resources elsewhere.

Professor Anderson told us that he has heard such advice is often given—that one should become settled financially and also gain experience as an engineer working on large scale products. Though skills from industry may be a good way to be more effective later as an engineer doing social good, in all likelihood many of those who go to industry are not going to return to ICTD because, as Professor Anderson put it, "life takes over."

Sam saw her new Microsoft engineering job as a way to gather resources, including the institutional support of her employer (emphasis added).

> I definitely see myself being involved in some way in the future, even if right now that's currently, I have a pin on it because I'm just starting my first full time engineering job at Microsoft, and yeah, which is, it's been great, but it's something where *once I start becoming more comfortable and start seeing the time and the resources, I can start pursuing and seeing where those other opportunities lie,* and maybe see how a company like Microsoft could help with it. How maybe I can be involved later or take a sabbatical.

In this way, accumulating resources is seen as a reason to defer impact. For Shen Wen, conditions of her scholarship required her to take a job at a bank in Malaysia (her home country). She wants to propose mobile banking at her company to help the unbanked, thus also planning to keep some involvement with from within industry. And she wants to eventually teach CS in Malaysia—which she identifies as a developing country—to build capacity. Sam and Shen Wen's perspectives indicate that, while they do not see social impact immediately in their careers, they hope to be able to incorporate it in the future.

Alternate Pathways. Some students' discussion of their career paths did not fit the trend of deferring social impact. In contrast to the other eight students, Deepak saw his work at Microsoft as contributing to social impact already because he was able to get assigned to Microsoft's relatively rare projects in the public and nonprofit sectors.

> I started at Microsoft and the first thing I did was look for this kind of work. And I don't know why I am so interested in it or why it's so fun for me, but it's almost something that, like, I need to do, at least for some of my time.

Though most of the students described Big Tech jobs in opposition to social impact, Deepak has found a way to do work that aligns with his values.

On the other hand, Katie and Priya shared that they were considering going into academia or pursuing a PhD as it was the most viable path they saw to centering social impact as their career. In Priya's words,

> I also feel like the opportunities in this field are pretty limited as far as I know. . . . I really don't know if I would pursue a Ph.D. or a Masters or continue in a lab or continue this research or try to go into industry. So I feel like if I go down the research route, there are so many opportunities for computing in development. But if I go down the industry route, it might be difficult for me to continue this because I don't know if there are a lot of companies. . .

For Katie, despite the advice she received about going to industry to get money and experience, her ideal path would be to become a professor and run an interdisciplinary engineering lab focused on global health technology. To pursue that, she was considering applying for PhD programs.

Through their reflections on ICTD research involvement, students contrast their desire for social impact (which they see as being realized through ICTD work) with traditional CS jobs, yet they still take the traditional jobs through patterns of career funneling recognized in prior work. Even though most do not intend to do the social impact they desire immediately, they all hope to include (or even center) social impact in their jobs eventually. We refer to this as deferring social impact. Investigating students who instead eschew the default CS career path, Cui argues that, 'The legitimation of alternatives is a crucial step to transitioning students from reluctantly recruiting for Big Tech companies to confidently pursuing alternatives." Among students we interviewed, ICTD and related areas were described to us as valuable and interesting, but when it came to career decisions, mainstream industry jobs won out. It is one thing for alternative fields to be legitimated broadly, but legitimating specific career paths for new graduates is another.

Finally, we caution that these findings should not be read as a general fact about CS students interested in social impact, but as an interesting phenomenon among some. In contrast, when reporting on an earlier iteration of this same capstone course a decade ago, Anderson et al. stated "Several students from the course are planning to continue work in ICTD in graduate school, another accepted an ICTD-related internship" [16]. Conversely, it may be the case that some of our interviewees saw us as "doing ICTD" and therefore presented themselves as more likely to pursue social good work.

4.6 Discussion

4.6.1 Deferral and other careers

If you come visit the new Gates Center at the Paul G. Allen School of Computer Science and Engineering, you enter through the Microsoft Cafe. Perhaps you are headed to the event space on the top floor, the Zillow Commons, so you head up the Sujal and Meera Patel Innovation Stairway. Perhaps you go down the the Amazon Auditorium for a talk, or you visit me (Philip) across the street in the Allen Center, in my office named in recognition of Brian Valentine, a Microsoft and Amazon executive.

In this environment, is it a surprise that, although they contrast social impact with mainstream engineering jobs, most students still took or planned to take jobs as programmers at large tech companies? Most students planned to defer the social impact they desire, either by leaving such jobs later or by seeking a way to contribute to positive social change within industry. The students who wanted to center social impact in their careers in the short-term saw academia as the most feasible path. We do not seek to make normative judgements about students' career choices; students with more privilege may feel less pressure to select a high-paying job. Identifying the deferring social impact phenomenon contributes an elaboration of the career funneling theory introduced by Binder et al. who traced linkages between prestige, job recruitment, and insecurity [26]. And the concept is not entirely new, even if the name is; Giridharadas's portrait of Hilary Cohen documents in detail her decision to defer her plans to contribute to social change [60].

Binder et al [26]. focus their career funneling theory on mechanisms that explain why undergraduates value a narrow set of careers as prestigious. As a follow-on to their main findings, Binder et al. note that students also deferred the career they really wanted in favor of a more prestigious first job. They note that "the belief they could later get the career they really wanted undergirded interviewees' justifications for taking jobs they felt compelled toward now—jobs that shored up prestige and kept fears of the inscrutable job market at bay." We see a similar pattern in our data, where students end up taking a job at a large tech company despite their concerns about their ability to have social impact with such careers. Our findings show students' belief that this work experience will enable them to make social impact later, since they may become more skilled at software engineering through their work experience or may have access to more resources through their affiliation with a large company.

In Peters's longitudinal study of students' participation in CS, one student shifted away from trying to combine politics and computing since "he doubts he can find a job that 'is about saving the world"' [119]. This example parallels the experiences of the students described in section 4.5.2 who are interested in going into academia to pursue ICTD-adjacent work because they do not see such a career path in industry. In Peters's analysis, students' interdisciplinary interests are marginalized and "[p]erforming an identity as a (technical) problem solver helps to fit in."

The phenomenon of students who are motivated by social impact taking mainstream jobs is also reported by Giridharadas, with a case study in the consulting industry. He tells the story of Hilary Cohen's choice to go to Goldman Sachs after graduation [60, p.22].

> She considered jobs in the nonprofit sector that had been advertised on campus or online. Somehow, though, they felt risky to her. Sure, she would be cutting to the chase of making a difference, but wouldn't she be forgoing the skill-building and self-cultivation offered by the big private-sector firms? Some of the NGOs she looked at seemed to have no career plan for a young person, no promise of a trajectory of growing responsibilities and impact.

Giridharadas goes on to dismantle the claim that training in consulting is the best way to "change the world," but the parallel in computer science is murkier: scholars disagree on whether software development skills learned in Big Tech may transfer to "social good" work.

4.6.2 Implications for Computing Education

Amid concerns about dropping enrollments, CS educators in the mid 2000s were concerned that students were not interested in the field. Schulte and Knobelsdorf motivated their 2007 paper citing these enrollment statistics and arguing that, "When looking at students in general, we have to admit that CS has never been popular" [133]. Four years later, Lewis et al. investigated CS enrollment with similar concerns and referenced "signs of a possible turnaround" [89]. In the context of both overall enrollment concerns and computing education's persistent research focus on the gender gap in enrollment, computing for social good was presented as an antidote—a way to recruit more students to the field and appeal to more women. At UW in 2021, computer science is one of the (if not *the*) most prestigious and in-demand majors. Our data show that in this case many students reported that the involvement in ICTD research transformed (positively) their thinking about CS. Anecdotally, it seems that as a whole CS majors at UW are more likely to focus on Big Tech jobs than social impact—we hypothesize that this can be attributed to career funneling.

Sax et al. found that "social activist values" was the most statistically explanatory variable in their data for the gender gap in computing majors at the undergraduate level [131]. Our data suggest one possible explanation for this link: some students are concerned about the position of computing in global capitalism. In such students' analyses, mainstream computing focuses on serving the needs of the wealthy. This is both a new contribution to the literature on conceptions of computing and a challenge for computing education and computing as a whole. In light of the gap between students' desired social impact and their ambivalence about their career paths, as CS educators we should ask ourselves whether we teach computing for social good because we value its outcomes, or because we see it as a carrot to entice students (particularly women) into CS classrooms.

4.7 Conclusion

In response to RQ1 (how undergraduates understand their involvement in ICTD), we find that students narrate their involvement in terms of social impact. They describe ICTD and social impact in contrast to the default values of computing, which several students critiqued for being overly invested in profit and serving privileged ends. The default pathway of software engineering does not perturb this view of computing as serving the privileged, and students described their encounters with ICTD as "eye-opening."

In response to RQ2 (how the students reason about their career goals), we find that respondents tend to express ambivalence about their CS and software engineering career choices. All of the students expressed the hope to continue to combine social impact and computing work, yet they often chose to take mainstream jobs at big tech companies where they were concerned about not being able to make such impact. Several students voiced a plan to defer social impact until a time at which they had more resources and skills after working at a mainstream tech company. Those who did not plan to defer social impact sought academic paths.

Our findings suggest some directions for future work. Studies on the connections between CS students' desires for social impact and career paths among other populations (e.g., other types of institutions, other countries) or over a longitudinal timespan could expand our understanding of the decision to defer social impact. Our findings demonstrate the importance of understanding the specific mechanisms of career funneling in computing, though this is currently limited to the work of Binder et al [26]. and Cui [37]. Moreover, computer science and engineering departments should be working to familiarize students with a diversity of computing careers, and future research can explore whether/how this can broaden conceptions of computing.

Returning to the theme of the dissertation, this chapter shows how students maintain their interest in computer science through engagement with social impact projects.[2] Their

[2] In fact, the students' interest in CCIS also maintained my (Philip's) interest in the project.

interest in computing in turn reproduces the discipline, which promotes such projects as a strategy of diversifying the computing workforce.

Chapter 5

CONCLUSION

5.1 CS4Good

Among the many social structures that technologists maintain are the many computer science departments around the world. All around computer science, the alarm bells are ringing [105, 21, 49, 113, 163, 2], and one of the few responses from mainstream computer science is the move toward "CS4Good." There is a certain rhetorical subversiveness in that phrase: if we applaud some computer science "for good," there must be some other computer science that is *not* for good. But as "CS4Good" has gone mainstream, I think that it has lost that small critical edge.

As computer scientists, we must ask ourselves quite seriously what our discipline means for the world and what we would like to *make it mean*. In the Paul G. Allen School of Computer Science and Engineering (CSE), the answers are contested and yet many (faculty, graduate students, and undergraduate students) seem not to engage much with the question. A surface analysis might argue that computer scientists are choosing to be apolitical, to focus on the technical matters of their research. While this may be true, my experience suggests that computer scientists are not disinterested in the crucial meaning-making question, but rather that there is an established compromise and it can be exhausting to re-argue the same questions.

The current settlement is well summarized by two recently-announced developments in our school. First, faculty have arranged a program through which CSE PhD students can do Artificial Intelligence research with funding and mentorship through Meta (a.k.a. Facebook) [115]. This is the latest in a long list of alliances between CSE and "Big Tech." Second, the school has published a web page on "CS4Good," which lists publications from Allen School researchers that "[apply] computing innovation to address societal challenges and improve people's lives" [1]. For the students I talked to in chapter 4, there is tension, or even conflict, between CS4Good and cozy relationships with Big Tech. At the CSE level, however, they comfortably coexist. The "social good" turn in computer science has become gradually more widespread over the last decade. With this new web page, CSE leadership embraces many projects labeled "good" and benefits from the association; the purpose of the page to market the school to potential students and to others at UW.

These developments pushed me to write about CS4Good, but my main interest is in what it means for ICTD research specifically to be included under the CS4Good banner. ICTD scholars have long been anxious about the definition of "development." Dodson et al. published a literature review hoping for papers to "[articulate] clear development objectives, such as a particular Millennium Development Goal" and they look for "what metrics, if any, underpin the pursuit of that goal, and whether baseline data was used to inform project design" [42]. This particular framing aligns closely with the development economics interest in investing money to improve specific indicators of progress, but push for scholars to define their development objectives is more wide-reaching. This is evidenced by debates over whether ICTD work should work towards, for example, the Millennium Development Goals (today, the Sustainable Development Goals) or the expansion of human capabilities (following Amartya Sen) or conscientization (following Paulo Freire) [29][1].

ICTD has seen some engagement with critique of development, specifically the work of Arturo Escobar [46]. Chirumamilla and Pal argue that ICTD can embrace play and entertainment to resist the development optic that sees users/beneficiaries of ICTD projects "as perpetually 'backward,' perpetually in need of improvements decided upon by a (usually Western) other" [33]. The bulk of the critical ICTD work focuses on the many sorts of problematic relationships that can arise between researchers, funders, and project users/participants/beneficiaries. Dearden and Kliene provide a good recent overview [40].

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[1]The referenced work by Burrell and Toyama does not name to conscientization; that is based on my more recent engagement in these discussions.

Here I want to add to the body of critical ICTD work an attention to the affective economy of ICTD within computer science. (I get the term *affective economy* from Sara Ahmed [9].) For the students of chapter 4, they see their work on CCIS as "social impact," with substantial positive affect based on its perceived moral importance. This matches the reactions I get when I describe ICTD projects to other computer science students: quick praise without skepticism. Affective economies work by association: ICTD work is good, so the people working on it are good, and the computer science department where it is hosted is good. The use of ICTD projects within CS4Good in publicity materials meant to improve the status of our department confirms this.

To be clear, my position is not that ICTD work is "bad." Rather, quick moral judgments based on the purported goals of a project and an uncritical belief in development are risky at best, and even people working on projects they believe to be doing their ethics well need to consider how that work is discursively represented to render other things "good" by association.

5.2 Bill's world

I'm standing outside the childhood home of Bill Gates in a quiet corner of the wealthy, overwhelmingly white Seattle neighborhood of Laurelhurst. The home is grand, overlooking beautiful Lake Washington. It's a short walk from the house I share with five housemates. Gates' name is on the new computer science building at UW and the computer science building at the university I attended as an undergraduate. His traces seem inescapable.

CCIS is funded by Gavi grants. Gavi's top funder today is the UK government (recall that the British Empire ruled Uganda from 1894-1961); second is the Bill & Melinda Gates Foundation. During CCEM's time, the Gates Foundation was investing less in global health, but now they are one of the primary players. McGoey asks, "Given that the Gates Foundation spends less annually on global health than many rich nations, why is Bill Gates a regular presence at summits such as the G20 in 2011? And why has the WHO management taken to consulting the Gates Foundation on major policy decisions?" [98, p.154]. She speculates that marketing, consistent media coverage of the foundation, and supportive public opinion combine to give the Gates Foundation an outsized influence on global health policy.

The Gates Foundation's endowment, mainly from the fortunes of Bill Gates and Warren Buffett, is relatively new money. CCEM, in contrast, received a lot of support from the development and global health organizations developed at the end of World War II (e.g., USAID, WHO, UNICEF). But CCEM was also supported by old money, from the legacy of 19th century robber baron Rockefeller. McGoey tells a remarkable story from a 2012 global health workshop at the University of Edinburgh. One attendee asked the audience, "Whose impact on India's health policies has been *worse*? The Gates Foundation or Rockefeller?" McGoey writes,

> Attendees shuffled in their chairs, trying not to glance too obviously at the Indian researchers scattered throughout the room 'At least Rockefeller built institutions!' one researcher, dressed in a sari, called out eventually. 'The Gates Foundation just leaves chaos. Not only is it changing the ideology of public health – it is deinstitutionalizing public health.' [98, p.169]

It has long been argued that philanthropy like that of Gates and Rockefeller serves an image-cleansing role for the giver. By giving away a small portion of one's ill-gotten gains, the wealthy can remake their public image as a do-gooder. This too works through affective economies.

Gates' fortune comes, of course, from the success of Microsoft, which is infamous for strong-arming OEMs (Original Equipment Manufacturers) into giving Microsoft a competitive edge. Most well-known among these is perhaps Microsoft's actions to promote Internet Explorer over the more popular Netscape Navigator. In 1995-1996, Compaq, the highest-volume Windows partner, shipped its Presario PCs with AOL and Navigator icons on the default desktop screen instead of MSN and Internet Explorer. The de-prioritization of their software caused Microsoft to threaten that Compaq would be barred from selling Windows unless they changed the icons. In 1998, the Department of Justice filed an anti-trust lawsuit against Microsoft, and in 1999 the judge found that Microsoft had illegally abused their monopoly power in the PC operating system market [3].

In the same lawsuit, but less well-known, the court examined Microsoft's actions against Intel. Intel in 1995 developed a Native Signal Processing (NSP) interface for their x86 processors so that software developers could build high(er) performance audio and video applications without additional hardware. Windows at the time did not support such applications, and Microsoft was building their version for Windows, Direct X. Not only did Intel's NSP compete with Direct X, it made its interfaces available to any operating system, not just Windows. Microsoft in response used its influence over the OEMs to demand that Intel stop work on NSP. Judge Thomas Penfield Jackson wrote:

> Even as late as the end of 1998, though, Microsoft still had not implemented key capabilities that Intel had been poised to offer consumers in 1995.
>
> 102. Microsoft was not content to merely quash Intel's NSP software. At a second meeting at Intel's headquarters on August 2, 1995, Gates told Grove that he had a fundamental problem with Intel using revenues from its microprocessor business to fund the development and distribution of free platform-level software. In fact, Gates said, Intel could not count on Microsoft to support Intel's next generation of microprocessors as long as Intel was developing platform-level software that competed with Windows [3].

The judge ordered that Microsoft be split into two companies, one for operating systems and one for applications, but upon appeal the final decision was instead that Microsoft cannot demand these sorts of concessions from OEMs.

5.2.1 Base erosion and profit shifting

The Guardian reported on the massive 2020 profits of Microsoft's Ireland subsidiary which "has no employees except directors."

> The subsidiary, which is resident for tax purposes in Bermuda and collects licence fees for the use of copyrighted Microsoft software around the world, recorded an annual profit of $314.7bn in the year to the end of June 2020, according to accounts filed at the Irish Companies Registration Office [109].

Microsoft, like many other multinationals, makes use of "base erosion and profit shifting" schemes like this to avoid taxation, and they work something like this: a company produces some technology in Country 1 and sells it in Country 2, but to reduce the tax they would owe to Country 1 or Country 2, they set up another subsidiary in Country 3 (e.g., Ireland). The subsidiary in Country 1 sells the intellectual property rights for the technology over to the subsidiary in Country 3, and then when the subsidiary in Country 2 sells the technology, the profits are paid to the subsidiary in Country 3. This allows the company to use the laws of Country 3 to determine their tax liability, and Country 3 is carefully chosen to reduce taxation as much as possible. The most common tax-avoidance scheme was the "Double Irish," which is no longer possible after 2020 [50]. Microsoft, instead, uses the "Single Malt" variant which relies on language in the Ireland-Malta tax treaty [4].[2]

Tying back into chapter 3, tax avoidance like this is a significant problem for Uganda. In 2013, Tanzanian Member of Parliament Zitto Kabwe claimed that multinationals avoid $50 billion of taxes in Africa annually, in comparison to $30 billion in annual aid, and the situation is exacerbated by the neoliberal economic policies required by the World Bank and IMF in the 1980s and 1990s [112]. A 2021 report by the EU Tax Observatory confirms that indeed, due to tax abuse, "Higher income countries lose more tax revenues in absolute terms. However, lower income countries lose a higher share of their collected tax revenue" [47]. Uganda specifically loses substantial revenue to tax avoidance. The Tax Justice Network identified at least $365 million in annual tax revenue lost to multinational schemes like the Single Malt. This figure is significanly less than Uganda receives in aid, but the authors

[2]Base erosion and profit shifting (BEPS) schemes are constantly evolving. The OECD has attempted to disable BEPS legal tools, as has US tax reform, but neither has been effective, as firms are able to find new loopholes [136].

describe this estimate as “the tip of the iceberg” [144].

5.3 The unbearable lightness of CS4Good

Just like philanthropy that sanitizes a public image, I argue that the affective economics of CS4Good rehabilitate the image of the computer science discipline. This parallel's Pal's argument that #chi4good may deliver the greatest benefits to HCI researchers [116].

Famously, Google's motto was “Don't be evil,” but with the 2015 Alphabet restructuring, it was replaced with “Do the right thing” [156]. In isolation, “Do the right thing” seems benign, but the change removes the resistance to “evil.” Worker-organizers at Google, for example, argued that the original motto supported internal pushback against controversial projects.

> “Google realized that 'don't be evil' was both costing it money and driving workers to organize,” the ex-Googlers said in a statement on Monday. “Rather than admit that their stance had changed and lose the accompanying benefits to the company image, Google fired employees who were living the motto” [11].

Whereas “don't be evil” gave some power to worker-organizers, “do the right thing” is defanged. This is what I refer to as an “unbearable lightness.”[3]

The CS4Good label is applied to ethically concerning projects I've participated in (not discussed here). Placed under the CS4Good heading among a long list of papers, they gain currency as “good.” So, just like “do the right thing,” “CS4Good” is limited in its ability to resist the not-good parts of computer science. The label does not require us to have any clear ethical stance; any affiliation with an under-specified “good” will do, and careful analysis like that in chapter 3 is not expected. As “CS4Good” on our department webpage transmutes problematic scholarship into a strong public image for recruiting students and funding, the label is doing important maintenance work to keep the image of computer science afloat

[3]Thanks to Ricardo Gomez for suggesting this phrase.

amid persistent critique. Thus, the label is unbearably light, and those of us whose work is put under it should be careful.

Though many computer scientists are aware generally of critical perspectives on the field, to make the lessons specific to our situations we need to study. Instead, many computer scientists choose to stay ignorant: to "stay in their lane" and expect others to take responsibility for "the social." When computer scientists see themselves as under-qualified to engage the social, they may consult or even co-author with scholars from other disciplines. (Of course, in my experience, the computer scientists never *fund* those other experts.) If this interdisciplinarity is driven by a refusal to personally engage with ethical issues, seeking instead to rely on the ethics of others, it is a refusal to grow into a "critical awakening" [96]. More pessimistically, the insistence on minding one's own business can be interpreted as a strategy of willful ignorance, the exercise of what McGoey describes as "the ability to use blame-shifting and ignorance alibis to avoid liability for causing harm and suffering to less powerful groups" [**?** , p.307]. In this regard, limited interdisciplinary engagements also are used to maintain computer science.

To truly nurture our people and our institutions, we need to move beyond CS4Good. But we need something like CS4Good because we need alternatives to the career funnel and our students want avenues to pursue their interests in helping others more than than earning a profit. But CS4Good is too flimsy, its ethics too dilute. The search for alternatives is not hard; there are so many critical computing scholars eager to see adoption within CS schools. In particular, we need to embrace sociotechnical analysis with a historical sensibility within computer science [140].

5.4 Positionality

I do not come at these three cases as an outside observer; rather, I am entangled in all of the relationships examined here. I entered this PhD program with the goal of designing, deploying, and evaluating an ICTD intervention. Like the students described in chapter 4, I had been excited to seek out a career path in computer science beyond (as one of those students put it) making "the world better for people who are rich." And lest the reader think I was too critical of the students in chapter 4, I empathize with them a lot as I am also headed now to a "regular" computer science job. To the extent that we are critical of the connections between cold chain software and international donors' support of Museveni, I am implicated as one of the main software developers of CCIS.

For the data collection of chapter 2 I came in with the goal of building a toolkit (which never came to fruition) to help spread community networks. This was a close collaboration with AlterMundi. Coming in as supporters of AlterMundi may have made us less attentive to the experiences of those in the neighborhood who do not use the community networks (in contrast to Nic Bidwell's more diverse sampling of interviewees).

Finally, the affective economy of ICTD is also one I benefit from, at least loosely, as my research has been seen by other computer scientists as working toward a noble goal. Perhaps writing this critique of CS4Good will change those perceptions?

5.5 Summary

This thesis has focused on asking what social structures are maintained by our work on computing for good or for development or for impact. In chapter 2, we saw that the maintenance of community networking technology helps bring people together, which it can do despite or because of its disrepair, and this may be more important than internet access. Whereas maintenance and repair of community networks AlterMundi is involved in supports significant local community bonds, maintenance of CCEM supports the relationships between PATH and international donors and Museveni's government. In chapter 3, I argued that seemingly-banal technologies have complex social lives that take a position on long-running struggles by stabilizing relationships like those between the Ugandan government and foreign donors. This underlines the importance of a historicist sensibility in our analyses. Chapter 4 turned our attention to how notions of "social good" circulate among computer science students who worked on programming a prototype of CCIS, highlighting both the importance of alternatives to Big Tech and the ways that programming labor on a project "for good" maintains student interest in computer science. The conclusion describes how ICTD projects maintain the status of the computer science department because they are put to discursive use as examples of "CS4Good" and argues that this is a response to computer science's "image problem" just like the philanthropy that funds ICTD projects. What, then, should we do? Study our history and approach every claim of universal good with a careful skepticism.

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