Air/time Travel: Rethinking Appropriation in Global HCI and Futures of Electronic Exchange

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ABSTRACT

This paper reexamines appropriation in human-computer interaction (HCI), which refers to the unexpected alterations made to artifacts by users. We analyze when earlier informal practices of exchanging airtime for cash became enclosed into proprietary mobile money platforms, and show that this enclosure has a longer history in global telecommunications. Building on interviews with 19 experts in computing, policy, and media, we challenge teleological narratives of the inevitability of mobile money often overlooked in computing and global development. We develop an 'appropriation matrix' introducing a dialectic of re- and reverse- appropriation animated by three elements—users, artifacts, and imaginaries—that unexpectedly switch between production and consumption, complicating invention and innovation in formal and informal economies. This matrix may help HCI and development better understand how different values, visions, and practices might have led (or could still lead) to different designs of products like mobile money.

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; *Empirical studies in HCI*.

KEYWORDS

airtime, mobile money, appropriation, design, speculation, history

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1 INTRODUCTION

> "Now there is a pilot project in Kenya, the first in the world, to transfer money, Western Union style, to anybody with a cellphone. It is exciting, yes, but then people have been sending money to each other in Kenya for years. Send minutes to someone, and they can resell them for cash." – Wainaina, 2007 [174]

Airtime in Africa and many parts of the Majority World is multifaceted.[1] For telecommunications companies (telcos), it is a way to offer customers a bundle of services such as voice and SMS [143]. For third-party value-added service providers, airtime is a mechanism through which their products are priced and purchased, for example, the sale of ringtones or local music [121]. For users (also dubbed subscribers), airtime moderates access to telco services and products [178], but it is also an affordance [27, 54, 76] that has been used to transfer *value* electronically. Unlike in Europe and North America, where airtime is 'always-on' for the majority of personal mobile devices, in Africa, 98% of airtime is 'prepaid' [167], metered into seconds to offset its relatively enormous cost (by Gross National Income per capita) [26]. Users in Africa have, thus, developed 'calculative agencies' [171] and 'metered mindsets' [37] to work around, for instance, shared phone use and the scarcity of airtime itself. Accordingly, these workaround and access dynamics have produced varied and unprecedented use cases [21, 25, 71].

Prominent among these cases are two instances that exemplify inventive hacks and innovations: unexpected modifications or adaptations of artifacts by users, a phenomenon widely recognized as **appropriation** in HCI [35, 40]. First, the use of 'missed calls' [36] (which will be interchangeably referred to as 'beeping' or 'flashing'); communicative acts where a user could call someone, ring a number of times and thus register a caller identification (ID), but hang up before the call was answered and billed, achieving gratis the function of a pager from the last century. Second, the use of airtime as *currency*. In what anthropologist of money Bill Maurer termed the 'creative instability' of airtime [105], users could use airtime as a 'commodity' in exchange for others, while on the other hand, deploying it as a 'commodity' to facilitate communication via mobile telephony (i.e., through voice, SMS/texts, and more recently internet broadband). This form of exchange – "now, airtime; then, money" [105] – was not billed extra by telcos: rather when profits were made in the exchange, they were made by ad-hoc traders, including trusted networks of small shop owners.

Airtime exchange has been eclipsed by mobile money [23, 39, 72, 89, 101, 102], which was first successfully launched at scale in 2007 in Kenya as "an innovative [mobile] payment service for the unbanked" [72]. Mobile money is a form of electronic exchange

[1] We follow Ferguson [52]'s position against the imagery of "the global" that "Africa" is marginal to. Indeed, Alam [4] has valuably defined the "Majority World" (widely known as the Global South) to include Africa and other often heterogeneous, often naturally endowed, but often economically poorer regions. Although it might not be immediately apparent, the concept of "airtime" in global telecommunications circuits is perhaps most prominent across countries and regions in the Majority World, where airtime and the practices around its exchange have been related. Therefore, when we speak of airtime and other concepts related to mobile telephony, we (and our interview participants, from whom we took our cue) are referring to these pan-African and Majority World commonalities, and how they differ across countries and regions.

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that is primarily accessible without the internet via widespread and low-latency protocols and interfaces such as Unstructured Supplementary Service Data (USSD) and SIM Application Toolkit (STK), which are part of the Global System for Mobile Communications (GSM). According to GSMA's 2021 *State of Industry Report on Mobile Money*, there were 1.21 billion mobile money accounts worldwide [6]. Notably, East Africa accounted for a quarter of global mobile money accounts and about 45% of transaction volumes ($18.6 billion in 2020). Since its launch, expectations for and analogies used to describe mobile money have changed many times: for example, while some hoped it would be a 'digital wallet,' over 50% of its transactions remain "cash in, cash out."

In this paper, we study the transition of airtime exchange to mobile money, noting that the perception of the latter as inevitable may be misleading, and that this transition remains understudied and undertheorized within HCI and global development. Mobile money has seen over 15 years of development, improvement, and imbrication into the fabric of local communities, and airtime exchange has to some degree been de-centered from those lives. External and internal aspirations often focus on formalizing the economy, utilizing visions and practices that tend to dismiss *the informal*, despite its importance.[2] These and other factors contribute to tendencies to adopt reductive teleological views of the transition from airtime exchange to mobile money. Many portrayals assume that *mobile money is a superior, mature version of airtime exchange*; its progression seemingly inevitable, transitioning from undesirable cash-based economies to seamless *cashlessness*; from an undeveloped past to a developed tomorrow. To address such reductive narratives and tensions emerging from appropriation practices, the study was launched with two key research questions:

- **RQ1:** What are the differences between airtime exchange and mobile money, and how were they experienced by those involved in the transition? What was gained and lost, and by whom?
- **RQ2:** What were the mechanisms by which informal user practices were appropriated and formalized, and what are the implications for other (future) such formalizations?

We conducted 19 online semi-structured interviews with a heterogeneous group of experts in computing, policy, and media industries, seeking to recover unrecorded aspects of airtime exchange and initial experiences of mobile money. During this process, we came to understand that the 'appropriation' we had initially identified (RQ2) – commonly understood as unexpected modifications or adaptations of artifacts by users – was only one of several stages of appropriation conducted both by formal and informal users in the space of GSM. We also learned that the 'users' who appropriated mobile telephony involved more and different actors than often portrayed, and that the boundaries between these users (humans and organizations) changed and reversed throughout this short history. In addition, the 'artifacts' users appropriated and the 'imaginaries' they deployed to motivate and rationalize their actions involved a multi-dimensional range of "objects, facts, actions, and people in the [electronic exchange] world and the [electronic exchange] world in them" [42]. This led us to develop a multi-dimensional **appropriation matrix** (section 4), a novel theoretical tool for empirical, analytical, and heuristic use, as a way of understanding how and why these technologies of electronic exchange differ, how they change, and when they get enclosed, and by whom. In doing so, we do not only center the 'embeddedness' of electronic exchange in social and cultural practices and institutions [33, 64, 134] but also attend to historical sensibilities [151, 156] central to understanding different trajectories that mobile money might have taken, and their potential implications.

[2]The International Labour Organization (ILO) estimates 85% of Africa's employment is informal [79].

2 BACKGROUND

2.1 A primer on GSM and prepaid mobile telephony in Africa and beyond

The GSM is "an openly published international [telecommunications] standard" developed in Europe for Europe, whose architecture and "associated protocols are only known to a relatively small group of [Research & Development (R&D)] engineers" [175].[3] One of the key architects of GSM telephony described its 'phenomenal' and 'relatively quick' uptake in Africa (and the Majority World) as an 'unintended consequence' [166]. The success of South African-headquartered Mobile Telecommunications Network (MTN) Group is an illustrative example of this 'unintended consequence': "MTN's first business plan in the early 90s estimated that the company would have 350,000 subscribers by 2010. Instead, it had 129 million subscribers in 22 countries" [57]. In its expansion to Uganda in 1998, MTN launched the first pay-as-you-go (prepaid) model outside of South Africa – a model where subscribers in cash-driven economies could actively buy telecommunications products (i.e., voice and text) at metered and locally affordable rates. This model has since become the preferred payment method for the majority of mobile phone users in the Majority World.

The prepaid model of telecommunications, which rose to and continues to dominate Africa [167], was partly driven by USSD, a less known protocol first introduced in GSM's second generation and continuously carried through to 5G. USSD is a bidirectional, real-time, low-latency text interface connecting telco servers to phones. Key combinations like *100# initiate a mobile phone application interpreted session – depending on the type of phone, labeled MS/UE in Fig. 1 per GSM specifications – where the server sends a message that is presented to the user as text and a set of options [50, 51, 67]. When the user enters an option this is sent to the server, which can return more instructions and options, allowing cascading and branching interactions. USSD had originally been designed to enable network engineers to query telecommunications networks, but it was repurposed to support end-user value-added services such as airtime top-ups, transfers of one's airtime to another user's number, and balance inquiries. USSD has been termed a 'universal app' [131] for its availability on every mobile handset, including its notable interface for mobile money.

The prepaid model uses airtime as credit through which mobile telecommunications services (i.e., voice, SMS/text, and more recently internet data) are metered. [37]. Foster [54] explains that

[3]This paper does not go into conversations on standards. In the US, Qualcomm popularized a competing standard, Code-division multiple access (CDMA). However, we maintain the focus on GSM in the paper as it was dominant in markets in Africa and other countries of the Majority World.

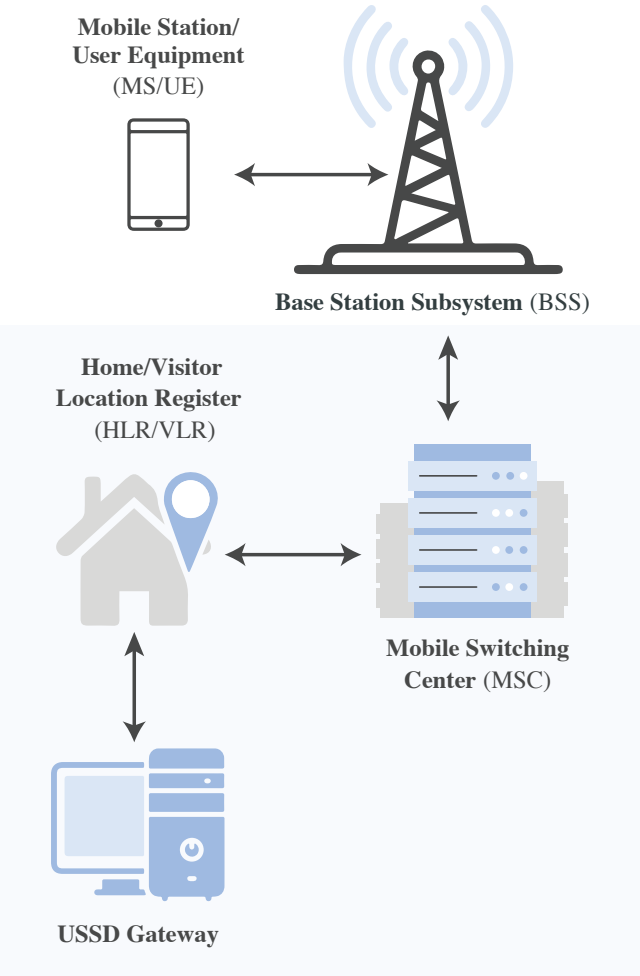

Figure 1: A rendering of the stack of GSM. Of interest is Signaling System No. 7 (SS7), a set of telephony signaling protocols that are used to set up and terminate calls in GSM [147]. SS7 also separates signaling from voice circuits. In this snapshot, SS7 interacts at various levels such as MS/UE, BSS, MSC, HLR/VLR, and USSD. In the findings (section 5), we will focus on signaling and how it was broken and mended in prepaid telephony (USSD) and roaming (HLR/VLR).

under such a model "users commonly 'top-up' their air time by purchasing small amounts, often in the form of scratch cards sold by street vendors." Scratching a layer of gray tamper-proof coating off the card reveals a code which, when entered into a user's phone through a USSD interaction, stores the credit in a user's account. This credit has been analogized by users to fuel in car, charge in a battery. With the advent of electronic airtime, the visits to street vendors have certainly reduced [153] but airtime is still central in mobile telephony. It therefore comes as no surprise that airtime or its lack – and its role as an affordance in mobile telephony [3, 27] – catalyzed new and unconventional uses such as beeping or airtime exchange. While the prepaid model is propelled by cheap SIM cards and assemblages of low-level protocols like USSD through which airtime is circulated, the "human infrastructures" that fuel this model cannot be underestimated [66, 144], particularly the airtime sellers [18, 98] and mobile money agents [129] without whose affective work the networks would never have spread. [4]

2.2 HCI and airtime and (mobile) money

Airtime and mobile money are used in economic and social exchanges. Scholars generally agree that airtime exchange preceded mobile money [1, 32, 44, 72, 145, 174]; as airtime animated particular forms of sociality and exchange [109, 145] before its enclosure into mobile money and other digital finance products. Although telcos may appear to have eliminated informal practices such as airtime exchange following the advent of mobile money, these practices persist, culturally situated, and economically negotiated [96].

HCI has primarily engaged with airtime and (mobile) money at personal and organizational levels of finance. We situate HCI and design research across two focal areas: first, on airtime, and second, and more recently, on mobile money and emerging financial technologies (FinTech). Studying airtime, designers in the United Kingdom (UK) proposed a creative network hack to trade unspent but expired 'unlimited' phone credits [75]. Following the promise of digitalizing of the 'informal' [103], researchers in India have studied the tensions and negotiations of airtime use and distribution within small and medium-sized enterprises, while researchers found that airtime could be used to compensate micro work [43, 163]. In the mobile money arena, HCI-oriented studies have focused on specific applications such as information security [132]. More recent scholarship in HCI has attended to the interactions between technology and finance in global contexts such as the use of technology in remittance circuits [140], the use of airtime in constructing datafied digital credit profiles [60, 154], and the promises and perils of digital currencies and 'programmable money' in electronic exchange worlds [48, 49, 60, 91]. This work has adopted critical and reflexive perspectives on money, prioritizing concrete lived experiences of people at the margins [60, 106, 116, 117, 180].

3 METHODOLOGY

Following Star and Strauss [160], this study sought to "[study] the understudied." While there have been numerous studies on the innovation of mobile money, fewer studies have systematically paid attention to airtime exchange and other informal practices before mobile money, and what may have been gained or lost as these practices were formalized into mobile money – from the late 1990s through the 2000s. It is easy to (heuristically) understand why telcos would seek to formalize and replace an informal activity happening on their networks with one they controlled, and from which they extracted maximum value; why governments would want visibility into transactions; and that aspects of the mobile money user experience are superior to the informal trades of airtime. However, most portrayals of these transitions remain "winners' histories," failing to acknowledge how deeply the wins were built atop a prior stack of innovations and labor.

[4] See also Monga [111]'s notes on 'human infrastructures' in *Nihilism and negritude.*

3.1 Study population and semi-structured interviews

In "studying the understudied," we centered actors whose work is often overlooked in winners' histories, and whose knowledges and practices have been barely documented, sometimes without proper attribution. As such, we focused on "behind-the-scenes workers" [159] who were active in the transition from airtime exchange to mobile money: privileging [oral] stories from people in middle management or below who were active in mobile money's embryonic phase. The research participants in our study population were people predominantly from Africa whose ages ranged from 36 to 75 years, and whose diverse sets of experiences and expertise gave them insight into indigenous innovation and practices [2]. We also spoke to two white Americans from the United States who pioneered and scaled prepaid billing systems in the 80s and 90s. While our participants were experts in various fields, most of them rarely captured headlines or commanded significant power within the institutional contexts in which they were embedded or affiliated, although they still had agency in limited but not insignificant ways. These included mobile money agents translating corporate visions to tangible value exchange practices [66, 169], engineers (and consultants) *making do* in the wake of telecommunications network breakdowns [125], media practitioners using indigenous media to translate possibilities (and risks) of emerging forms of mobile technology [119, 130], and enterprising policy wonks trailblazing a new form of bureaucratic imagination [122, 151].

P-ID	Gender	Country	Expertise
P01	M	Kenya	Telecom /Innovation
P02	W	Uganda	Competition Research
P03	M	Uganda	Telecom/Innovation
P04	M	Kenya	FinTech
P05	W	Kenya	Media
P06	W	Uganda	Enterprise
P07	M	Uganda	Enterprise
P08	M	Kenya	Banking /Telecom
P09	M	Uganda	Innovation
P10	M	Nigeria	Innovation
P11	W	Uganda	Airtime Agent
P12	W	United States	Telecom/Innovation
P13	M	Tanzania	ISP/Innovation
P14	M	Kenya	Policy
P15	M	Kenya	Media/Legal
P16	M	Tanzania	Regulation
P17	M	Malawi	ISP/Innovation
P18	M	Tanzania	Marketing
P19	M	United States	Telecom

Table 1: Displays participants by their ID (P-ID), gender, country of origin, and expertise.

As we were focused on the historical (perhaps still incomplete) transition from airtime exchange to mobile money, we spent considerable time studying the archive, interrogating old and contemporary sources regarding this transition in media reports and blogs, policy reports and memos, privileged deeds and agreements, and other documents from current and former actors in government, the private sector, and global development. Alongside a detailed first-person account of a GSM founder [166], we engaged substantively with reflexive and ethnographic materials on mobile telephony in Africa and other parts of the Majority World, documented at a time of major shifts in mobile telephony in the 90s and 2000s. For instance, Ndemo and Weiss [121]'s book on the digital revolution in Kenya; Horst and Miller [71]'s 2006 book, *The Cell Phone*, a classic comparative ethnography of the 'domestication' of the mobile phones *for* poverty alleviation in Ghana, India, Jamaica, and South Africa. Closer to narratives on airtime exchange and mobile money, we drew on Odumosu [126]'s ethnography of MTN engineers in Nigeria, and Ghosh [59]'s multi-sited ethnography of mobile money infrastructures in Uganda and India.

Collectively, these studies helped us to observe the *multi-sitedness* of practices such as beeping and airtime exchange beyond East Africa, where the first instances of airtime exchange were first documented [145] (other similar instances are reported in regions such as West Africa [126] and Southern Africa [149]). We were surprised by Foster [54]'s ethnographic portrait of beeping and airtime exchange in Papua New Guinea, practices which are remarkably similar to those in Africa. Importantly, this notion of multi-sitedness also informed our identification and recruitment strategy for research participants (more on this below). Some of our participants (notably P01, P10, P12, P13, P17, P19 as shown in table 1, and as you will see in the findings) were also 'multi-sited,' operating in numerous countries across continents such as Africa, Latin America, and North America.

We used semi-structured interviews, a proven method of data collection in qualitative and interpretive work in HCI, for empirical evidence. Studies related to this paper have interviewed a varying number of participants; from eight participants [11] to over 100 [25]. We conducted 19 online interviews with experts in computing, policy, and media industries. Interviews were conducted across two stages. In the first stage, we conducted 11 online interviews between August - November 2022 (P01 - P11). In the second stage, we conducted eight online interviews between June - August 2023 (P12 - P19). These interviews were conducted in English as it is the professional language of computing and global development. The interviews lasted anywhere between 30 minutes to nearly 1.5 hours, totaling over 20 hours of recorded audio content.

We recruited the research participants in the following ways. In the first stage, we circulated a Google form on technology-specific mailing lists in East Africa and on our personal LinkedIn and Twitter accounts. The form asked potential participants to nominate themselves or other professionals who might have played a part in mobile money's design and development in the late 90s and the late 2000s. This step surfaced 38 unique nominations. Although we had expected to randomly select about 15 people, we opted for those whose experiences were temporally closest to the transition from airtime exchange to mobile money (i.e., the 90s and 2000s). We sent consent forms to those who accepted to participate in the

study and eventually held nine online interviews. In the second stage, we leveraged our networks and contacts in the technology and development sector in East Africa, Southern Africa, and the United States, and secured 10 interviews. The first stage aimed to surface participants whom we could have easily missed had we only pursued the second stage. We used snowball sampling in both stages; three of 19 participants were thus included.

3.2 Positioning statement

Throughout the research process, the first author's identity and experience as a former technology blogger and graduate student from Uganda played an important role in access to participants, interpretation of archival materials and research findings, and in doing the bulk of the writing. The second author is a white North American researcher with an established history of work and collaboration in Africa, and he played an important role in the initial project formulation, study design, and writing. In Zimbabwe during the mid-2000s the second author witnessed the importance of airtime exchange as both a service and currency and could not stop thinking about the Wainaina quote that starts this paper; the first author lived through mobile money's meteoric rise and impact in East Africa, and wrote professionally about FinTech.

Mobile money has become a central feature of everyday life in most parts of Africa. However, debates on its provenance occasionally spring to the front stage. While our research explored various stories and histories of electronic exchange, it did not attempt to answer the (perhaps unanswerable) question: who invented mobile money? This was not the goal of the study. This question is so culturally and politically over-determined that even during this study, stochastic social media posts questioning mobile money's invention (unrelated to our study) generated significant debate and propagated conspiracies; some of our participants might have sought to set the record straight. While we could fact-check important claims, for example, Zain's launch of mobile money before Safaricom's launch of M-Pesa in Kenya (as you will see in the findings), we leave the question of singular corporate and national invention to other authors, and here seek to spotlight the user-inventors who developed its progenitor, and the transformations of appropriation.

3.3 Transcription and analysis

The first author alongside an undergraduate research assistant used an online transcription service to transcribe the interviews; both had to manually verify and correct mistakes in the initial automated transcriptions. To analyze the interview data, we followed a grounded theory research approach based on a combination of practices from Glaser and Strauss [61] and adapted to HCI [114]. Grounded theory is an inductive method that builds theory 'up' from the data, and it is exemplified through iterative comparisons of data and theory.

We used Atlas.ti, a qualitative data analysis software to analyze the data. Following the grounded theory approach, we used techniques of constant comparison to develop appropriate codes and themes. We developed hundreds of descriptive tags ('open codes') for items and stories in the data and subsequently generated related items ('thematic codes') such as 'licenses/regulation,' 'banks vs. telcos,' 'innovation,' etc. from which we enumerated our findings. This paper leveraged theoretical sampling, an analytic practice also established in grounded theory [22], where we learned from the first stage of interviews and desk research that the *appropriation* we had initially identified (RQ2) – and this is the appropriation common in most HCI and design research – had been preceded by a prior appropriation of European GSM technology by African telcos, who creatively invented new business and technical practices for local markets. Having provisionally built a 'theory,' exemplified by the 'appropriation matrix' in which airtime exchange and its enclosure took center stage, we found, in the second stage of the interviews, many moments where appropriations might have played out differently, or where a different balance of actors might have yielded different design decisions.

In the section below, we will articulate the fundamental elements for rethinking appropriation in global HCI and how these elements inform the appropriation matrix. Subsequently, our findings will be presented in section 5.

4 RETHINKING APPROPRIATION IN GLOBAL HCI

In HCI, appropriation is a relational accomplishment that involves unexpected adaptations or modifications of artifacts performed by users in concert with others and with things [12, 35, 40, 115, 125, 165]. A substantial amount of literature in HCI and design research [35, 40, 74, 93, 99, 115], as in science and technology studies (STS) and media studies [3, 95, 128, 146, 172], emphasizes the creative practices of [individual] users, how they encounter and how they 'domesticate' technology for material and symbolic purposes. In this work, appropriation is a transitive verb; users *perform* appropriation to some artifact within given ecologies, and in doing so, users mobilize imaginaries; variegated stories and logics to rationalize or motivate certain forms of action (we will examine this setup in subsection 4.1). Because artifacts "can be modified and re-programmed, whether the ability to modify is explicitly enabled through design or uncovered through hacking" [12], then appropriation can be said to have deep roots in the technical, cultural, and political. As a result, appropriation might have positive and negative consequences rarely imagined by the designers or promoters of a given technology [47]. But if users stick to the defaults as Bar et al. [12] suggest, then appropriation is "unsuccessful."

Closely related to HCI, however, researchers embedded in information systems research, organizational studies, and to an extent computer-supported cooperative work (CSCW), have drawn on influential sociological theories such as structuration to foreground mutually reinforcing relations between user agency and structural conditions, arguing that user action shapes appropriation in [organizational] structures and vice versa [127]. Within this vein of sociological inquiry, DeSanctis and Poole [31] are more direct in their articulation of appropriation. Their Adaptive Structuration Theory suggests that groups (in organizations) appropriate "structural features of a technology" by directly using technology or making judgments about it [31, 86]. Structural features might include "anonymous recording of ideas in a group decision support system" [86], and these features and their underlying values are very similar to affordances (referred to throughout this article).

'Micro' emphases of appropriation – where individuals and organizational settings are the primary units of analysis – have generated critical insights on appropriation. Empirically, scholars have shown that users appropriate artifacts' 'material' affordances [27, 58, 76] through 'modes' [12] or 'analytic categories' [47] that range from merely changing an artifact to radically transforming it. Localist or ethnographic work has particularly excelled at describing how users reveal that artifacts have complicated stories, mobilities, and (en)closures beyond designer or producer desires and goals [3, 28, 93, 108, 172]. Using complementary theoretical analyses, Tchounikine [165] for instance argues that "appropriation is a complex process, and complex processes require analyses from multiple perspectives." He extends localist work through an array of lenses on 'artifacts' and 'instruments.' In his telling, designers create artifacts (and their affordances), but instruments are dynamically created by users for particular purposes. As a result, an artifact can be converted into multiple instruments depending on user goals. Pipek and Wulf [133] might describe the revealing of instruments as *infrastructuring*: particular attention to user activities beyond designer objectives. Through this 'materialist' theoretical lens, there is closer attention to artifacts and how they are appropriated and "[synchronized] with local environments" [55, 56]. However, localist and middle-range theories have "largely unexplored," according to Bar et al. [12], "the interplay between economic, cultural, and political tensions," which are central to appropriation.

Critics at the intersection of HCI and organizational studies have called for the reconsideration of the 'local' in favor of non-local sensibilities that characterize much of our inter-networked intellectual and socio-economic milieux. Localist or micro-level studies often focus on individuals and organizations in the 'here and now' [112] at the expense of complex and sustained dynamics of technology transformation and change, which include 'trans-local' [20] and 'extended views of design' [112, 135, 165]. To address such tensions, Paul N. Edwards [46] advocates for a research approach that adopts important but often overlooked or underexplored meso and macro perspectives. In other words, there has been pushback against an exclusive focus on the artifact or the user or both, with focused attention drawn towards the complexities of 'infrastructure' [112], where culture, politics, and economy meet possibilities articulated in the very materials of technology.

4.1 Reexamining the elements of appropriation: Users, artifacts, and imaginaries

Early in our study, we imagined that the transition from airtime exchange to mobile money could be explained by prior theories of appropriation. As we dove into the oral history and secondary literature, however, we first realized that users were not stable subjects, then gradually that neither were artifacts, nor how people imagined the two were – or should be – related. We had to redefine the *elements* involved in what proved to be three elements of appropriation: users, artifacts, and imaginaries (although there could be more elements of other economic, social, and cultural import). These elements are crucial to understanding why appropriation unfolded in the way that it did. The interpretation of these elements – and eventual construction of the appropriation matrix (more in section 4.2) – is in dialog with two approaches that yield knowledge, but in ways that we suspect can also obscure other knowledge. The first, characterized by much HCI work, is to analyze appropriation at the level of artifact or user or both. This approach yields tremendous information about how users domesticate and tame technologies, but leaves out other stages of appropriation, larger actors, and has not seen much uptake in policy and regulatory circles. The second approach, common in development economics and much of public policy tends,[5] as it should, to focus on economic impact, and indeed the economic import of mobile money is massive and undeniable. However, this approach obfuscates the preexisting practice of airtime exchange and its enduring effects across ecologies of electronic exchange in the Majority World [157]. Our approach attempts to leverage both approaches above, reconciling them through an HCI lens.

Our setup begins with users who *perform* appropriation to something (what we are calling *infra-artifact-structure*) within given ecologies, and in doing so, users mobilize imaginaries – variegated stories and logics and desires. To *locate* users of interest, first, we show that users are better understood depending on their position along the production-consumption spectrum within particular spatiotemporal orders. We then introduce infra-artifact-structures to challenge the conventional understanding of the *artifact* as a stable entity. To this effect, we foreground the imaginaries users mobilize around given infra-artifact-structures in electronic exchange ecologies.

4.1.1 From users to a user-producer spectrum. Users matter! [128]. As shown above, most research in mobile money worlds focuses on [human] users – also known as subscribers – and their work to 'tame' or 'domesticate' technology [53, 70, 155], or under the influential research program of repair studies [63, 68, 80]. But this central focus may elide organizations from consideration; as non-human actors, and not just spaces where appropriation happens. Therefore, to adequately rethink appropriation, it is necessary to recognize that *users* are not monoliths, nor are they always only users. Users are located along a production-consumption spectrum, and their position can change dynamically. Many appropriation scholars have attempted to grapple with locating users along the production-consumption spectrum. For example, Mackay & Gillespie [95] have argued that Ruth Schwartz Cowan explicitly linked consumption and production in the 80s.

Toluwalogo Odumosu, a former engineer and now STS scholar, has an especially productive inflection of users, production, and consumption. From ethnographic interviews with MTN Nigeria system engineers in the mid-2000s, Odumosu [125] develops 'constitutive appropriation' to understand how users make an artifact "theirs" (of course, users making something "theirs" is the coda of appropriation). But Odumosu stands out because he carefully argues that appropriation is performed at various individual and societal levels, and is "not necessarily circumscribed to studies of the marginal" unlike Eglash [47] and Bar et al. [12] who respectively foreground marginality and adversarial-first frames of analysis. Borrowing from Marx's *Grundrisse* [100], Odumosu paraphrases that "production is simultaneously consumption" just

[5] Development economics is a sub-discipline of economics that focuses on the study of economic factors and policies underlying *development* in the Majority World. Development economics is an influential discipline in global development.

as "consumption is simultaneously production." This simultaneity might hark to prosumption [139], a portmanteau of production and consumption that is centered around the idea that consumers are not passive recipients but reconstruct innovations in material ways. For example, von Hippel [170]'s 'user-innovators' and Benkler [15]'s 'commons-based peer production,' may be interpreted as aspects of prosumption. However, in Odumosu's case (as in ours) the production-consumption simultaneity affords a richer and more dynamic analytical substrate than prosumption, a reified category that might flatten otherwise complex relations and ontologies. For example, in Odumosu's ethnographic portrait on "making mobiles African," he argues that when system engineers at MTN Nigeria appropriated GSM telephony, they could have been understood as designers/*producers* of local communication technology. However, for global technology provider Ericsson, in this case MTN's supplier of network equipment, MTN was a user/*consumer*. Production and consumption are not opposites, and might happen simultaneously.

4.1.2 From artifacts to infra-artifact-structures. The conventional understanding of appropriation is about how people configure artifacts in various socio-material sites, and how these configurations "produce changes in practice due to [these artifacts'] introduction" [141]. However, Oudshoorn and Pinch [128] have argued that this 'user-first' centrality is common to "media studies" unlike "historians and sociologists of technology [who] have chosen technology as their major topic of analysis" (HCI and design research appears to endeavor to establish a footing in either field). In the study of appropriation in mobile phone ecologies, HCI researchers have often treated artifacts as stable entities. Yet it is rarely the case that a mobile phone is a *stable* artifact. If Jonathan Sterne [162, p. 182] is correct, then a mobile phone is shorthand "for a whole set of related institutions, technologies, people, and practices." His argument is an invitation to consider the simultaneity of artifacts and infrastructures. Consequently, we frame the recursive entanglement between artifacts and infrastructures as **infra-artifact-structures** to capture the richness of the mobile phone in given ecologies.[6] To adequately identify and study infra-artifact-structures in their recursiveness and dispersion [92], we adopt 'inversion' throughout this article: "recognizing the depths of inter-dependence of [infra-artifact-structures]...and the real work of politics and knowledge production" [16] (from this sentence onwards we will return to using *artifact* for simplicity's sake, although we mean infra-artifact-structure writ large). In this case, we consider the mobile phone – with its many components; airtime, SIM cards, USSD and other network protocols; its changing cast of users and practices; its designers and their politics, etc., all factors principal to GSM (and prepaid mobile) telephony – as far from *stable* and entangled in many dimensions.

Yet this entanglement is only the first step. To rethink *the* artifact in appropriation, it must be placed within *exchange* relations through which its 'life history' is illuminated [7], and through which user practices and actions in appropriation can be fully accounted for. It is through this process that appropriation is accomplished. Such orientation, for example, contests simplistic narratives on 'technology transfer' [73] which are predicated on linearist and unidirectional flows (from West-to-rest) and are unmoored from the material realities of the Majority World [66, 94]. While there are richer takes on technology transfer, suggesting 'mutual adaptation' of technology's reinvention and simultaneous adaptation to organizations [141], we want to emphasize the relations between users and artifacts that are flux, incomplete, and as Guma [66] eloquently writes, "in transition." Therefore, the analysis of the practices around phone use must not be limited to what users do *to* the mobile phone itself but rather around the key elements of the mobile phone within given ecologies.

4.1.3 Imaginaries. Imaginaries are the medium between entities on the user-producer spectrum and infra-artifact-structures. Imagination is not only foundational to HCI and design but also to social, economic, and political life [14]. Drawing on Larkin [92, p. 329], artifacts "emerge out of and store within them forms of desire and fantasy": these forms are imaginaries. But imaginaries surmount desire and fantasy. Beckert [13, p. 177] in his book *Imagined Futures* argues that 'fictional expectations,' 'narrative infrastructures,' 'sociotechnical imaginaries,' and other such grammars do not only generate and perform distributions of value, power, and agency but also "set agendas, create relationships, define roles, and influence the allocation of resources."

On the micro level, for example, imaginaries of value exchange might be animated around mobile phones (and mobile money) [13] and user manipulations and workarounds (within moral and non-moral expressions of appropriation, with varying outcomes). Accordingly, Benabdallah et al. [14] assert that the "ramifications of technological artifacts are dependent on the imaginaries they are built from, for better or worse." As we have already seen above (4.1.2), ramifications also depend on the concrete and everyday uses of artifacts. On meso or macro levels, however, the stories get grander – perhaps more deterministic – but are mobilized through institutional visions or even public policy or state law. For example, institutions like the World Bank have since the 80s foregrounded Information and Communication Technologies (ICTs) as enablers of "knowledge for development in the information age" [138], and their visions can be seen through large-scale structural adjustment plans that the telecommunications world was not spared from [5]. Moreover, the mobile phone's (and mobile money's) ascendance in global development has not only appealed to the visions and practices of the Bank but also to governments, large corporations, and other multilateral development actors [17, 81, 176].

4.2 Appropriation matrix

The appropriation matrix is intended as a theoretical tool that might have empirical, analytical, and heuristic value for studying transformations in electronic exchange worlds across sites including HCI, design, and global development. As a reminder, the newly reformulated elements described in the preceding section above – users, artifacts, imaginaries – are combined into unique vectors (or stages), which constitute the appropriation matrix.

The appropriation matrix has three historical vectors that were roughly temporally serial but also recursive and overlapping. The

[6] In the study of appropriation, infrastructures play a crucial role because, just like artifacts, they provide *platforms* (or bases) for social action, collaboration, and organization [46, 83, 161]. While artifacts are entangled, they are widely seen as discrete. Infrastructures, on the other hand, while 'naturalized' as discrete, they are entangled, subsuming artifacts [112], standards and protocols [82, 158], institutional regimes and community codes [16, 84, 161].

first, **appropriation**, was the initial appropriation of GSM by companies and governments in Africa following telecommunications market liberalization in the 90s. The second, **re-appropriation**, occurred when users met a technology that had been developed with very different material, social, and cultural realities in mind, and built their own ways of exchanging value by creatively reinventing it. In the third vector, **reverse-appropriation**, telcos (and other entities) saw the improvements African users had made informally, and formalized it, replacing user practices with formal technical systems and extracting rent in the process. The matrix, therefore, provides a *vector space* to explore ongoing *transformations* between historically layered routines and practices, policy shifts, continuities and discontinuities in technology use and design [45, 84, 97, 151, 152]; presenting some sort of dialectical tension between "the past," and "the present and the epistemic, the not yet known, possible and desired future" [164].

4.2.1 Appropriation. We argue that appropriation commenced through the socially mediated engineering practices within telcos in Africa, complemented by financial investments within architectures of regional and international finance, and the demands of telecommunications liberalization in the 90s [5]. It is important to note that by the time mobile telecommunications was adopted in Africa, it had already undergone an extensive period of tension and negotiation in Europe and the United States, and was thus beyond its 'embryonic phase' [87]. The initial mobile telecommunications deployments in the early 90s in Africa were advanced and standardized (i.e., GSM and to some extent CDMA). In this stage of appropriation, telcos based in Africa (notably, MTN in the Anglophone sphere) drew on their staff and cachet of institutional resources including funding and mass marketing campaigns to make "mobiles African" [125]. In making mobiles African, they worked around challenging technical limitations on signaling and dimensioning – associated with protocols such as USSD or voice, and services like SMS – to repurpose prepaid mobile telephony.

We suggest that mobile telephony in Africa was not merely *transferred* in the first place – as Temple [166] testifies in his detailed personal history of GSM, arguing that the system's 'phenomenal' uptake in Africa was an 'unintended consequence' – and neither was it simply 'tailored' to fit the local conditions in various sites and places. In telecommunications circuits, telcos in Africa were *consumers* of networking equipment developed in the West. The differences in user/subscriber behavior across geographies (beeping, for example) confronted assumptions about 'standard' practices (postpaid calls). As a result of these practices, telcos claimed to be overwhelmed and potentially *forced* to come up with tentative solutions. While telco subscribers are often portrayed as the users in HCI, telcos in this instance of appropriation were the *first* users who appropriated GSM to suit their local market realities [20, 126].[7]

4.2.2 Re-appropriation. Having shown that appropriation was initiated by telcos – users at that moment – we argue that acts of re-appropriation were driven by customers of telecommunications. There is a wide and influential body of work across disciplines that engages with this stage of appropriation in mobile telephony in Africa and beyond [66, 71, 72, 101, 105, 113]. This is where HCI and ethnographic approaches to understanding how users in the Majority World tame technologies is especially valuable [107]. In particular, during this phase, users systematically explored the affordances of GSM infrastructure and phones, and created a set of dynamic sets of acts, practices, and informal standards.

Because GSM was (and continues to be) orders of magnitude more expensive for Majority World users [25], many of the new technologies of exchange these users created exploited affordances that were free, like beeping or airtime exchange. For example, users in countries such as Rwanda, Uganda, and Papua New Guinea communicated "free of charge amongst" themselves without "saying a word or typing a character" through beeping [36]: a culturally specific mode of communication that enables users to relay negotiated messages such as "pick me up now" or relational signs such as "I am thinking about you" [36]. Users in various regions like East Africa [145], Southern Africa [149], and West Africa [125] exchanged monetary value through airtime vouchers. We want to be clear: customers of telcos did not simply invent new uses of GSM telephony. By finding ways to use the networks and devices differently than intended, these users invented new *technologies*.

4.2.3 Reverse-appropriation. We analogize this process to enclosure. We argue that entities such as telcos took note of practices around re-appropriation, and attempted to incorporate these practices into their business offerings. Literature that valorizes 'user-innovators' and their contributions to corporate products and innovation [124, 168] describes this process well, as do studies attuned to the tensions within the relationship between users and producers [12, 110]. Examples in this case: telcos replaced beeping with a 'free' service that granted users a finite number of 'please call me back' messages [179], but would charge for more than the allotment. Some might argue that telcos ran roughshod over hitherto unsanctioned user practices and innovations [12] to *stabilize* [3] their systems against actions that 'congested networks' (reportedly due to the wide use of 'missed calls' and rampant airtime exchanges which consumed telcos' resources, but which they could not earn revenue from) [179]. In the stage of reverse-appropriation, telcos formalized approaches that centralized value extraction for themselves, for example, charging users and replacing various actors and exploits with new software and franchise employees.

This stage of appropriation expands the range of players beyond those involved in the first two stages. Telcos, governments, third-party companies, and development agencies all featured prominently in this stage. In this context, we see examples of attempts, successful or otherwise, to appropriate user practices into standard industry offerings not only by telcos themselves [23, 66] but also by profit-driven local and global entities [32, 69, 177]. It is also important to note that in this stage, mobilizations of technology speculation and futures making are most apparent, surfacing through mainstream media [24] and global development imaginaries [62].[8]

[7] Citing Asad [9], Lu and Qiu [94] seem to suggest that *appropriation* [of technical practices] could be seen as a central, institutionalized practice more than individual undertakings. Meanwhile, readers of Polanyi such as Jessop [85] have shown that "intellectual labour can be subsumed" in institutions and commoditized into outputs that make part of "a networked, digitized production-consumption process."

[8] Indeed, we also see stories such as Mark Zuckerberg's — Meta (formerly Facebook) CEO — 'surprise' 2016 visit to Nairobi in Kenya to learn about mobile money [90] perhaps inspiring Diem (promoted as Libra in 2020), the now failed digital currency project, which was led by Facebook and other multilateral development entities.

5 FINDINGS

This section highlights key insights from our interviews, ordered along the three vectors of the appropriation matrix: appropriation, re-appropriation, and reverse-appropriation. It should be noted that each vector interacts with the elements of appropriation – users, artifacts, and imaginaries – at varying levels of detail or magnitude.

5.1 Appropriation: The foundations of prepaid telephony and its bearings on ecologies of electronic exchange in Africa and beyond

The explosion of mobile telephony in Africa and other parts of the Majority World is credited to developments such as the prepaid model and technical advancements in signaling. Whereas the first prepaid billing systems for mobile telephony were invented in the US in the 1980s and deployed in Europe in the mid-90s, the prepaid model took off in the Majority World at the turn of the new millennium. Literature has already shown how telcos appropriated telecommunications by refiguring network elements to allow more signaling capacity essential for unique user behaviors such as beeping [36]. Yet the findings also show that telcos capitalized on tensions and changes in regional and global telecommunications products, standards, and regulations to borrow practices that were essential for the growth of their respective markets.

The majority of the changes in telecommunications followed the liberalization program of the 90s [5], for better or worse. A participant who served in a top regulatory body in Tanzania elaborated that *"relationship between a regulator and an operator [also known as telco] can only be efficient through the instrument of the license"* [P16]. Interestingly, despite the said efficacy of licensing instruments, the development and adaptation of *"the actual technology [was] really the operators' [responsibility]"* [P16]. Below, we show how operators (and their collaborators) appropriated GSM. Throughout this section, we also establish the foundation for **(RQ1)** regarding the differences between airtime exchange and mobile money, and how they were experienced by those involved in the transition.

5.1.1 ***"Many Dollars or Shillings": Signaling adaptations in telecommunications in Africa.*** We spoke with two telecommunications experts who were central in establishing prepaid billing systems in the US and parts of the Majority World [P12] [P19], notably in Africa and Latin America. Selective signaling, [P12] argues is how *"telecommunications works"*. The journey from analog telecommunications in the 70s to the advent of modern signaling systems such as the SS7 was a result of longstanding engagements between stakeholders in Europe (notably the UK, Germany, France, and Sweden), the US in North America, and Japan in Asia). As GSM's designers never imagined its use in markets outside of Europe, telcos in Africa and Latin America were immediately confronted with challenges, like unexpected user behaviors that demanded not only changes in signaling capacities but also necessitated sustained productive relationships with their suppliers in the Western world who had not confronted such problems before.

An early signaling adaptation was named *post call prepaid service* where call records databases were reconciled with the switch to *"determine how to decrement an amount of money that had been paid by the subscriber that went into a stored value system"* [P12]. For example, in the early 90s, [P19] revealed that a Tanzanian operator deployed a system built in the US where call records were read off the switch to determine the cost of the call. This early version of prepaid telecommunications served a tiny minority of the population, and it was *"successful."* Around this time, customers visited telcos' physical locations to load ***"many dollars or shillings"*** on their accounts [P19]. In fact, as systems advanced, following the advent of SS7 in 1997, signaling systems were able to ascertain call origin and destination (through the HLR or VLR), and therefore determine whether a customer had sufficient funds to make a call in *"real-time."*

But as prepaid telephony grew exponentially in various countries in the Majority World, signaling challenges came to bear. There were unique user patterns in countries like India (as was in Nigeria [126] or Kenya [179], for example) that broke networks in unique ways. As [P19] confessed, sometimes expanding signaling capacity via Transmission Control Protocol/Internet Protocol (one of the then-novel ways of expanding capacity) did not work in India in 2005. This is not to suggest that there was one 'correct' way to *fix* signaling, rather, the engineering processes that redesigned networks and artful integrations with global suppliers were highly contingent.

5.1.2 ***"USSD Was a Hack": Repackaging USSD, SIM cards, and airtime.*** Signaling as we have seen above was interacted with via 'voice' calls, which were and remain a key component of telecommunications. USSD, on the other hand, is also directed through signaling traffic; it does not get as much treatment as *voice* does, yet its appropriation into mobile telephony is crucial. A participant who has over a decade of experience as an enterprise software architect said that telcos leveraged USSD for value-added services like prepaid billing (airtime), despite USSD never having been designed with such use cases in mind [P07]: Telcos *"sort of just hit on something. And it seemed to work at the time."* He added that ***"[USSD] was a hack,"*** and indeed *"backend systems [evolved] to be able to support [prepaid service]"* [P07]. According to the original USSD specifications (GSM 02.90 & GSM 03.90) [51], USSD was designed to enable simple and efficient ways for mobile phones to communicate with international GSM-enabled mobile networks (remember that international roaming was a big part of the GSM standard). It is appropriation of USSD by telcos that telephony value-added services such as loading airtime or even transfer of mobile money (as we shall see subsequently) are predominantly done through USSD.

> *"SIM [cards] didn't show up until GSM showed up...SIM was a way for GSM phones to [manage] their addressing."* [P12]

The massive uptake of GSM in Africa unbundled the phone from subscriber identity, democratizing phone *access* through accessible SIM card ownership. In the early days of mobile telephony, phones were prohibitively expensive. As such, the SIM card enabled those who did not have mobile phones to have some sort of digital location: "*SIM card as digital ID*" [P18]. While the SIM card was not a technical necessity for prepaid telecommunications, it enabled telcos to better manage users, especially those on roaming; a feature that was central to the GSM spec [P19] (also mentioned in the

preceding paragraph above). For the greater part of the new millennium before mobile money (circa 2007), USSD was primarily used to load or share airtime and make balance inquiries on their SIM cards. As such, airtime became the first product that subscribers interacted with for mobile communications. One of our participants, an ISP and marketing expert [P18], cited the *sachetization* of airtime as exemplary of Prahalad's [136] "Fortune at the Bottom of the Pyramid." Several participants agreed with [P01]'s assertion that with airtime, *"you do whatever you want to do with the little money that you have that you've prepaid for."* Telcos such as Safaricom endeared the masses to their products by not only sachetizing airtime but also introducing cheaper ways for subscribers to use their airtime through "*per second billing, so that people could just spend what they needed to*" [P05]. The same way vendors unboxed cigarettes to sell one at a time is the same way telcos *"unboxed the one-minute, one-day bundles to per second"* [P18].

Meanwhile, the repackaging and distribution of airtime introduced major opportunities and challenges for telcos, users, and stakeholders in between. For the telcos such as the one [P19] consulted for in Latin America, promotions and marketing campaigns gravitated around airtime bonuses and discounts (for instance, there are similar cases in Zambia [130] and Papua New Guinea [54]). These promotional and marketing campaigns posed significant challenges for sudden network expansions (and we document these challenges in 'signaling adaptation' above). For end-user subscribers, however, airtime was a site through which they negotiated the terms of engagement with telcos and where they exercised agency. We will get more into these tensions and negotiations under 're-appropriation,' and we will also show that the SIM card was not a stable artifact that telcos and standards-making bodies deployed to serve subscribers but rather was a site for meaning-making and knowledge production in telecommunication worlds.

5.2 Re-appropriation: Formal and informal electronic exchange manifestations

The practices through which people exchanged electronic value varied significantly between sites and places, in name and practice, significance and resonance, but all successfully 'hacked' telecommunications infrastructure to provide value and functionality that had not previously existed. It cannot be overstated that even though these hacks were often conducted by ordinary people like mobile money agents and their communities, they were nonetheless the invention of new technology. In some cases, however, these hacks were performed by engineers. Nevertheless, we show that these innovations were done without approval from telcos or regulators, and profits were sometimes forgone (but this was not always the case.)

5.2.1 ***"Send Me 10 Minutes of Airtime": Airtime exchange and its many shades.*** This entailed the use of airtime to exchange value through telecommunications. Almost all participants we interviewed (except for the two non-African respondents) reported that they had either directly experienced airtime exchange or had at least heard of it; particularly in East Africa where the initial cases of this practice were first formally reported – alongside instances in Botswana, Southern Africa [145]. In many of the cases, airtime exchange constituted the use of airtime as a 'special money'. In the most cited instance, airtime was used as a substitute for fiat money. For example, when [P15] ran out of cash in the early 2000s in northern Kenya, his sister sent him airtime codes that he exchanged for cash. Yet in many other understudied instances, airtime was used in political campaigns, notably as a form of *"voter bribery"* [P01] [P18]; in other cases, as a gift, which bound loved ones to webs of reciprocity [P04] [P08] [P14] [P18] (this would later be enclosed into 'Sambaza' or 'Me2U' as we show in the section on reverse-appropriation).

In unprecedented situations of economic, political, or ecological strife, airtime became even more central. Following the post-election violence in Kenya in 2007, there was a shortage of airtime and its transfer between people marked its importance not only as a modality for communication but also as a currency. In Zimbabwe, informal electronic exchange took unique and perhaps troubling forms in the run-up to the economic and political crises of the 2000s. A participant who lived in Zimbabwe at the time said that people used both airtime and gallons of fuel to moderate value exchange.

> *"If you wanted to buy some goods or something, they wouldn't convert the money into Zimbabwean dollars; they would just tell you, you* ***send me 10 minutes of airtime****...sometimes we used fuel as well, like five liters of fuel."* [P01]

Unsurprisingly, participants varied in their perceptions of the importance of airtime exchange. Those who had worked in the telecommunications and banking sectors in the early 2000s, for example, downplayed the centrality of airtime exchange [P03] [P05]. One participant minimized it specifically because it was informal: "*there's never a point where people formally used airtime as currency, It was just an informal practice amongst customers.*" [P05]. A telecommunications engineer in Uganda said that although they knew for sure that there was *"small-scale retailing for airtime...and small-scale use of airtime as a currency, it's not something that I ever heard about within the [telecommunications] industry at the time"* [P03]. Others pointed to its centrality for some groups (foreign students) or particular situations.

5.2.2 ***"Cash Printing Machines": Bridge-builder entrepreneurialism.*** We use the term 'bridge-builders' to describe the actors who facilitate the development of technology to serve community-centric needs, in pursuit of profit or other social or cultural imperatives. Bridge-builders, in our study, operated at national, regional, and global scales in the appropriation of mobile telecommunications. While they were entrepreneurial and creative in their practices, none of our respondents necessarily described their work as "innovative" (in fact, they remarked that *innovation* was not part of their vocabulary and that they only wanted to use the new digital technologies to *"to solve [problems]...and make money"*) [P17] [P13] [P14].

Airtime sellers and eventual mobile money agents were the primordial manifestations of bridge-builders at local and national levels.[9] A participant [P11] who worked as an agent in the early days

[9]Agents are a principal component of the informal sector in Africa, as they bridge the gap between the served and the underserved, or excluded. However, in the case of telecommunications, agents were also *users*. Much as they distributed telecommunications goods, they also consumed them. In other words, they were higher in the pecking order of subscriber valuation; they were in a way *super* users. But important to note, majority of agents were enrolled/contracted by large-scale agents and telcos

of mobile money expansion in rural Uganda said that as an agent, despite the hardships of enrolling skeptical subscribers in rural Uganda, she had the room to try out unsanctioned methods – such as airtime exchange – to transfer electronic value and demonstrate to the doubters that it was possible to send money through a mobile phone. In other examples in Kenya and Tanzania, agents acted as local contact points for informal credit in their communities [P13]. In whatever case, agents at varying levels of the value chain had some sort of agency to conduct their businesses.

Regional and global 'bridge-builders' were just as important, and they can be categorized in two ways. The first group built their value-added services exclusively within telecommunications infrastructure. The second group leveraged telecommunications in unsanctioned ways to build services. Since goods such as ringtones and local music and wallpapers were highly in vogue, many budding entrepreneurs in the region leveraged the opportunity to build relevant value-added services. As our interlocutor (in the first category) elaborated below [P09], airtime was the mechanism through which mobile subscribers purchased these value-added services and products:

> *"[Developers] were getting people to pay for those ringtones through the airtime...When we used to use web browsers, for phones that had screens, you would pay for data; your airtime was basically your data. So I feel like loading of airtime effectively became your first transaction to paying for services that were auxiliary to the use of airtime [such as] SMS and calls...[and ringtones and wallpapers]."* [P09]

In the second category, bridge builders rarely sought permission from incumbent telcos. A poignant example involves international calling bypass (simbox) operations by our interlocutor [P17] from Malawi who has been in the ISP and tech industry for over 31 years and has plied his trade in 21 African countries. International calling bypass operations emerged in the 90s at a time when international calling was expensive even for the middle class. Sensing a ripe opportunity, entrepreneurs like [P17] partnered with aggregators and businesses all over the world to develop calling cards *bypass* pernicious international calling rates. People like him drew on technology changes of the day such as the "sender keeps all" policy that mandated fees for the originating call, and SIM cards that made it much easier to run an international calling operation compared to one where physical landline boxes raised suspicion. Put simply, international calling operations masqueraded as *local* calls, yet they were in fact *international*.

> *"What happened in the background was either a satellite connection that was illegally taking this call out of an international gateway or when the internet came, there was a conversion where the analog [signal] would be converted into digital and then transmitted over the internet into another system on the other side, which would then take the digital converted into analog and terminate it at the cost of a local call."* [P17]

This and similar businesses grew so fast that they literally were ***"cash printing machines"*** [P17]. Of course, if it is not apparent at this stage, international calling cards (printed outside the ambit of incumbent telecommunications) took on characteristics similar to airtime, and for a short time and at a small scale the exchange of international calling cards was reminiscent of airtime exchange. This international calling operation and related bridge-builder businesses were not only hunted down and forcefully closed by the regulators but also suffered the wrath of technological advances in traditional telecommunications and voice-over-IP. Many of these bridge-builders operated in legal gray zones, just like the telcos, but often were at the receiving end of punitive state responses. For instance, [P17] reported that his international bypass calling operations were promptly shut down by the communication regulator in Kenya. [P01] shared that a telco mogul in Zimbabwe was imprisoned several times for unclear reasons in the early days of telecommunications liberalization. Similarly, [P13] shared how he was arrested in the early 90s for entering Tanzania his home country with an unlicensed "24 baud modem."

Yet it also seemed like there was wiggle room, a possibility to negotiate the tensions in regulation. Despite his run-ins with the law, [P13] said that the forward-looking and flexible Tanzanian licensing regime had helped him build information service businesses. Tanzania had implemented 'technology-neutral' licenses in the mid-2000s (cf. Kenya's [173] slow implementation of similar licenses). Despite such licensing regimes, [P13] suggested that if you could "*navigate [regulatory gray zones] gingerly and find the right people to work with, then you can basically circumvent and get enough pressure to the powers that be to amend the laws*." However, participants [P04] [P13] [P18] still argued that the regulatory gaps from which mobile money had developed had now become closed, foreclosing possibilities of innovation by startups.

5.3 Reverse-appropriation: Enclosure of formal and informal practices into private products

This is the coda of appropriation before the process restarts at varying tenors, at multiple scales. Reverse-appropriation involves a series of players and interests, and while this particular section centers on telcos and banks, we will also come across startups and regulators. In this section, we answer the second research question **(RQ2)**, concretizing the mechanisms by which informal user practices were appropriated and formalized, and the implications of such appropriations. A quick reiteration of established examples of reverse-appropriation includes the enclosure of practices such as 'beeping' and key aspects of 'airtime exchange.' Telcos enclosed beeping when they built a replacement for it; a free SMS service dubbed 'please call me,' where users could send a capped number of free 'please call me' messages within the same network [36, 179]. In the case of airtime exchange, the 'gifting' component of airtime was enclosed into well-marketed colloquial terms that have seeped into vernaculars. For example, 'Sambaza' – a Swahili word for "to distribute or to share" [142], popular and marketed under the same name in Kenya and as 'Me2U' in Uganda. In the paragraphs below, we show how telcos further appropriated formal and informal electronic exchange practices within complex networks of labor and value that they (still) dominate.

to work as 'last mile' distributors of telco products and services. In conducting their work, agents undertook the technical, economic, and cultural work of translating the possibilities of using mobile telecommunications for electronic value exchange to their local communities. Of course, there were economic and social considerations and rewards at hand for their *translational* work.

5.3.1 ***"You Don't Have Agents, You Don't Have Infrastructure": Building informal agent networks.*** Although complex networks of human airtime sellers and distributors [18, 44, 98, 129] emerged to vend airtime in the streets and even in rural areas, the continued sachetization of airtime had significant cost implications on airtime production and distribution. In Tanzania, for example, "*the most sold voucher was 200 Tanzanian shillings; so small that costs were eating up everything*" [P13].[10] Telcos wanted airtime to be "voucherless" and they wanted subscribers *"to [buy airtime] the way they were sending airtime (airtime exchange) to each other"* While telcos' sought to digitize airtime as part of their operational efficiencies, stakeholders such as airtime agents had different concerns. An agent who scaled telecommunications services in Uganda in the early 2000s remarked that airtime vouchers *"looked cancerous"* [P11], arguing that scratching the gray-ish coating on airtime vouchers to reveal the top-up code exposed one to potentially cancerous chemicals. In other cases, there were real concerns about the theft or even loss of the physical scratchcards. As such, the digitization of airtime also constituted appropriation by the telcos. However, the physical vs. digital airtime debate was an amalgamation of public health and sustainability issues that are beyond the scope of this paper.

The successes of electronic airtime distribution, in part proved that agency networks would be capitalized on to evangelize and expand mobile money reach. Many participants lauded the telcos, notably MTN and Safaricom, for mobilizing the requisite resources to develop strong structures and tiered incentives that enabled agent networks to flourish.

> *"Safaricom on its part also did heavily invest in creating an agent network...they set up agencies with people who had existing businesses, as well as leveraging their existing network of agents who were working on mobile [airtime] businesses."* [P05]

Given agents' proximity to communities [P18] [P15], one participant from Kenya [P05] added that agents provided an essential interface through which subscribers interacted with 'partners' [agents] who were willing to be the face of the 'community' [telco]. As such people felt "*very comfortable and familiar with the brand,"* and did not need to visit the telcos' headquarters anymore as was in the earlier days of mobile telephony [P05].

In line with responses from participants who scaled prepaid telecommunications in Latin America and other parts of the world [P12] [P18], besides signaling challenges that arose as networks scaled, the distribution of airtime and maintenance of agent networks seemed like a more pressing challenge. Two participants [P05] [P10] even claimed the initial failed efforts of telcos and many companies in mobile money markets "in Africa" can be traced to their tepid efforts at establishing strong agent networks. For example, a consultant [P10] who scaled telecommunications operations all over Africa said that MTN did not build any retail infrastructure specific to mobile money [in Nigeria] as they built on top of the existing telephony retail infrastructure. Telcos did not only capitalize on agent networks but also weaponized them against potential competitors; for example through agent exclusivity agreements [26] and monopoly power. This participant summarily put it that: ***"[Y]ou don't have agents, you don't have [mobile money] infrastructure"*** [P10].

5.3.2 ***"Becoming a Threat": How telcos dominated banks and everything else.*** Telcos have become a permanent feature of everyday life in most African countries, permeating media, practices, and behaviors, and even transitioning into other spheres (such as banking). We call this process naturalization (akin to the reification of natural monopolies in particular places; powerful or revered or both [25]). For many observers this leads to an ambivalence: both a pride at how successful telco adaptations have been, but also a critique of how telcos use their monopoly power. From a technical standpoint, the majority of the participants spoke fondly of USSD's sustained role in supercharging the 'prepaid' model that caters to the needs of the masses at locally relevant and metered rates. USSD's universality [131] did not only entrench prepaid telephony but also created a ramp for value-added services like mobile money.

> *"When you use the same interface that people are used to already...and airtime was already something they needed. So bringing in mobile payments was easy for them to accept because the interface has not changed."* [P10]

This naturalization also seeped into the telecommunications industry itself, fostering imitation, experimentation, and surprise. For instance, it was said that the 2009 launch of MTN mobile money in Uganda was inspired by the successes of Safaricom's M-Pesa in Kenya in 2007. Despite M-Pesa's success in Kenya, MTN Uganda was skeptical about mobile money's potential and had not conducted market or usability studies.

> *"[MTN Uganda] placed the mobile money service under Publicom [its subsidized rural telephony service], which in my opinion shows that it wasn't taken very seriously initially. And management was probably as surprised as the rest of us when [the mobile money service grew rapidly]."* [P03]

In Kenya's case, some participants amusingly reported that M-Pesa was not the first mobile money service in the country [P18] [P15] [P08] [P05]. One of the participants reported that Zap, a mobile money product *"run by two guys [at Zain]"* [P08] was the first to launch in the market.

Yet the emergence of telco-led value-added services was a bellwether of the impending opportunities for collaborations and conflicts between telcos and other entities, notably banks, which were confronted with a competitor who quickly rose through the ranks of mass financial services provision. For most African nations since independence, banks controlled access to *formal* financial services, flanked only by small-scale informal finance [104]. While banks initially dismissed mobile money – for instance, [P15] shared that the managing director (MD) of a large commercial bank in Kenya was unfazed by M-Pesa's market entry – they quickly realized that it was ***"becoming a threat"*** [P15]. M-Pesa was doing 'viral' numbers [102], and for the best part, banks grew even more insecure because *"[they] were still very, very primitive"* [P10]. In the early 2000s, a lot of banks did not have proper switching and were not

[10] In 2000, this was equivalent to 0.25 US dollars, according to World Bank data - https://data.worldbank.org/indicator/PA.NUS.FCRF?locations=TZ

as efficient as they are today. In East Africa; *"[it was not until later in the] 2000s that banks came up to speed with systems that allowed [...] instant settlement"* [P03]. Given telcos owned the 'rails' to the consumer market via mobile telephony value-added services, they had a significant advantage in dominating retail financial services.

If the language of technical difference obfuscates the nature of the relationships between telcos and banking entities, perhaps considering business relationships between these entities might be helpful. The advent of mobile money was closely followed by the development of telco loyalty programs; these programs rewarded telco subscribers with 'special purpose' tokens for spending airtime within the network. One of the most popular versions of such tokens is 'Bonga Points,' Safaricom's loyalty program that launched in Kenya in 2007 [142]. Even though tokens essentially worked like airtime, their use outside of telco networks, particularly at telco-approved merchants such as supermarkets and fuel stations, was reminiscent of airtime exchange. However, the loyalty program's initial design did not cater to external value exchange as airtime exchange: the Points were locked within the telco itself although these Points could also be used in secondary exchanges (à la airtime exchange). When a startup built a platform to trade Bonga points, *"they were shut down by Safaricom"* [P04] – only for the telco to launch a similar product in the aftermath.

5.3.3 *"An Economist Who Understood Mobile Money": Navigating (or failing to navigate) barriers around appropriation*.

Reverse-appropriation was – and is – not something particular to telcos. Many banks, startups, and development agencies have engaged in reverse-appropriation (with varying degrees of success). Many instances of reverse-appropriation were enabled by regulators and governments. For example, almost all participants (except those from Tanzania and the US) credited Kenya's *laissez-faire* regulation for enabling the emergence of mobile money. Some even cited the famous Hughes and Lonie [72] paper as proof of Kenya's government's thought leadership. A participant [P14], who had a top job in the Kenyan government and worked on resolving the tension between banks and telcos in the mobile money arena confessed that there was a way to navigate and spearhead "*policy around the ministers if they were not aligned*." In this case, the technocrats who had understood the potential merits of facilitating M-Pesa's legal status coordinated among themselves and forwarded the mobile money issue to H.E. Mwai Kibaki, then the president of Kenya who was ***"an economist...and understood it [mobile money]."*** The banking lobby's effort to fight M-Pesa's legality failed, but that was not the end of back-and-forth relationships between banks and telcos (as we have shown in the preceding sections, there are still, as expected, certain forms of tension and competition between telcos and everyone else).

Yet despite regulatory approval, there were no guarantees of success under reverse-appropriation. While the narratives presented below should not be construed as derisive depictions of failure or experimentation, they show that entities outside of traditional telecommunications also performed reverse-appropriation, drawing on variegated user practices or widely observed industry trends (which produced varying outcomes). In one example, [P18] argued that before M-Pesa there was a small Tanzanian company called E-Fulusi, which was the *"first mobile money aggregator operator in East Africa that [in 2004] had permission from the central bank and telecommunications regulator."* This like the example on Zap preceding M-Pesa are helpful comparisons. However, [P18] concluded:

> *"[E-Fulusi's] issue was that they didn't have several million dollars of liquidity to put into the system. In order for you to operate a million dollars worth of transactions you need to actually deposit a million dollars into a physical bank account."* [P18]

But there was a startup company that had millions of dollars and could not attain market success. [P17] recounted the story of this unsuccessful attempt, focusing on the startup's endeavor to replicate mobile money. Founded in 2010 (three years after M-Pesa launch in Kenya), the startup boasted of *"a virtual wallet where [you could] load physical cash through an agent network, and through which you could cash out."* The participant [P17] who joined the startup to scale operations in seven (of the 13) targeted countries in Africa said that their products were not only telco and bank-agnostic but also very secure (for instance, they used advanced voice biometrics and PIN authentication for their merchant proprietary point-of-sale terminals). Reflecting on the startup's failure, he resolved that "*[t]he thing that killed the business was [we] tried to do too much at the same time."* There are several related stories of reverse-appropriation that predate mobile money's success. For example, a large consortium of a US-based company firm and banks based in Uganda (with the support of global development actors) drew inspiration from the promise of 'Me2U' airtime transfer in Uganda to develop a better smart card product in Uganda [32]. Much to the consortium's dismay, this attempt to roll out smartcards in the mid-2000s did not succeed.[11]

6 DISCUSSION

This paper's definition of appropriation is consistent with most definitions of appropriation, which refer to the unexpected manipulations or adaptations made to artifacts by users in concert with others or with things [12, 35, 40, 115, 125, 165]. In the pursuit of a better understanding of mobile money's invention, this paper found an unexpectedly rich dialectic of appropriations between user/producers and producer/users, and their artifacts and imaginaries. Through the appropriation matrix, we reveal a tangle of invention, institutional power, and happenstance that have not been fully accounted for in portrayals of the transition from airtime exchange to mobile money in HCI and design, and development.

6.1 Implications for empirics: Following the action of users, artifacts, and imaginaries

The three elements of appropriation – users, devices, and imaginaries – offer conceptually and analytically useful in two important ways: first, identification of relevant actors and sources of action, and second, charting the direction in which appropriation(s) unfolds (through growth and change). Because appropriation is a relational accomplishment (manifested *in* unexpected alterations

[11] Relatedly, still in Uganda, in the early days of mobile money in the late 2000s, anthropologists at Nokia, then a large global tech corporation conducted a study of mobile money's then slow uptake in some parts of the country but were impressed by the way rural users were fast to "conceptually grasp" how mobile money worked based on how they "related the service to buying and selling airtime" [69].

Table 2: The table below is a high-level summary of the appropriation matrix including the elements of appropriation (users, artifacts, imaginaries) in their respective vectors (appropriation, re-appropriation, reverse-appropriation). The text in this table is color-coded to guide the reader in 'following the action' of elements of appropriation: the elements highlighted in navy blue are underscored by the concept of *production*; in dark red, by *accomplishment*; and in dark green, by *consumption*. Below, in section 6.1, we detail the conceptual bases of these elements and how they fit into the matrix.

Production ↔ *Accomplishment* ↔ *Consumption*

Appropriation	Re-appropriation	Reverse-appropriation
Users - Telcos (consumers of global GSM) - Governments - Development actors	*Users* (producers of new technologies e.g., airtime exchange) - Subscribers - Small-scale entrepreneurs (human infrastructures) - Value-added service (VAS) providers	*Users* - Telcos - Banks and startups (including VAS) - Governments - Development actors
Artifacts - GSM aspects (e.g., SS7 and USSD) - Human infrastructures (airtime agents)	*Artifacts* - Airtime exchange and beeping - VAS (e.g., international simbox calls)	*Artifacts* - Mobile money products and services - Human infrastructures (mobile money agents)
Imaginaries - Marketing and advertising - Grand [development] visions and plans (e.g, operational efficiency; ICT for Development)	*Imaginaries* - Metered/calculative mindsets - Bridge-builder visions and imperatives (e.g., agents and VAS providers)	*Imaginaries* - Grand [development] visions and plans (e.g., operational efficiency; financial inclusion) - Regulatory regimes (e.g., M-Pesa approval vs. simbox crackdowns)

to artifacts), each stage of appropriation involves some kind of interaction between the three elements. Accordingly, the elements of appropriation reveal insights about particular actors and actions (material and symbolic) involved in appropriation across space and time. In section 4 (on rethinking appropriation), we reexamine elements of appropriation that are underpinned by a three-category substrate: ***Production*** ↔ ***accomplishment*** ↔ ***consumption***. In this section, we will show how each element of appropriation interacts with the three-category substrate (See the color-coded text in the appropriation matrix table 2, drawn from sections 4 and 5). Although each category (production, accomplishment, and consumption) has distinct characteristics, they simultaneously operate and apply to all three elements.

Let us start with our first element: **users** (who might be producers or consumers or both). Odumosu [126]'s 'constitutive appropriation' helps set the stage on how users at individual or societal levels make technology "theirs." Odumosu's declaration, mentioned earlier, that production and consumption are simultaneous means that they are also co-constitutive; they are "not ontologically reified." Drawing on his ethnographic portrait in Nigeria, we would argue even further that MTN Nigeria was a *user* (or consumer) of global telecommunications infrastructure – not only MTN's systems engineers. Through its engineers (and other political and institutional resources), we argue that MTN reconfigured the telecommunications system. Evidence from our interviews complements the view that telcos in Africa were users who utilized institutional and regulatory resources; notably historical [77, 78] and contemporary [10] global investments and capital flows, and were bound to global vendor chains [20] (see section 5.1.1 on signaling adaptations in telecommunications). Yet in the same vein, we argue that subscribers, who are consumers of telecommunications products and services, are producers. Odumosu emphasizes that consumption of a product entails "[*producing*] knowledge about its possible and varied uses, constituting cultural practices around the artifact or system, the formation of community, and in some cases even the reconfiguration of the artifact or system itself." However, in electronic exchange worlds, consumers vary. For example, in our findings, we see heterogeneous groups of formal and informal users who have variegated interests and demands in electronic exchange circuits (cf. 'user publics' [137]). These users also included actors such as mobile money agents and third-party software developers who leveraged (or appropriated) telecommunications in their own ways. Accordingly, we argue that telcos are consumers (of networking equipment and services) just as users/subscribers are producers (of meaning, value, and in this case new *technologies*).

Throughout this article, we challenge the *stability* of **artifacts**: we develop the term 'infra-artifact-structure' to capture entanglements in artifact worlds and the worlds in which artifacts circulate. Following Larkin [92], an artifact (our modification) is "recursive and dispersed." This portrayal shows one such part of an artifact's complexity. As we show in the findings, telcos in Africa adapted the GSM to the realities of their markets, despite the standard never having been designed for the Majority World [166]. These adaptations included technical (e.g., signaling adaptations) and business innovations (e.g., the prepaid model). It is important to note that by the time GSM was adapted to African markets, the standard had already undergone periods of tension and negotiation in Europe and the US. Subscribers, on the other hand, worked around mobile telephony's affordances to exchange value and meaning (e.g., airtime exchange and beeping, respectively). These creative hacks or practices, whether by telcos or subscribers, varied in name and significance but they demonstrated that telcos and subscribers

were intensely bound to the same object: the mobile phone. And this mobile phone was used differently within various ecologies of electronic exchange [157]. However, **imaginaries** are pivotal in articulating the relationship between users and artifacts. For organizations, imaginaries mobilize allocations of resources and authorship of grand visions and strategic plans. For individuals, especially at the margins, imaginaries might help them 'make do' in everyday life. But imaginaries serve a larger role: disciplining. Meso and macro-level imaginaries wield certain forms or potential of disciplinary power that are circumvented or challenged by individuals and groups at the micro level. The international calling bypass operation in Kenya is a great example of how users have appropriated mobile telecommunications [19, 38, 65] in acts of 'creative resistance' [54] or even 'appropriation to parity' [146]. In direct response (but this could be preemptive too), powerful actors like regulators have promptly shut down such operations on the grounds of "illegality."

It is the work of the researcher, therefore, to identify the (additional) elements of appropriation through 'inversion,' a tactic of surfacing what is usually relegated to the invisible [16]. Karasti and Blomberg [88] write that it is incumbent that the researcher construct the field (for empirical and analytical work) but should be open and curious to "new ways of conceptualizing." Dell and Kumar [30]'s HCI4D agenda supports this point. Dell and Kumar's agenda argues for more (perhaps *better*) theorization in HCI alongside improved and inclusive cross-disciplinary engagements between HCI/design practitioners and development economists (disciplines read in different registers), and with communities in and from the Majority World.

6.2 Implications for analytics: Using the appropriation matrix as an explanatory framework

In our framing of the appropriation matrix, we approached the word 'matrix' as a space of transformation. Its Latin origin indicates that 'matrix' is a site of formation and development. Both framings point to the same thing: growth, change. While we seem to co-opt *transformations* and *vector spaces* in our theorization, we do not use these concepts within their mathematical definitions; rather, we use these concepts within the appropriation matrix to extend the conversation on electronic exchange to empirically driven work in fields such as HCI and development economics and beyond.[12] Following Dourish [41], "[w]hat is critical here is not the account of what happened, but the explanatory frame by which this account can be organized and the narrative that connects historical moments." This framing has two important implications for empirics (observations or aspects that support certain evidential claims) and heuristics (assumptions or biases underlying certain positions) regarding appropriation in global HCI. In the paragraphs below, we will show how the matrix: i) facilitates a rigorous and transparent assessment of evidence, and ii) strengthens assumptions about observations or trends of technology change in ecologies of electronic exchange. Altogether, the appropriation matrix challenges reductive teleologies by placing *the* empirics and heuristics of electronic exchange within relevant local or global contexts where open and reflexive analysis can happen.

Appropriation is at the heart of the transition – or transformation – from airtime exchange and mobile money, and evidence from our research indicates that there were three discrete vectors of appropriation, i.e., appropriation, re-appropriation, and reverse-appropriation. While the appropriation matrix in this paragraph delves into the *structure* of appropriation, readers are reminded that the elements of appropriation perform the necessary work that animates the appropriation matrix (see preceding discussion point for conceptual and theoretical clarification on the element of appropriation). In the first vector of **appropriation**, telcos and governments adapted GSM to local conditions in various African markets following telecommunications market liberalization in the 90s [5]. Our participants revealed that technical aspects of GSM such as USSD and business models such as prepaid were refigured to facilitate the take-off of mobile telephony in the Majority World. Yet, as we also showed, government actors in places like Tanzania created licensing frameworks that enabled the design and development of value-added services. In the second vector, **re-appropriation** occurred when users met a technology that had been developed with very different material, social, and cultural realities in mind, and built their ways of exchanging value by creatively misusing it. Our findings showed how entrepreneurs in formal sectors built a whole range of value-added services including international calling operations (between Kenya and India, for instance) and other information services. In informal sectors, ordinary users including mobile money agents performed essential roles in enabling practices such as airtime exchange in countries such as Uganda, Zimbabwe, Botswana, and Kenya. In the third vector, under **reverse-appropriation**, telcos (and other entities) saw the improvements users had made, and commoditized them, replacing variegated formal and informal user practices with formal and proprietary systems, thus extracting value in the process. As we showed in the findings, reverse-appropriation is characterized by an even larger cast of actors including telcos, banks, startups, and governments.

6.3 Implications for heuristics: Using the appropriation matrix to challenge teleological narratives in HCI, development economics, and beyond

It is easy to (heuristically) understand that aspects of mobile money are *better* than airtime exchange and that mobile money offers a more coherent vision of formalization, where users leverage *cashlessness* in domestic and cross-border exchanges, and corporations and governments gain better visibility into these transaction trails. However, the majority of such heuristic arguments often give way to teleological narratives in ecologies of electronic exchange. Mobile money's said inevitability – as the supposed final form of airtime exchange writ small or money writ large [105] – is one such manifestation of teleology. Moreover, dominant development discourses tend to valorize the transition from informal practices (such as

[12]The mathematical, computer science, and even the science fiction connotations of matrices were not lost on us. Nick Seaver's [150] – but really Malinowski's term – *bastard algebra* is telling. No discipline is pure, our paper is evidence but more so the "enduring sub rosa algebraic imaginations in the social sciences." Nonetheless, we hope the appropriation matrix is allowed to "overflow [its] borders and relate without permission."

airtime exchange) to formal technology (like mobile money). The appropriation matrix can therefore be used to develop reflexive heuristics essential for challenging reductive teleologies in ecologies of electronic exchange. We show this in two cases: in HCI and development economics.

In HCI and design, the appropriation matrix can facilitate critique and imagination that recognizes the contingency of mobile money's trajectory. The appropriation matrix shows that there were many factors at play and that the eventual design of mobile money could have been different (and perhaps could change in the future). To be sure, appropriation is not something that happens once and is resolved at moments of enclosure; appropriation is ongoing and its implosions vary depending on time and place. Even though the vectors in the appropriation matrix may appear roughly serial, they are recursive and overlapping. Given the multi-sitedness of appropriation in electronic exchange worlds, it is possible that some stages (or vectors) could have been experienced differently than others, in different places. Our findings show that reverse-appropriation, for instance, was more apparent in Kenya than in the UK. In Kenya, reverse-appropriation entailed the work of entities such as telcos, multinational R&D labs, consortia of banks, and development agencies. The UK, however, primarily covered the initial operational and technical costs through Vodafone Group [72].

In development economics and other policy-oriented disciplines that focus primarily on economic impact, hypotheses are formulated, in part, using heuristics. Hypothesis generation is seemingly the sole non-*scientific* aspect of an otherwise highly formalistic or quantitative discipline [148]. While the economic impact of mobile money is tentative, Aron [8] convincingly argues that "interpreting the evidence on the economic impact of mobile money is not straightforward," because of data and methodological shortfalls. The appropriation matrix could help policy researchers confront some of these challenges by, for instance, disentangling the mobile phone from mobile money service. As articulated in section 4.1.2 (on infra-artifact-structures), the mobile phone is entangled in multiple ways, and economists could better account for such entanglements (for example the role of airtime and USSD) in their hypotheses. When do airtime transactions account for economic impact in a given geography, for example? The appropriation matrix can additionally be useful in explaining *unobservable* aspects of mobile money such as the enduring practices related to airtime exchange or larger structuring forces such as corporate or statist imaginaries.

6.4 Implications for the moral economies of appropriation: *All the way down*

The ethical ebb and flow of appropriation is complex: many users engaged in airtime exchange or beeping without considering it theft, while a few allegedly broke the law by using voice-over-IP to undercut high prices for international calling (simbox fraud). We do not argue that it is surprising that the widespread 'hacks' local communities invented, creating value by appropriating telco networks, later became commercialized or enclosed. Indeed, this is the norm in capitalism, not the exception, extolled or lamented alternately [29, 170]. As Delfanti and Söderberg [29] point out, even the tools that self-identified hackers develop to resist or bypass corporate power are doomed to be eaten. "The technical innovations coming out of this conflictual symbiosis, such as, for instance, modular software code, mesh computer networks, distributed retrieval systems (i.e. filesharing protocols), and private cryptography, have all been integrated in the material infrastructure of capitalism" [29]. One might wonder, rhetorically, what hope does a boda-boda (two-wheeled motorcycle) driver hoping to send money home to family have to resist enclosure? Yet in many cases – postal banking, public education, public roadways, physical currency itself – political decisions have been made to declare certain types of essential human activity a public good, not proprietary, monopolistic, or subject to unchecked commercialization. Might the electronic storage and transfer of value be one of these?

This study focused extensively on appropriation within the orbits of regional telcos such as MTN and Safaricom (Airtel, to an extent). The telecommunications market in Africa is oligopolistic, meaning that a few players dominate their respective markets [5]. Market structures are important, however they do not solely determine all the characteristics of technologies developed and sold within them. Why did Safaricom and MTN consistently produce similar electronic exchange products? The short answer could be that these telcos simply adjusted their technology designs in alignment "with the development trajectories set out by these and other experts" [112]. In other words, companies might copy each other. Sociologists frame this 'alignment' as 'institutional isomorphism' [34]; where organizations within a particular field become more similar over time. This isomorphism embodies moral tenors: telcos copied from each other, and from users too. For example, telcos copied and replicated their competitors' products and services (and even marketing campaigns!).[13] As telcos copied users – including third parties like agents and software developers – we argue that they absorbed user knowledge and inventions, displaced norms and practices, and enclosed formal and informal electronic exchange practices into their revenue streams.

Safaricom's 'openness' has been fronted an exception to the rule. Guma's [66] illustrative paper on mobile money and urban infrastructures in transition suggests that Safaricom's M-Pesa "opened up to further incremental improvisation and progressive widening with its initial deployment, unearthing unanticipated usages from users who were determined to inscribe other functions into the technology." This assertion is true to some extent. While users receive(d) credit for championing the workarounds in M-Pesa [72, 169], they are not recognized in formal registers of knowledge and intellectual property. M-Pesa's patent filing [118] in the US did not even credit the system's inspiration to innovative ordinary folks in Kenya but observed the pre-existence of similar systems in other parts of the world, particularly in the Philippines where relatively smaller mobile payments systems were first deployed in the early 2000s [123, 168]. It is unsurprising that local communities are credited and celebrated publicly, but not remunerated [120].

[13]These adaptations were often done without substantive consideration for user feedback or input (Uganda's mobile money case, for example). This is not to suggest that telcos suffered from a particular lack of imagination or ability to innovate. They had talented designers, engineers, and marketers.

6.5 Limitations and future work

This study had two major limitations. First, the interview sample size might have been limited; although *small n* sample sizes are not uncommon in HCI and design studies, this research could have benefited from a wider sample size, including an additional group of actors in computing, policy, and media. Second, there was limited literature on key aspects of GSM like USSD and SS7. While the study benefited from a large amount of academic (e.g., Odumosu [126]) and non-academic (e.g., Temple [166]) literature, technical aspects such as USSD lacked substantial longitudinal literature across different corporations or regions, despite their importance in GSM networks. Moreover, a handful of HCI-oriented studies on USSD are application-specific, for example, studies about m-health or mobile money itself [131]. Economics-oriented research barely mentions USSD, despite USSD's distinct role in global telecommunications and development. Future work could address these limitations. In addition, future work could develop a theoretical model of designing formalization from a citizen-centric, rather than corporate-centric, perspective. We anticipate that this goal is impossible with a technology design alone, but rather would require a closer simultaneous design of technology and policy, instantiated by one or more social movements or currents of change.

7 CONCLUSION

This paper reexamined appropriation in global HCI and rethought fundamental elements of appropriation. As such, the paper developed *the* appropriation matrix, a novel theoretical tool for understanding and interpreting technology transitions (and their world-disclosing properties) in three discrete but often overlapping stages: appropriation, re-appropriation, and reverse-appropriation. In particular, we drew on the transition from informal electronic exchange practices such as airtime exchange into commoditized products like mobile money. Despite mobile money's many and important contributions to society, it is, like every commercial product, a negotiation amongst users (telcos, subscribers, development actors, etc.), their artifacts (what we have called *infra-artifact-structures*), and imaginaries (visions and practices that mobilize or are used to rationalize action). We have drawn on such negotiations to open conversation between HCI and development economics challenging reductive assumptions on the inevitability of *newer* or certain technologies (e.g., mobile money) while also providing a framework for deeper empirical and analytical work in both fields (and beyond).

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REFERENCES

[1] 2004. Digital Solutions Ltd v MTN Uganda Ltd (Miscellaneous Application 546 of 2004) [2004] UGCommC 35 (19 October 2004); | Ulii. https://old.ulii.org/ug/judgment/commercial-court/2004/35

[2] Muhammad Sadi Adamu. 2022. No More 'Solutionism' or 'Saviourism' in Futuring African HCI: A Manyfesto. *ACM Transactions on Computer-Human Interaction* 30, 2 (Nov. 2022), 1–42. https://doi.org/10.1145/3571811

[3] Madeleine Akrich. 1992. The De-scription of Technical Objects. In *Shaping Technology/Building Society. Studies in Sociotechnical Change*. MIT Press, 205. https://shs.hal.science/halshs-00081744

[4] Shahidul Alam. 2008. Majority World: Challenging the West's Rhetoric of Democracy. *Amerasia Journal* 34, 1 (Jan. 2008), 88–98. https://doi.org/10.17953/amer.34.1.l3176027k4q614v5

[5] Rachel Alemu. 2018. *The Liberalisation of the Telecommunications Sector in Sub-Saharan Africa and Fostering Competition in Telecommunications Services Markets: An Analysis of the Regulatory Framework in Uganda.* Springer-Verlag, Berlin Heidelberg. https://doi.org/10.1007/978-3-662-55318-3

[6] Simon Andersson-Manjang and Nika Naghavi. 2021. *State of the Industry Report on Mobile Money 2021.* Technical Report. GSMA. 86 pages.

[7] Arjun Appadurai (Ed.). 1986. *The Social Life of Things: Commodities in Cultural Perspective.* Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511819582

[8] Janine Aron. 2018. Mobile Money and the Economy: A Review of the Evidence. *The World Bank Research Observer* 33, 2 (Aug. 2018), 135–188. https://doi.org/10.1093/wbro/lky001

[9] Talal Asad. 2020. The Concept of Cultural Translation in British Social Anthropology. In *The Concept of Cultural Translation in British Social Anthropology.* University of California Press, 141–164. https://doi.org/10.1525/9780520946286-009

[10] Abraham Augustine. 2023. Safaricom gets mobile money licence for Ethiopia. https://techcabal.com/2023/05/11/safaricom-gets-ethiopia-licence/

[11] Kagonya Awori, Frank Vetere, and Wally Smith. 2015. Transnationalism, Indigenous Knowledge and Technology: Insights from the Kenyan Diaspora. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, Seoul Republic of Korea, 3759–3768. https://doi.org/10.1145/2702123.2702488

[12] François Bar, Matthew S. Weber, and Francis Pisani. 2016. Mobile technology appropriation in a distant mirror: Baroquization, creolization, and cannibalism. *New Media & Society* 18, 4 (April 2016), 617–636. https://doi.org/10.1177/1461444816629474 Publisher: SAGE Publications.

[13] Jens Beckert. 2016. *Imagined Futures: Fictional Expectations and Capitalist Dynamics.* Harvard University Press.

[14] Gabrielle Benabdallah, Michael W. Beach, Nathanael Elias Mengist, Daniela Rosner, Kavita S Philip, and Lucy Suchman. 2023. The Politics of Imaginaries: Probing Humanistic Inquiry in HCI. In *Designing Interactive Systems Conference*. ACM, Pittsburgh PA USA, 131–134. https://doi.org/10.1145/3563703.3591457

[15] Yochai Benkler. 2006. *The Wealth of Networks: How Social Production Transforms Markets and Freedom.* Yale University Press, New Haven [Conn.]. OCLC: ocm61881089.

[16] Geoffery C. Bowker and Susan Leigh Star. 2000. *Sorting things out: Classification and its consequences.* MIT Press, Cambridge, MA, USA.

[17] Warigia Bowman. 2015. Imagining a Modern Rwanda: Sociotechnological Imaginaries, Information Technology, and the Postgenocide State. In *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*, Sheila Jasanoff and Sang-Hyun Kim (Eds.). University of Chicago Press, 0. https://doi.org/10.7208/chicago/9780226276663.003.0004

[18] Roland Brouwer. 2010. Mobile Phones in Mozambique: The Street Trade in Airtime in Maputo City. *Science, Technology and Society* 15, 1 (March 2010), 135–154. https://doi.org/10.1177/097172180901500106 Publisher: SAGE Publications India.

[19] Jenna Burrell. 2010. Evaluating Shared Access: social equality and the circulation of mobile phones in rural Uganda. *Journal of Computer-Mediated Communication* 15, 2 (2010), 230–250. https://doi.org/10.1111/j.1083-6101.2010.01518.x

[20] Gian Marco Campagnolo, Neil Pollock, and Robin Williams. 2015. Technology as we do not know it: The extended practice of global software development. *Information and Organization* 25, 3 (July 2015), 150–159. https://doi.org/10.1016/j.infoandorg.2015.06.001

[21] Jan Chipchase and Indri Tulusan. 2007. Shared Phone Practices: Exploratory Field Research from Uganda and Beyond. https://web.archive.org/web/20070104042341/http://www.janchipchase.com/sharedphoneuse

[22] Adele E. Clarke, Carrie Friese, and Rachel Washburn. 2018. *Situational analysis: grounded theory after the interpretive turn* (second edition ed.). SAGE Publications, Inc., Thousand Oaks, California. OCLC: 988864558.

[23] Alex Comninos, Steve Esselaar, Ali Ndiwalana, and Christoph Stork. 2009. Airtime to Cash: Unlocking the Potential of Africa's Mobile Phones for Banking the Unbanked. In *IST-Africa 2009*. International Information Management Corporation, 16.

[24] Sara Corbett. 2008. Can the Cellphone Help End Global Poverty? https://www.nytimes.com/2008/04/13/magazine/13anthropology-t.html

[25] Christopher Csikszentmihalyi, Jude Mukundane, Gemma F. Rodrigues, Daniel Mwesigwa, and Michelle Kasprzak. 2018. The Space of Possibilities: Political Economies of Technology Innovation in Sub-Saharan Africa. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3173574.3173880

[26] Christopher Csikszentmihalyi, Gemma Rodrigues, Jude Mukundane, Daniel Mwesigwa, and Michelle Kasprzak. 2018. *Social Tech Ecosystems in Sub-Saharan Africa*. Technical Report. Zenodo. https://doi.org/10.5281/ZENODO.1244086 Version Number: 1.

[27] Jenny L. Davis. 2020. *How Artifacts Afford: The Power and Politics of Everyday Things*. MIT Press.

[28] Marianne de Laet and Annemarie Mol. 2000. The Zimbabwe Bush Pump: Mechanics of a Fluid Technology. *Social Studies of Science* 30, 2 (2000), 225–263. https://www.jstor.org/stable/285835 Publisher: Sage Publications, Ltd..

[29] Alessandro Delfanti and Johan Söderberg. 2015. Repurposing the Hacker. Three Cycles of Recuperation in the Evolution of Hacking and Capitalism. https://doi.org/10.2139/ssrn.2622106

[30] Nicola Dell and Neha Kumar. 2016. The Ins and Outs of HCI for Development. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. Association for Computing Machinery, New York, NY, USA, 2220–2232. https://doi.org/10.1145/2858036.2858081

[31] Gerardine DeSanctis and Marshall Scott Poole. 1994. Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory. *Organization Science* 5, 2 (May 1994), 121–147. https://doi.org/10.1287/orsc.5.2.121 Publisher: INFORMS.

[32] Rani Deshpande, Mark Pickens, and Hermann Messan. 2006. *Uganda - Country-level savings assessment CGAP savings initiative*. Technical Report. The World Bank. http://www-wds.worldbank.org/servlet/WDSContentServer/IW3P/IB/2006/05/10/000090341_20060510161043/Rendered/PDF/360820UG0Savings1assessment01PUBLIC1.pdf ISBN: 9789586822701.

[33] Paul Dimaggio and Sharon Zukin (Eds.). 1990. *Structures of Capital: The Social Organization of Economic Life*. Cambridge University Press, New York.

[34] Paul J. DiMaggio and Walter W. Powell. 1983. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review* 48, 2 (1983), 147–160. https://doi.org/10.2307/2095101 Publisher: [American Sociological Association, Sage Publications, Inc.].

[35] Alan Dix. 2007. Designing for appropriation. In *Proceedings of the 21st British HCI Group Annual Conference on People and Computers: HCI...but not as we know it - Volume 2 (BCS-HCI '07)*. BCS Learning & Development Ltd., Swindon, GBR, 27–30.

[36] Jonathan Donner. 2007. The Rules of Beeping: Exchanging Messages Via Intentional "Missed Calls" on Mobile Phones. *Journal of Computer-Mediated Communication* 13, 1 (Oct. 2007), 1–22. https://doi.org/10.1111/j.1083-6101.2007.00383.x

[37] Jonathan Donner. 2015. *After access: inclusion, development, and a more mobile Internet*. MIT press. OCLC: 907512564.

[38] Jonathan Donner and Marcela X. Escobari. 2010. A review of evidence on mobile use by micro and small enterprises in developing countries. *Journal of International Development* 22, 5 (2010), 641–658. https://doi.org/10.1002/jid.1717

[39] Kevin P. Donovan. 2012. Mobile Money for Financial Inclusion. In *Information and Communications for Development 2012: Maximizing Mobile*. The World Bank, Washington, D.C., 61–75. https://doi.org/10.1596/978-0-8213-8991-1

[40] Paul Dourish. 2003. The Appropriation of Interactive Technologies: Some Lessons from Placeless Documents. *Computer Supported Cooperative Work (CSCW)* 12, 4 (Dec. 2003), 465–490. https://doi.org/10.1023/A:1026149119426

[41] Paul Dourish. 2006. Implications for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06)*. Association for Computing Machinery, New York, NY, USA, 541–550. https://doi.org/10.1145/1124772.1124855

[42] Joseph Dumit. 2014. Writing the Implosion: Teaching the World One Thing at a Time. *Cultural Anthropology* 29, 2 (May 2014), 344–362. https://doi.org/10.14506/ca29.2.09 Number: 2.

[43] Nathan Eagle. 2009. txteagle: Mobile Crowdsourcing. In *Internationalization, Design and Global Development (Lecture Notes in Computer Science)*, Nuray Aykin (Ed.). Springer, Berlin, Heidelberg, 447–456. https://doi.org/10.1007/978-3-642-02767-3_50

[44] Econ One Research, Inc and ESG International. 2002. *Uganda Telecommunications: A Case Study in the Private Provision of Rural Infrastructure*. Technical Report. ITU. 63 pages.

[45] David Edgerton. 2007. *The shock of the old: technology and global history since 1900*. Oxford University Press, Oxford. http://newcatalog.library.cornell.edu/catalog/6011711.

[46] Paul N Edwards. 2003. Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems. In *Modernity and Technology: The Empirical Turn*, Thomas J Misa, Philip Brey, and Andrew Feenberg (Eds.). MIT Press, Cambridge, MA, 185–225. https://www.semanticscholar.org/paper/Infrastructure-and-Modernity-%3A-Force-%2C-Time-%2C-and-Edwards/1bad48fd3cfb56194b2f1bc4e8727fe0d2ce48c7

[47] Ron Eglash. 2004. Appropriating technology: An introduction. In *Appropriating technology: Vernacular science and social power*, Ron Eglash (Ed.). University of Minnesota Press, Minneapolis, vii–xxi. OCLC: ocm54825985.

[48] Chris Elsden, Tom Feltwell, Belén Barros Pena, Bettina Nissen, Inte Gloerich, Chris Speed, and John Vines. 2020. Designing Futures of Money and FinTech. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference*. ACM, Eindhoven Netherlands, 429–432. https://doi.org/10.1145/3393914.3395904

[49] Chris Elsden, Tom Feltwell, Shaun Lawson, and John Vines. 2019. Recipes for Programmable Money. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow Scotland Uk, 1–13. https://doi.org/10.1145/3290605.3300481

[50] European Telecommunications Standards Institute (ETSI). 1996. Digital cellular telecommunications system; Unstructured Supplementary Service Data (USSD) - Stage 2 (GSM 03.90). https://www.etsi.org/deliver/etsi_gts/03/0390/05.00.00_60/gsmts_0390v050000p.pdf

[51] European Telecommunications Standards Institute (ETSI). 1997. Digital cellular telecommunications system; Unstructured Supplementary Service Data (USSD) - Stage 1 (GSM 02.90). https://www.etsi.org/deliver/etsi_gts/02/0290/05.01.00_60/gsmts_0290v050100p.pdf

[52] James Ferguson. 2006. *Global Shadows: Africa in the Neoliberal World Order*. Duke University Press, Durham, NC.

[53] Claude S. Fischer. 1994. *America Calling: A Social History of the Telephone to 1940*. University of California Press.

[54] Robert J. Foster. 2018. Top-Up: The Moral Economy of Prepaid Mobile Phone Subscriptions. In *The Moral Economy of Mobile Phones*, Robert J. Foster and Heather A. Horst (Eds.). ANU Press, 107–126. https://www.jstor.org/stable/j.ctv1rmks3.12

[55] Rayvon Fouché. 2006. Say It Loud, I'm Black and I'm Proud: African Americans, American Artifactual Culture, and Black Vernacular Technological Creativity. *American Quarterly* 58, 3 (2006), 639–661. https://www.jstor.org/stable/40068387 Publisher: Johns Hopkins University Press.

[56] Nicolas Friederici, Michel Wahome, and Mark Graham. 2020. *Digital Entrepreneurship in Africa: How a Continent Is Escaping Silicon Valley's Long Shadow*. MIT Press.

[57] Dianna Games. 2013. *Business in Africa*. Penguin Random House South Africa.

[58] William W. Gaver. 1991. Technology affordances. In *Proceedings of the SIGCHI conference on Human factors in computing systems Reaching through technology - CHI '91*. ACM Press, New Orleans, Louisiana, United States, 79–84. https://doi.org/10.1145/108844.108856

[59] Ishita Ghosh. 2018. *Challenging the dominant narratives of a Digital Financial Inclusion*. Ph. D. Dissertation. University of California, Berkeley.

[60] Ishita Ghosh and Jacki O'Neill. 2020. The Unbearable Modernity of Mobile Money. *Computer Supported Cooperative Work (CSCW)* 29, 3 (June 2020), 227–261. https://doi.org/10.1007/s10606-020-09373-1

[61] Barney Glaser and Anselm Strauss. 2017. *Discovery of Grounded Theory: Strategies for Qualitative Research*. Routledge, New York. https://doi.org/10.4324/9780203793206

[62] Mark Graham, Casper Andersen, and Laura Mann. 2015. Geographical imagination and technological connectivity in East Africa. *Transactions of the Institute of British Geographers* 40, 3 (2015), 334–349. https://doi.org/10.1111/tran.12076

[63] Stephen Graham and Nigel Thrift. 2007. Out of Order: Understanding Repair and Maintenance. *Theory, Culture & Society* 24, 3 (May 2007), 1–25. https://doi.org/10.1177/0263276407075954 Publisher: SAGE Publications Ltd.

[64] Mark Granovetter. 1985. Economic Action and Social Structure: The Problem of Embeddedness. *Amer. J. Sociology* 91, 3 (1985), 481–510. http://www.jstor.org/stable/2780199

[65] Prince K. Guma. 2014. *Reimagining Rurality in Mobile Money Times: Life, Identity, and Community*. IMTFI Final Report. Institute for Money, Technology & Financial Inclusion (IMTFI).

[66] Prince K. Guma. 2020. Incompleteness of urban infrastructures in transition: Scenarios from the mobile age in Nairobi. *Social Studies of Science* 50, 5 (Oct. 2020), 728–750. https://doi.org/10.1177/0306312720927088 Publisher: SAGE Publications Ltd.

[67] Puneet Gupta. 2010. *End to End USSD System*. Technical Report 53. TATA Tele Service Limited, India. 54 pages. https://www.academia.edu/10189416/END_TO_END_USSD_SYSTEM

[68] Christopher R. Henke. 1999. The Mechanics of Workplace Order: Toward a Sociology of Repair. *Berkeley Journal of Sociology* 44 (1999), 55–81. http://www.jstor.org/stable/41035546 Publisher: Regents of the University of California.

[69] Rachel Hinman and Julus Matovu. 2010. Opportunities and challenges for mobile-based financial services in rural Uganda. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems (CHI EA '10)*. Association for Computing Machinery, New York, NY, USA, 3925–3930. https://doi.org/10.1145/1753846.1754080

[70] Eric Hirsch and Roger Silverstone. 2003. *Consuming Technologies: Media and Information in Domestic Spaces*. Routledge.

[71] Heather A. Horst and Daniel Miller. 2006. *The cell phone: an anthropology of communication*. Berg, Oxford ; New York. OCLC: ocm70129065.

[72] Nick Hughes and Susie Lonie. 2007. M-PESA: Mobile Money for the "Unbanked" Turning Cellphones into 24-Hour Tellers in Kenya. *Innovations: Technology, Governance, Globalization* 2, 1-2 (April 2007), 63–81. https://doi.org/10.1162/itgg.2007.2.1-2.63

[73] Thomas P Hughes. 1987. The evolution of large technological systems. In *The social construction of technological systems: New directions in the sociology and history of technology*, Wiebe Bijker, Thomas P Hughes, and Trevor Pinch (Eds.). Vol. 82. MIT Press, Cambridge, MA, 51–82.

[74] Jina Huh, Lisa P. Nathan, Six Silberman, Eli Blevis, Bill Tomlinson, Phoebe Sengers, and Daniela Busse. 2010. Examining appropriation, re-use, and maintenance for sustainability. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems (CHI EA '10)*. Association for Computing Machinery, New York, NY, USA, 4457–4460. https://doi.org/10.1145/1753846.1754173

[75] Pan Hui, Richard Mortier, Kuang Xu, Jon Crowcroft, and Victor O. K. Li. 2009. Sharing airtime with Shair avoids wasting time and money. In *Proceedings of the 10th workshop on Mobile Computing Systems and Applications (HotMobile '09)*. Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/1514411.1514417

[76] Ian Hutchby. 2001. Technologies, Texts and Affordances. *Sociology* 35, 2 (2001), 441–456. https://www.jstor.org/stable/42856294 Publisher: Sage Publications, Ltd..

[77] IFC. 1999. Disclosure - CelTel Uganda. https://disclosures.ifc.org/project-detail/SPI/9924/celtel-uganda

[78] IFC. 2003. IFC Invests $100 Million In Nigerian Cellular Operator. https://ifcpressreleasesprod.aseprod.ifc.org/all/pages/PressDetail.aspx?ID=20795

[79] International Labour Organization. 2024. SDG indicator 8.3.1 - Proportion of informal employment in total employment by sex and sector (%) – Annual. https://webapps.ilo.org/shinyapps/bulkexplorer29/?lang=en&id=SDG_0831_SEX_ECO_RT_A

[80] Steven J. Jackson. 2014. Rethinking Repair. In *Media Technologies: Essays on Communication, Materiality, and Society*, Tarleton Gillespie, Pablo J. Boczkowski, and Kirsten A. Foot (Eds.). The MIT Press, 221–240. https://doi.org/10.7551/mitpress/9780262525374.003.0011

[81] Steven J. Jackson. 2019. Introduction Global Inequalities. In *digitalSTS: A Field Guide for Science & Technology Studies*, Vertesi Janet and David Ribes (Eds.). Princeton University Press, 157 – 159.

[82] Steven J. Jackson and Sarah Barbrow. 2015. Standards and/as Innovation: Protocols, Creativity, and Interactive Systems Development in Ecology. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. Association for Computing Machinery, New York, NY, USA, 1769–1778. https://doi.org/10.1145/2702123.2702564

[83] Steven J. Jackson, Paul N. Edwards, Geoffrey C. Bowker, and Cory P. Knobel. 2007. Understanding infrastructure: History, heuristics and cyberinfrastructure policy. *First Monday* 12, 6 (June 2007). https://doi.org/10.5210/fm.v12i6.1904

[84] Steven J. Jackson, Tarleton Gillespie, and Sandy Payette. 2014. The policy knot: re-integrating policy, practice and design in cscw studies of social computing. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing (CSCW '14)*. Association for Computing Machinery, New York, NY, USA, 588–602. https://doi.org/10.1145/2531602.2531674

[85] Bob Jessop. 2007. Knowledge as a Fictitious Commodity: Insights and Limits of a Polanyian Perspective. In *Reading Karl Polanyi for the Twenty-First Century: Market Economy as a Political Project*, Ayşe Buğra and Kaan Ağartan (Eds.). Palgrave Macmillan US, New York, 115–133. https://doi.org/10.1057/9780230607187_7

[86] Matthew Jones, Wanda Orlikowski, and Kamal Munir. 2004. Structuration theory and information systems: A critical reappraisal. *Social theory and philosophy for information systems* (2004), 297–328. Publisher: John Wiley & Sons, Chichester.

[87] Ulrik Jorgensen and Ole Henning Sorensen. 1999. Arenas of Development - A Space Populated by Actor-worlds, Artefacts, and Surprises. *Technology Analysis & Strategic Management* 11, 3 (Sept. 1999), 409–429. https://doi.org/10.1080/09537329107438

[88] Helena Karasti and Jeanette Blomberg. 2018. Studying Infrastructuring Ethnographically. *Computer Supported Cooperative Work (CSCW)* 27, 2 (April 2018), 233–265. https://doi.org/10.1007/s10606-017-9296-7

[89] Jake Kendall, Bill Maurer, Phillip Machoka, and Clara Veniard. 2011. An Emerging Platform: From Money Transfer System to Mobile Money Ecosystem. *Innovations: Technology, Governance, Globalization* 6, 4 (Oct. 2011), 49–64. https://doi.org/10.1162/INOV_a_00100

[90] Lily Kuo. 2016. Mark Zuckerberg has made a surprise visit to Nairobi to learn about mobile money. https://qz.com/africa/771809/mark-zuckerberg-has-made-a-surprise-visit-to-nairobi-to-learn-about-mobile-money/

[91] Sibel Kusimba. 2021. *Reimagining Money: Kenya in the Digital Finance Revolution*. Stanford University Press.

[92] Brian Larkin. 2013. The Politics and Poetics of Infrastructure. *Annual Review of Anthropology* 42, 1 (2013), 327–343. https://doi.org/10.1146/annurev-anthro-092412-155522

[93] Silvia Lindtner, Ken Anderson, and Paul Dourish. 2012. Cultural appropriation: information technologies as sites of transnational imagination. In *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work*. ACM, Seattle Washington USA, 77–86. https://doi.org/10.1145/2145204.2145220

[94] Miao Lu and Jack Linchuan Qiu. 2023. Transfer or Translation? Rethinking Traveling Technologies from the Global South. *Science, Technology, & Human Values* 48, 2 (March 2023), 272–294. https://doi.org/10.1177/01622439211072205 Publisher: SAGE Publications Inc.

[95] Hughie Mackay and Gareth Gillespie. 1992. Extending the Social Shaping of Technology Approach: Ideology and Appropriation. *Social Studies of Science* 22, 4 (1992), 685–716. https://www.jstor.org/stable/285460 Publisher: Sage Publications, Ltd..

[96] Sunduzwayo Madise. 2015. Mobile Money and Airtime: Emerging Forms of Money. *Malawi Law Journal* (Feb. 2015). https://doi.org/10.2139/ssrn.2589058

[97] Laura Mann and Gianluca Iazzolino. 2021. From Development State to Corporate Leviathan: Historicizing the Infrastructural Performativity of Digital Platforms within Kenyan Agriculture. *Development and Change* 52, 4 (July 2021), 829–854. https://doi.org/10.1111/dech.12671

[98] Laura Mann and Elie Nzayisenga. 2015. Sellers on the street: the human infrastructure of the mobile phone network in Kigali, Rwanda. *Critical African Studies* 7, 1 (Jan. 2015), 26–46. https://doi.org/10.1080/21681392.2015.974136

[99] Wendy March, Margot Jacobs, and Tony Salvador. 2005. Designing technology for community appropriation. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems*. ACM, Portland OR USA, 2126–2127. https://doi.org/10.1145/1056808.1057120

[100] Karl Marx and Martin Nicolaus. 1973. *Grundrisse. Foundations of the critique of political economy*. Vintage Books, New York. Original date: 1939.

[101] Ignacio Mas and Olga Morawczynski. 2009. Designing Mobile Money Services Lessons from M-PESA. *Innovations: Technology, Governance, Globalization* 4, 2 (April 2009), 77–91. https://doi.org/10.1162/itgg.2009.4.2.77

[102] Ignacio Mas and Daniel Radcliffe. 2010. Mobile payments go viral: M-PESA in Kenya. *Journal of Financial Transformation* 32 (March 2010), 169–182.

[103] Mokeira Masita-Mwangi, Faith Ronoh-Boreh, Nyambura Kimani, Nancy Mwakaba, Grace Kihumba, Imelda Mueni, and Jussi Impio. 2011. Designing an e-solution for linking informal self-help groups in Africa: a case study. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems*. ACM, Vancouver BC Canada, 799–814. https://doi.org/10.1145/1979742.1979675

[104] Bill Maurer. 2012. The Disunity Of Finance: Alternative Practices To Western Finance. In *The Oxford Handbook of the Sociology of Finance*, Karin Knorr Cetina and Alex Preda (Eds.). Oxford University Press, 0. https://doi.org/10.1093/oxfordhb/9780199590162.013.0022

[105] Bill Maurer. 2012. Mobile Money: Communication, Consumption and Change in the Payments Space. *The Journal of Development Studies* 48, 5 (May 2012), 589–604. https://doi.org/10.1080/00220388.2011.621944

[106] Bill Maurer, Smoki Musaraj, and Ivan Small. 2018. *Money at the margins: Global perspectives on technology, financial inclusion and design*. Vol. 6. Berghahn Books. Journal Abbreviation: Money at the Margins: Global Perspectives on Technology, Financial Inclusion and Design Pages: 322 Publication Title: Money at the Margins: Global Perspectives on Technology, Financial Inclusion and Design.

[107] Clapperton Chakanetsa Mavhunga. 2014. *Transient Workspaces: Technologies of Everyday Innovation in Zimbabwe*. MIT Press.

[108] Clapperton Chakanetsa Mavhunga, Jeroen Cuvelier, and Katrien Pype. 2016. "Containers, Carriers, Vehicles": Three Views of Mobility from Africa. *Transfers* 6, 2 (June 2016), 43–53. https://doi.org/10.3167/TRANS.2016.060204

[109] Kevin McKemey, Nigel Scott, David Souter, Thomas Afullo, Richard Kibombo, and O Sakyi-Dawson. 2003. *Innovative Demand Models for Telecommunications Services*. Technical Report. CTO and Gamos, UK. 63 pages.

[110] Kate Meagher. 2018. Cannibalizing the Informal Economy: Frugal Innovation and Economic Inclusion in Africa. *The European Journal of Development Research* 30, 1 (Jan. 2018), 17–33. https://doi.org/10.1057/s41287-017-0113-4

[111] Célestin Monga. 2016. *Nihilism and Negritude: Ways of Living in Africa*. Harvard University Press, Cambridge, MA.

[112] Eric Monteiro, Neil Pollock, Ole Hanseth, and Robin Williams. 2013. From Artefacts to Infrastructures. *Computer Supported Cooperative Work (CSCW)* 22, 4-6 (Aug. 2013), 575–607. https://doi.org/10.1007/s10606-012-9167-1

[113] Olga Morawczynski. 2009. Exploring the usage and impact of "transformational" mobile financial services: the case of M-PESA in Kenya. *Journal of Eastern African Studies* 3, 3 (Nov. 2009), 509–525. https://doi.org/10.1080/17531050903273768

[114] Michael Muller. 2014. Curiosity, Creativity, and Surprise as Analytic Tools: Grounded Theory Method. In *Ways of Knowing in HCI*, Judith S. Olson and

Wendy A. Kellogg (Eds.). Springer, New York, NY, 25–48. https://doi.org/10.1007/978-1-4939-0378-8_2

[115] Michael Muller, Katja Neureiter, Nervo Verdezoto, Alina Krischkowsky, Anna Maria Al Zubaidi-Polli, and Manfred Tscheligi. 2016. Collaborative Appropriation: How Couples, Teams, Groups and Communities Adapt and Adopt Technologies. In *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion*. ACM, San Francisco California USA, 473–480. https://doi.org/10.1145/2818052.2855508

[116] Srihari Hulikal Muralidhar. 2019. Making Digital Money "Work" for Low-Income Users: Critical Reflections for HCI. *International Journal of Mobile Human Computer Interaction* 11, 4 (Oct. 2019), 49–65. https://doi.org/10.4018/IJMHCI.2019100105

[117] Srihari Hulikal Muralidhar, Claus Bossen, and Jacki O'Neill. 2019. Rethinking Financial Inclusion: from Access to Autonomy. *Computer Supported Cooperative Work (CSCW)* 28, 3 (June 2019), 511–547. https://doi.org/10.1007/s10606-019-09356-x

[118] Timothy Murdoch, Christopher Bowley, Lesley-Ann Vaughan, Warren Carew, Nick Hughes, and Susie Lonie. 2007. Mobile Account Management. https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2007020394&recNum=1&maxRec=1&office=&prevFilter=&sortOption=&queryString=FP%3A%28WO+2007020394%29&tab=PCT+Biblio

[119] Aaron Mushengyezi. 2003. Rethinking Indigenous Media: Rituals, 'Talking' Drums and Orality as Forms of Public Communication in Uganda. *Journal of African Cultural Studies* 16, 1 (2003), 107–117. https://www.jstor.org/stable/3181389 Publisher: Taylor & Francis, Ltd..

[120] Serena Natile. 2020. Digital Finance Inclusion and the Mobile Money "Social" Enterprise: A Socio-Legal Critique of M-Pesa in Kenya. * Historical Social Research / Historische Sozialforschung Vol. 45* No. 3 (2020), Volumes per year: 1 . https://doi.org/10.12759/HSR.45.2020.3.74-94 Publisher: GESIS - Leibniz-Institut für Sozialwissenschaften Version Number: 1.

[121] Bitange Ndemo and Tim Weiss (Eds.). 2017. *Digital Kenya: An Entrepreneurial Revolution in the Making*. Springer Nature. https://doi.org/10.1057/978-1-137-57878-5 Accepted: 2018-11-01 23:55:55.

[122] Elijah Bitange Ndemo. 2015. Political Entrepreneurialism: Reflections of a Civil Servant on the Role of Political Institutions in Technology Innovation and Diffusion in Kenya. *Stability: International Journal of Security and Development* 4, 1 (March 2015), Art. 15. https://doi.org/10.5334/sta.fd Number: 1.

[123] Ali Ndiwalana and Oliver Popov. 2008. Mobile Payments: A Comparison between Philippine and Ugandan Contexts. In *IST-Africa 2008*, Paul Cunningham and Miriam Cunningham (Eds.). IIMC International Information Management Corporation, 1–10. https://miun.diva-portal.org/smash/get/diva2:133838/FULLTEXT01.pdf

[124] Eivor Oborn, Michael Barrett, Wanda Orlikowski, and Anna Kim. 2019. Trajectory Dynamics in Innovation: Developing and Transforming a Mobile Money Service Across Time and Place. *Organization Science* 30, 5 (Sept. 2019), 1097–1123. https://doi.org/10.1287/orsc.2018.1281 Publisher: INFORMS.

[125] Toluwalogo Odumosu. 2017. Making Mobiles African. In *What Do Science, Technology, and Innovation Mean from Africa?*, Clapperton Chakanetsa Mavhunga (Ed.). MIT Press, Cambridge, MA, USA, 137–150.

[126] Toluwalogo B Odumosu. 2009. *Interrogating Mobiles: A Story of Nigerian Appropriation of The Mobile Phone*. Ph.D. Dissertation. Rensselaer Polytechnic Institute, Troy, NY.

[127] Wanda J. Orlikowski. 1992. The Duality of Technology: Rethinking the Concept of Technology in Organizations. *Organization Science* 3, 3 (Aug. 1992), 398–427. https://doi.org/10.1287/orsc.3.3.398

[128] Nelly Oudshoorn and Trevor Pinch (Eds.). 2003. *How Users Matter: The Co-construction of Users and Technologies*. MIT Press, Cambridge, Mass.

[129] Emma Park. 2020. 'Human ATMs': M-Pesa and the expropriation of affective work in Safaricom's Kenya. *Africa* 90, 5 (Nov. 2020), 914–933. https://doi.org/10.1017/S0001972020000649 Publisher: Cambridge University Press.

[130] Lisa Parks. 2017. Water, Energy, Access. In *Signal Traffic: Critical Studies of Media Infrastructures*, Lisa Parks and Nicole Starosielski (Eds.). Vol. 1. University of Illinois Press. https://doi.org/10.5406/illinois/9780252039362.003.0005

[131] Trevor Perrier, Brian DeRenzi, and Richard Anderson. 2015. USSD: The Third Universal App. In *Proceedings of the 2015 Annual Symposium on Computing for Development (DEV '15)*. Association for Computing Machinery, New York, NY, USA, 13–21. https://doi.org/10.1145/2830629.2830645

[132] Rowan Phipps, Shrirang Mare, Peter Ney, Jennifer Webster, and Kurtis Heimerl. 2018. ThinSIM-based Attacks on Mobile Money Systems. In *Proceedings of the 1st ACM SIGCAS Conference on Computing and Sustainable Societies (COMPASS '18)*. Association for Computing Machinery, New York, NY, USA, 1–11. https://doi.org/10.1145/3209811.3209817

[133] Volkmar Pipek and Volker Wulf. 2009. Infrastructuring: Toward an Integrated Perspective on the Design and Use of Information Technology. *Journal of the Association for Information Systems* 10, 5 (May 2009), 447–473. https://doi.org/10.17705/1jais.00195

[134] Karl Polanyi. 1944. *The great transformation*. Farrar & Rinehart, Inc, New York. OCLC: 5375263.

[135] Neil Pollock and Robin Williams. 2010. e-Infrastructures: How Do We Know and Understand Them? Strategic Ethnography and the Biography of Artefacts. *Computer Supported Cooperative Work (CSCW)* 19, 6 (Dec. 2010), 521–556. https://doi.org/10.1007/s10606-010-9129-4

[136] C. K. Prahalad. 2006. *The Fortune at the Bottom of the Pyramid*. Pearson Prentice Hall.

[137] Marc Raboy. 1995. Access to Policy, Policies of Access. *Javnost - The Public* 2, 4 (Jan. 1995), 51–61. https://doi.org/10.1080/13183222.1995.11008607

[138] Marc Raboy. 1998. Global communication policy and the realisation of human rights. *The Journal of International Communication* 5, 1-2 (Dec. 1998), 83–104. https://doi.org/10.1080/13216597.1998.9751866

[139] George Ritzer and Nathan Jurgenson. 2010. Production, Consumption, Prosumption: The nature of capitalism in the age of the digital 'prosumer'. *Journal of Consumer Culture* 10, 1 (March 2010), 13–36. https://doi.org/10.1177/1469540509354673 Publisher: SAGE Publications.

[140] Yasaman Rohanifar, Sharifa Sultana, Shaid Hasan, Priyank Chandra, and Syed Ishtiaque Ahmed. 2022. "Kabootar": Towards Informal, Trustworthy, and Community-Based FinTech for Marginalized Immigrants. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (Nov. 2022), 1–32. https://doi.org/10.1145/3555109

[141] Sarah Rüller, Konstantin Aal, Simon Holdermann, Peter Tolmie, Andrea Hartmann, Markus Rohde, Martin Zillinger, and Volker Wulf. 2022. 'Technology is Everywhere, we have the Opportunity to Learn it in the Valley': The Appropriation of a Socio-Technical Enabling Infrastructure in the Moroccan High Atlas. *Computer Supported Cooperative Work (CSCW)* 31, 2 (June 2022), 197–236. https://doi.org/10.1007/s10606-021-09401-8

[142] Safaricom Newsroom. 2020. Mteja to Fuliza: a brief history of words. https://newsroom.safaricom.co.ke/mteja-to-fuliza-a-brief-history-of-words/ Section: Lifestyle.

[143] Nithya Sambasivan and Edward Cutrell. 2012. Understanding negotiation in airtime sharing in low-income microenterprises. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Austin Texas USA, 791–800. https://doi.org/10.1145/2207676.2207791

[144] Nithya Sambasivan and Thomas Smyth. 2010. The human infrastructure of ICTD. In *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*. ACM, London United Kingdom, 1–9. https://doi.org/10.1145/2369220.2369258

[145] Cerstin Sander, Peter Mukwana, and Altemius Millinga. 2001. *Money Transfer Systems: The Practice and Potential for Products in Tanzania and Uganda*. Technical Report. MicroSave, Nairobi. 60 pages.

[146] Christian Sandvig. 2013. Connection at Ewiiaapaayp Mountain: Indigenous Internet Infrastructure. In *Race After the Internet*, Lisa Nakamura and Peter Chow-White (Eds.). Routledge, New York, NY, 168–200.

[147] Martin Sauter. 2011. *From GSM to LTE: An introduction to mobile networks and mobile broadband*. Wiley, Chichester, West Sussex, U.K.

[148] Jutta Schickore. 2022. Scientific Discovery. In *The Stanford Encyclopedia of Philosophy* (winter 2022 ed.), Edward N. Zalta and Uri Nodelman (Eds.). Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/win2022/entries/scientific-discovery/

[149] Nigel Scott, Simon Batchelor, Jonathon Ridley, and Britt Jorgensen. 2004. The Impact of Mobile Phones in Africa. *Commission for Africa* (Nov. 2004), 18.

[150] Nick Seaver. 2015. Bastard algebra. In *Data: Now Bigger and Better!*, Tom Boellstorff and Bill Maurer (Eds.). Prickly Paradigm Press. https://press.uchicago.edu/ucp/books/book/distributed/D/bo20285526.html

[151] Phoebe Sengers, Kaiton Williams, and Vera Khovanskaya. 2021. Speculation and the Design of Development. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW1 (April 2021), 121:1–121:27. https://doi.org/10.1145/3449195

[152] David Serlin. 2017. Confronting African Histories of Technology: A Conversation with Keith Breckenridge and Gabrielle Hecht. *Radical History Review* 2017, 127 (Jan. 2017), 87–102. https://doi.org/10.1215/01636545-3690870

[153] Araba Sey. 2008. Where did all the Payphones go? Intermediaries, Innovation and Insecurity in the Mobile Phone Industry. In *International Communication Association Pre-Conference on Mobile Communication*. Montreal, Canada, 21.

[154] Alain Shema. 2019. Effective credit scoring using limited mobile phone data. In *Proceedings of the Tenth International Conference on Information and Communication Technologies and Development (ICTD '19)*. Association for Computing Machinery, New York, NY, USA, 1–11. https://doi.org/10.1145/3287098.3287116

[155] Roger Silverstone. 1994. *Television and Everyday Life*. Routledge.

[156] Robert Soden, David Ribes, Seyram Avle, and Will Sutherland. 2021. Time for Historicism in CSCW: An Invitation. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW2 (Oct. 2021), 459:1–459:18. https://doi.org/10.1145/3479603

[157] Janaki Srinivasan. 2021. The social meaning of mobile money: Navigating digital payments, savings and credit in the global South. In *Data-centric Living*. Routledge India. Num Pages: 22.

[158] Susan Leigh Star. 1990. Power, Technology and the Phenomenology of Conventions: On being Allergic to Onions. *The Sociological Review* 38, 1_suppl (May 1990), 26–56. https://doi.org/10.1111/j.1467-954X.1990.tb03347.x

[159] Susan Leigh Star. 1996. Working together: Symbolic interactionism, activity theory, and information systems. In *Cognition and Communication at Work*, Yrjo Engeström and David Middleton (Eds.). Cambridge University Press.

[160] Susan Leigh Star. 1997. Anselm Strauss: An Appreciation. *Sociological Research Online* 2, 1 (March 1997), 92–97. https://doi.org/10.5153/sro.92 Publisher: SAGE Publications Ltd.

[161] Susan Leigh Star and Karen Ruhleder. 1994. Steps towards an ecology of infrastructure: complex problems in design and access for large-scale collaborative systems. In *Proceedings of the 1994 ACM conference on Computer supported cooperative work (CSCW '94)*. Association for Computing Machinery, New York, NY, USA, 253–264. https://doi.org/10.1145/192844.193021

[162] Jonathan Sterne. 2003. *The Audible Past: Cultural Origins of Sound Reproduction*. Duke University Press, Durham, NC.

[163] Saiganesh Swaminathan, Indrani Medhi Thies, Devansh Mehta, Edward Cutrell, Amit Sharma, and William Thies. 2019. Learn2Earn: Using Mobile Airtime Incentives to Bolster Public Awareness Campaigns. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (Nov. 2019), 49:1–49:20. https://doi.org/10.1145/3359151

[164] Philip Tchernavskij and Susanne Bødker. 2022. Entangled Artifacts: The Meeting Between a Volunteer-run Citizen Science Project and a Biodiversity Data Platform. In *Nordic Human-Computer Interaction Conference*. ACM, Aarhus Denmark, 1–13. https://doi.org/10.1145/3546155.3546682

[165] Pierre Tchounikine. 2017. Designing for Appropriation: A Theoretical Account. *Human–Computer Interaction* 32, 4 (July 2017), 155–195. https://doi.org/10.1080/07370024.2016.1203263

[166] Stephen Temple. 2010. *Inside the Mobile Revolution: A Political History of GSM*. Technical Report. Temple CBE. 119 pages.

[167] Elo Umeh. 2021. Digital Transformation in Africa Requires Homegrown Solutions. https://hbr.org/2021/12/digital-transformation-in-africa-requires-homegrown-solutions Section: Digital transformation.

[168] Paul van der Boor, Pedro Oliveira, and Francisco Veloso. 2014. Users as innovators in developing countries: The global sources of innovation and diffusion in mobile banking services. *Research Policy* 43, 9 (Nov. 2014), 1594–1607. https://doi.org/10.1016/j.respol.2014.05.003

[169] Pauline Vaughan, Wolfgang Fengler, and Michael Joseph. 2013. Scaling Up through Disruptive Business Models: The Inside Story of Mobile Money in Kenya. In *Getting to Scale: How to Bring Development Solutions to Millions of Poor People*, Laurence Chandy, Akio Hosono, Homi J. Kharas, and Johannes F. Linn (Eds.). Brookings Institution Press, 189–219.

[170] Eric von Hippel. 2005. *Democratizing Innovation*. MIT Press, Cambridge, Mass.

[171] Antina von Schnitzler. 2008. Citizenship Prepaid: Water, Calculability, and Techno-Politics in South Africa*. *Journal of Southern African Studies* 34, 4 (Dec. 2008), 899–917. https://doi.org/10.1080/03057070802456821

[172] Antina von Schnitzler. 2013. Traveling Technologies: Infrastructure, Ethical Regimes, and the Materiality of Politics in South Africa. *Cultural Anthropology* 28, 4 (2013), 670–693. https://doi.org/10.1111/cuan.12032

[173] Timothy Mwololo Waema. 2007. *2007 Kenya Telecommunications Sector Performance Review: a supply side analysis of policy outcomes*. Technical Report. Research ICT Africa.

[174] Binyavanga Wainaina. 2007. Glory: The Soft Bigotry of Great Expectations. *Bidoun* 10: Technology (2007), 48–52. https://bidoun.org/issues/10-technology#glory

[175] Harald Welte. 2010. Anatomy of contemporary GSM cellphone hardware. https://web.archive.org/web/20110627040858/https://laforge.gnumonks.org/papers/gsm_phone-anatomy-latest.pdf

[176] World Bank. 2012. *Information and Communications for Development 2012: Maximizing Mobile*. Technical Report. World Bank, Washington, DC. https://doi.org/10.1596/978-0-8213-8991-1 Accepted: 2012-12-11T19:31:01Z ISBN: 9780821389911 ISSN: 1665-3599 Journal Abbreviation: Information et communications au service du developpement 2012 : exploiter au maximum la telephonie mobile - abrege.

[177] Audra Wormald, Rajshree Agarwal, Serguey Braguinsky, and Sonali K. Shah. 2021. David overshadows Goliath: Specializing in generality for internationalization in the global mobile money industry. *Strategic Management Journal* 42, 8 (2021), 1459–1489. https://doi.org/10.1002/smj.3270

[178] Susan P. Wyche and Laura L. Murphy. 2012. "Dead China-make" phones off the grid: investigating and designing for mobile phone use in rural Africa. In *Proceedings of the Designing Interactive Systems Conference (DIS '12)*. Association for Computing Machinery, New York, NY, USA, 186–195. https://doi.org/10.1145/2317956.2317985

[179] Susan P. Wyche, Nightingale Simiyu, and Martha E. Othieno. 2016. Mobile Phones as Amplifiers of Social Inequality among Rural Kenyan Women. *ACM Transactions on Computer-Human Interaction* 23, 3 (June 2016), 14:1–14:19. https://doi.org/10.1145/2911982

[180] Susan P. Wyche, Nightingale Simiyu, and Martha E. Othieno. 2019. Understanding women's mobile phone use in rural Kenya: An affordance-based approach. *Mobile Media & Communication* 7, 1 (Jan. 2019), 94–110. https://doi.org/10.1177/2050157918776684