

The Invisible Work of Maintenance in Community Health: Challenges and Opportunities for Digital Health to Support Frontline Health Workers in Karnataka, South India

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Frontline health workers are the first and often the only access point to basic health care services in low-and-middle income countries. However, the work and the issues frontline health workers face are often invisible to the healthcare system, with limited resources to assist them. This study explores the work practices, challenges and roles of frontline health workers in community health with particular focus on pregnancy care in South India. Drawing on the notion of maintenance and articulation work, we describe the maintenance work of frontline health workers maintaining, anticipating, reconciling, and supporting care infrastructures beyond data collection practices. Our findings highlight how socio-cultural practices, perceptions, status, and existing systems influence maintenance work practices. Based on our findings, we suggest moving beyond the focus on training and performance to design CSCW tools to support the maintenance work of frontline health workers as ‘system-builders’ to make healthcare infrastructures work in community health.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**.

Additional Key Words and Phrases: Maintenance work, community health, digital health, global health, HCI4D

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1 INTRODUCTION

Investigating healthcare work practices and infrastructures has long been an important concern within the Human-Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW) communities especially in clinical settings [42]. Recently there has been a greater focus to study

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the work performed by nonclinical personnel such as medical secretaries, hospital orderlies, social workers, and volunteers [2, 22, 124, 132, 133], as their efforts as part of the human infrastructure [133] that support the overall healthcare infrastructure often remains “functionally invisible” [122]. While previous research has investigated the invisible work of patients and caregivers outside the clinic [46, 66, 131, 146], there is limited research understanding the invisible work in community health [55, 93] and in general care infrastructures in the Global South [27, 82, 129].

In low- and middle-income countries (LMICs), exacerbating socio-economic inequalities, lack of trained healthcare professionals, lower access to medical resources, the fragmented nature of care services and the increase of non-communicable diseases challenge the provision of healthcare services. To alleviate some of these challenges, a number of close-to-community health care service providers [30, 75], frontline health workers, including community health workers, volunteers and health extension workers, are acting as *educators* and *mediators* of healthcare service providers with the community especially in remote areas [13, 75, 116]. Frontline health workers provide a wide range of community services that are highly context-specific to the needs of the LMICs including identification of sick people (e.g. high-risk pregnancies), provision of care and treatment through home visits (e.g., vaccinations, malaria), provision of health education and counselling (e.g., HIV, maternal care, family planning), collection of data (e.g., clerical duties, malaria outbreaks, medication), promotion of the utilisation of health services, referrals and follow-up checks [109, 112].

There is a growing interest to design technology to support the work of frontline health workers by assisting with dissemination of health education [77, 78, 136], providing on-demand feedback of household visits [35], receiving feedback from care recipients [85, 86], and providing training and learning opportunities [65, 80, 144, 145]. However, existing interventions mostly focus on literacy, training, data collection, work performance and accountability overlooking the issues frontline health workers face and the wider network of actors, sociocultural practices, disconnected knowledges, material and spatial elements that influence and shape their work practices [54, 55, 93, 117]. Yet, little is known about the essential work that frontline health workers do to enact these roles (educators and mediators) beyond their job descriptions as it is often unrecognized, relegated as invisible [5, 122], largely unnoticed and unsupported by healthcare systems, policy and technology designers. This “invisible” labor occurs in the back stage [17, 119], requiring different arrangements and continuous articulation [31, 111, 128] to link many infrastructural elements [125, 126, 128] to maintain frontline health work in the Global South [67, 93].

Designing technology for community health in the Global South does not only require an in-depth understanding of the sociocultural context, local needs, everyday knowledges, practices, and environments [7, 54–56, 67] but also an understanding of the invisible work to make care infrastructures work [93]. In this paper, we investigate the dynamic, invisible—yet essential—backstage work that frontline health workers do to maintain care infrastructures to better situate technology design within community health settings [67]. To gain this understanding, we conducted a qualitative study with 18 frontline health workers combining focus groups with sketching and mapping activities to investigate the everyday practices and challenges faced when providing community health services in rural and semi-urban areas of South India. We also drew on secondary data from an interview study with 27 households (19 pregnant women and 8 nursing mothers) regarding the everyday challenges in pregnancy care. This provided insights to the focus groups in terms of understanding community interactions, and the different roles of frontline health workers.

Our findings reveal a situated network of human infrastructure of four heterogeneous groups of frontline health workers as well as the infrastructural arrangements, sociocultural and technical elements that influence and shape the dynamic work of community health. Zooming in on community health practices we became aware of the nuances between frontline health workers’ official job descriptions and the realities of their work context and everyday challenges facing existing

infrastructures in practice [115]. Drawing on the notion of maintenance [73], we characterize the invisible work of frontline workers as maintenance work, a form of articulation work [111], that includes anticipating, repairing, reconfiguring, adapting, and managing infrastructural arrangements to maintain community healthcare infrastructures, beyond data collection practices [55, 90].

Our research makes multiple contributions to HCI, CSCW, and healthcare research. First, we provide a better understanding of the invisible work of maintenance of frontline health workers in support of community health infrastructures. This complements research investigating care infrastructures [24, 121] in practice going beyond the boundaries of the hospital [140] into community health [54, 55, 93]. Looking at maintenance work brings new sociocultural and technical insights about the invisible [122, 134], backstage [119], articulation [31, 125] work of frontline health workers in community health [55, 67, 93] that is central to system design [111, 128]. Second, our study contributes to previous studies examining the human infrastructure [69, 108] in healthcare [133] with particular focus on community health [93]. We expand previous reported roles of frontline health workers as educators, infomediaries and intermediaries [54, 109] calling for attention to the role of *maintainers* acting as “system builders” [68], adapting and reshaping heterogeneous and distributed infrastructural arrangements by negotiating community stakeholder’s needs, norms and expectations. Third, we propose maintenance-centered design as a strategy to make maintenance work visible enough to inform the development of policies, tools and interventions to support frontline health workers in community health.

2 RELATED WORK

2.1 Infrastructures and Healthcare

Star and Ruhleder [121] describe an infrastructure as “something that emerges for people in practice, connected to activities and structures” regardless of the domain e.g., domestic energy services, transportation, media and communication, healthcare, water, broadband, etc. [28, 120]. Rather than looking at infrastructure as a thing that is readily available to use for something else to operate on, “sinking into the background”, Star and Ruhleder [121] refer to infrastructure as a highly relational concept as “it becomes infrastructure in relation to organized practices” [121]. Many researchers have called for attention to the importance of investigating the complexities of infrastructures in practice [28, 63, 115]. Jensen and Winthereik [61] highlight the social and organisational components of infrastructures going beyond the practicalities of implementing technology paying attention to the ongoing practices, information and material elements that sustain information infrastructures.

In healthcare, infrastructures relate to the physical, social and structural elements, resources and functional capacities that support and sustain healthcare activities at all levels (from community and home care to national and regional services) including facilities (e.g., health centers, operating rooms), staff (involving education, training, supervision), equipment, management, financing, etc. [116, 135]. In particular HCI and CSCW research in healthcare has looked at the information and human infrastructure in place to support healthcare work practices in distributed environments such as hospitals [22, 23, 42, 44, 123], with specialized equipment, information and decision support systems, maintenance staff, and resources [10, 12, 19, 20, 148]. Healthcare information infrastructures have been introduced as a way to mitigate the increasing demand of healthcare service delivery aiming to reduce errors, support coordination, automate logistics, manage processes and enhance the efficiency and quality of care through the use of Information and Communication Technologies (ICTs) at all levels of the functional infrastructure [49, 95]. As care infrastructures reach far beyond the boundaries of the hospital [54, 140], the human infrastructure [133], the social system supporting care work, includes not only clinical and non-clinical personnel [42, 124, 132],

but also staff in municipality and residential facilities [21, 87], patients and caregivers [66, 131] and frontline health workers in the community [67, 93].

2.2 Frontline Health Workers: Work Practices, Challenges and Strategies in Community Health

The World Health Organization has identified two types of frontline health workers, the generalists and the specialists, according to the type of health services (e.g., preventive care, first aid) they provide and whether these are restricted to a specific program (e.g., malaria control, HIV, etc.) they enroll or not [70]. The routine work of frontline health workers is often arranged through household visits (weekly or monthly) to provide counseling (e.g., lifestyle, sexual health, antenatal care), make referrals to the nearest health center, support data collection (to inform the primary health center), and monitoring of communities (follow-up checks) [26, 88].

Although some frontline health workers report to have done first aid (e.g., for minors burns, wounds), performing a medical intervention is often not part of their role due to the more specialized knowledge and resources required [88]. Yet, there is limited research exploring the everyday context and needs of frontline health workers [54, 55] and the invisible work they perform [67, 93] to make community infrastructures work beyond their job's descriptions. This invisible work occurs in between and is often taken for granted [5, 122], remaining unacknowledged and in the back stage [119] of community health with limited resources, incentives, and training to face ill-equipped healthcare infrastructures [88, 109, 112, 138].

The fragmented and often imperfect healthcare infrastructures in LMICs [4, 8, 27] challenge the work of frontline health workers due to the lack of financial, technical and human resources [26, 88, 109], limited training and supervision [88, 112]. As the work of frontline health workers is highly context specific [112], this work can be mutually dependent and influenced by the existing norms, sociocultural practices, community power dynamics and situated relationships with multiple stakeholders with often conflicting perspectives [54, 55, 109, 138]. All these challenges are exacerbated by difficult geographical terrain, poor transport [109], poor urban and sanitation infrastructure, insecurity and urban violence [4, 60].

Strategies to aid the work of frontline workers include a number of supplies such as bicycles and canoes (Brazil), educational flyers and referral forms (Haiti), syringes and needles (Ethiopia), thermometers (Mozambique, Brazil, Pakistan) and basic equipment such as weight scales (Haiti, Kenya, Ethiopia, Pakistan), glucose meters (Kenya), and blood pressure monitoring devices (Ethiopia) [26]. ICTs are also being introduced to support frontline health workers and community health programs in the Global South [4, 26].

2.3 Digital Health to Support the Work of Frontline Health Workers in LMICs

ICTs are being implemented, tested and deployed to support health education through mobile multimedia in Lesotho [77, 78], personalized feedback of quality of care from care recipients [85, 86] and work performance from supervisors [85, 141] in Kenya, data collection through mobile technology in Nigeria [6], and screening (identification and referral) of post-surgical infections in Rwanda [118]. In particular, India has been a major focus for digital health research in community health exploring the use of technology by a particular type of frontline health workers, named ASHAs (Accredited Social Health Activists) and community volunteers [56, 65, 90, 93]. For example, text messages have been used to help frontline health workers to promote maternal health messages and facilitate discussions [99], video-based health education material to engage women in dialogue, enhancing frontline health workers motivation and learning during visits [98, 136, 137]. In addition, interactive radio shows have also supported frontline health workers to host real-time discussions with the community and localized sharing of experiences [64]. Mobile technology (e.g., calls,

SMS, WhatsApp) is also supporting the communication, coordination and sharing of work-related information (e.g., birth notifications) between frontline health workers [56, 81], providing simple visualizations of household visits [35], and facilitating data collection practices [90]. ICTs are also enhancing training programs [65, 80] and supporting peer learning [144, 145] combining different applications and various types of digital content. Challenges include lack of data integration within and across districts, time collecting and harmonizing redundant or nontransferable data, language of tools, low data quality, poor connectivity, low digital literacy, etc. [4, 33, 40, 65, 145].

While the digital transformation in community health is showing potential to support the work of frontline health workers, existing initiatives have mostly focused on supporting counseling, health education, training, data collection, feedback on quality of service and work performance [9, 62, 141]. These initiatives have often overlooked the wider network of human (beyond ASHAs) and nonhuman entities and how sociocultural practices influence and shape the work of frontline health workers going beyond job's descriptions, and work performance.

2.4 The Invisible Work of Maintenance

Important CSCW research highlights how the everyday context, roles and invisible work practices of frontline health workers in community health are not well understood [54, 55, 67, 93]. Drawing on the notion of maintenance “the mundane labour that goes into sustaining functioning and efficient infrastructures” [83, 105], we characterize the invisible work [122, 134] of frontline health workers as maintenance work [73], a type of articulation work [111], that helps managing the necessary actions to maintain community health infrastructures. Looking at maintenance work as a form of articulation work [48, 111], the “continuous efforts required in order to bring together discontinuous elements” [128], getting “things back ‘on track’ in the face of the unexpected... that is invisible to rationalized models of work” [122], can help understanding the unnoticed efforts of infrastructural maintenance [73, 105]. Examining community health infrastructures through the notion of maintenance would help capture “all the work it takes to keep everything running” [38] that would otherwise remain hidden in the background [31, 122]. Without an understanding of articulation work, we can only get idealized views of work practices “but not to describe actual situations” [43]. As stated by Star (2002), “It is often in such back stage work that important requirements are discovered” [119] which are valuable to inform system design [17, 96, 111, 128], especially where “solutions are nonexistent or troubling” [134] in the Global South [82, 130].

The notion of maintenance is closely related to previous CSCW research on maintenance engineers' work on smart factories [143], information maintenance work in knowledge production communities [97], and the maintenance and repair work of equipment [57, 104] and community networks [37]. While maintenance work is often characterized as highly technical in relation to breakdowns, error handling, and fixing things [57, 97, 104, 143], this is a simplistic view as it overlooks the political, sociocultural, infrastructural, material and economic elements that shape maintenance and repair practices [37, 57, 73, 104]. In healthcare, maintenance work is often linked to equipment failures at the hospital [100], however, Gui et al. (2018) described the repair work that parents engage in to fix breakdowns while navigating healthcare services to get what they need for their children [47]. Kumar et al. (2019) reported how community outreach workers engage in restoration work attempting to repair a “life disruption” by helping to restore patients' “old normals” [67]. While failures and breakdowns often bring attention to the material elements of repair and maintenance practices that sustain infrastructures [45, 94], these practices do not only take place after something breaks [57, 104]. Maintenance practices involve social and material associations including “mending, repairing, fixing, restoring, preserving, cleaning, recycling, up-keeping... an immense variety of more or less noticeable practices” [34].

3 CASE STUDY: PREGNANCY CARE INFRASTRUCTURES IN SOUTH INDIA

Our exploratory case study investigated the everyday challenges, practices, and experiences of frontline health workers supporting and sustaining community health infrastructures. To unpack the invisible work of maintenance, we pay particular attention to their roles, work practices, community perceptions, the spatial and material arrangements and the multiple human and non-human actors frontline health workers interact with while sustaining community health infrastructures. Our case study was situated in an interpretivist paradigm taking a practice-oriented research approach for health [16], HCI [39], and CSCW [47] research, aligned to the more-than-human approach to digital health [71]. A case study was chosen as it is well suited for providing an in-depth understanding of real-life contexts and issues and how they unfold in practice [92, 147], that can better inform the subsequent development of complex health [32] and technological [39, 124] interventions.

The study was part of a project investigating the everyday challenges of pregnancy care faced by women and their caregivers when interacting with care infrastructures. The project team include a multidisciplinary group of researchers with background in public health, nutrition, interaction design, social science applied to health, chronic disease prevention, human-computer interaction, and community-based interventions. The study received ethical approvals from the Srishti Institute of Art, Design, and Technology (India), the University of Leicester and Loughborough University (UK). We had three project workshops (2 in India and 1 in Leicester) where potential ethical issues were discussed and addressed. Workshops enabled the research team to discuss preliminary findings and help redefine the focus of the project.

3.1 Background: Healthcare Infrastructures in India

The Indian healthcare system consists of public and private healthcare providers [115] and other emerging providers such as nonprofit institutions and more traditional (e.g., Ayurveda, Unani) and alternative (e.g., Homeopathy) forms of medicine systems [107, 114]. The public healthcare sector marked its milestone in 2005 through the government initiated National health rural mission (later expanded as National Health Mission) to strengthen the rural public health system [29]. It emerged to target one of the biggest public health challenges, maternal and child health, aiming to improve the “availability of human resources, program management, physical infrastructure, community participation, financing and use of information technology” [29]. Public health services are divided in three main levels (see Figure 1). The primary level includes Sub-centers (SC) and Primary health centers (PHC). The subcenter is the first contact point between the primary healthcare system and the community and often focuses on maternal health, disease control and counseling [29]. The PHCs offer curative and preventive health services to the rural population including referrals for subcenters and it is the first contact point between the village and a medical officer [29]. The secondary level includes Community health centers (CHC) that provide highly specialized access to services including obstetric and pediatric care and medical specialists (e.g., obstetricians, physicians), and act as a referral for the PHCs [29]. The tertiary level includes sub-district hospitals with little outpatient services and the third level includes medical colleges, multispecialty tertiary hospitals, or district hospitals which are the last referral point and provide emergency facilities for obstetric and newborn care [29].

The public health system is supported by ambulance services, toll free-call services (known as Arogya Sahayavani), and the human infrastructure providing community health services including the Accredited Social Health Activists (ASHAs) [117] and the Junior Health Assistants (JHAs) also known as Auxiliary Nurse Midwives (ANMs) [110]. ASHAs often act as a link between the JHAs at the sub-centre, the Anganwadi workers (AWWs) and the community [110]. The Anganwadi workers are part of the Integrated Child Development Service programme under the Ministry of

Women and Child Development (MWCD), providing basic care services such as supplementary nutrition, health education and preschool education [59]. In addition, a Web-based mother and child tracking system (MCTS) and a number of government-supported health schemes exist to help address maternal health issues and reduce infant mortality (e.g., Pradhan Mantri Surakshit Matritva Abhiyan (PMSMA), Thaiy Bhagya, Janani Suraksha Yojane, Bhagyalakshmi) [29].

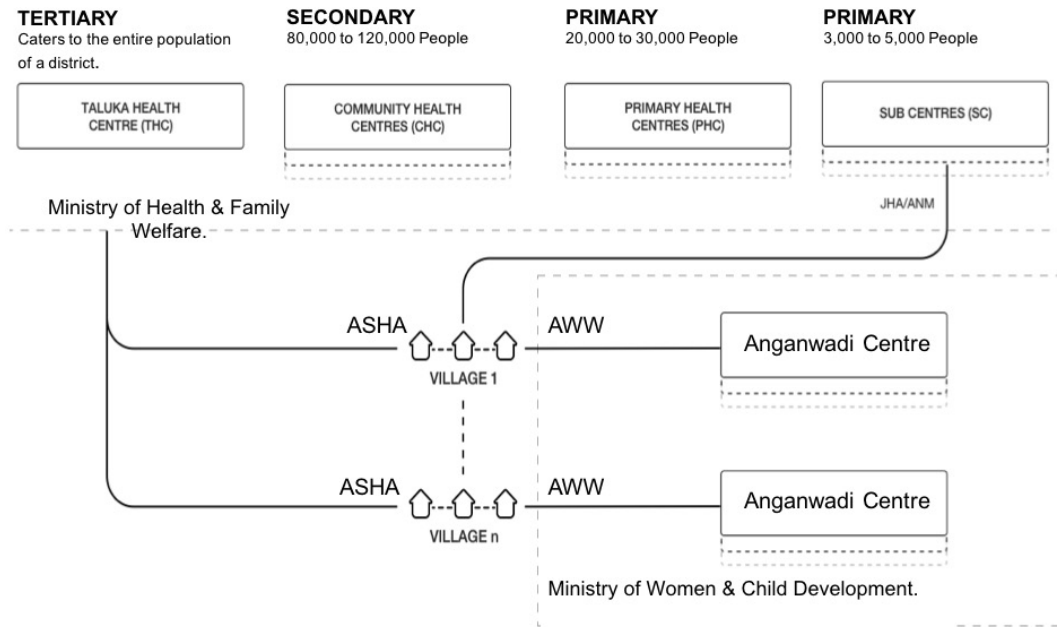


Fig. 1. Public Health Infrastructure in India and the first contact points with the community.

3.2 Study Setting and Participants

The study was conducted in rural and semi-urban areas of Channapatna town located in the Ramanagara district that belongs to Karnataka state, India’s eighth largest State. We reached these areas with the help of our local collaborator, MAYA Health. MAYA provides training to the micro-entrepreneur women who promote preventive health services in the communities known as Health Navigators (HN). Although Karnataka has made lots of progress in improving the public health infrastructure and services over the last decades, the maternal mortality ratio continues to be the highest among the four southern States [101]. Besides the urban-rural inequalities, there are regional disparities in the distribution of infrastructure and provision of services across Karnataka, for example 30% of CHCs do not have an operating theatre and only 23% of CHCs provide comprehensive emergency obstetric care services [101]. In the last decade Karnataka, has seen a shortfall of JHAs at the sub-center level, a shortage of medical specialists and a decline in the utilization of public health services as more people are preferring private care services [101].

We purposefully [92, 147] invited a number of frontline health workers and community households to participate, ensuring diversity in terms of health coverage of urban (U1-U5) and rural (R1-R5) areas, different frontline health workers (A for ASHA, HN for Health Navigators, JH for Junior Health Assistants, AW for Anganwadi workers) and households with either a pregnant

Table 1. Focus Groups and a Visit to the Taluk Health Center (THC)

Session	Description	Participant Code
S1	Focus group with AWWs workers and JHAs at the urban PHC	JH1-JH5; AW1-AW4
S2	Focus group with ASHAs at the urban Taluk Health Center	A1-A4
S3	Focus groups at the urban Anganwadi Centre	JH6; AW5
S4	Focus groups at the rural Anganwadi Centre	AW6; A5; HN1
S5	Visit to the Taluk Health Center and Additional Support Data	A1; A2

woman or a nursing mother. To get insights into the everyday challenges and work of frontline workers in community health, we used different methods for data collection (see Table 1).

3.3 Focus Groups with Frontline Health Workers

We held four focus groups with 18 frontline health workers: six JHAs (JHA1 – JHA6), five ASHAs (A1-A5), six AWWs (AW1-AW6), and one HN (HN1), covering rural and semi-urban areas around Channapatna town. During the focus groups, frontline health workers were invited to talk about their practices, roles, everyday challenges, current strategies and tools to support their work maintaining the community health infrastructure. We also used visual methods through sketching and mapping activities (see Figure 2) to visualize insights and facilitate reflections on the existing challenges of frontline health work. Focus groups were conducted by three researchers in the local languages Urdu or Kannada and lasted for about 45 minutes to two hours. Two of these focus groups were co-facilitated with a collaborator from MAYA.

3.3.1 S1: Focus Group with AWWs workers and JHAs at the PHC. The first focus group (S1) was conducted with four AWWs and five JHAs at the local PHC. After giving an introduction of the study and signing the informed consent, the first activity was profiling their own work to get an understanding of their perceived roles and job’s responsibilities. The JHAs and AWWs listed down this information in their local language (e.g., Kannada) using chart papers. After the profiling activity, participants were divided in two mixed groups, one group with two AWWs and three JHAs, and the second group with two AWWs and two JHAs and were moderated by two researchers. One group discussed the primary health care facilities and services of the district and the other group discussed the infrastructural services and technological aspects used in their local health care centre. Last, participants were encouraged to narrate specific incidents in relation to pregnancy which had been frustrating, annoying or surprising, inspired by the critical incident technique [52]. To aid this last activity, we used sketching to help with mapping the different care services and support discussions among participants and to build rapport (see Figure 2).

3.3.2 S2: Focus Group with ASHAs at the Taluka Health Center (THC). The second focus group (S2) was conducted at the district Taluk Health Center with four ASHAs, who were accompanying pregnant women from their respective localities to their appointments. This focus group helped us to get insights into their work practices including recruitment criteria, responsibilities, motivation and the various socio-technical actors they interact with to support work coordination and their challenges in the field. Earlier findings from the previous discussions were shared to understand their perspectives and corroborate findings.

3.3.3 S3 and S4: Focus Groups at the Urban & Rural Anganwadi Centres. Two focus groups were conducted with frontline health workers at Anganwadi centres both in urban and rural areas. At the rural area (S4), the focus group involved three frontline health workers (A5, AW6, HN6)

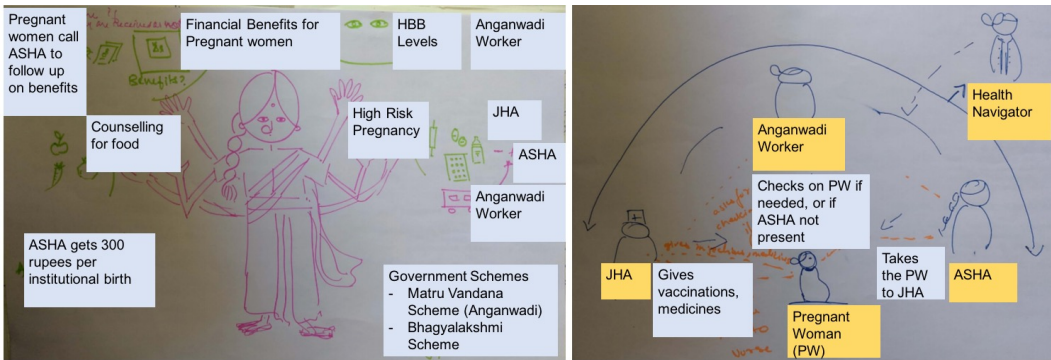


Fig. 2. (left) A researcher captured the multifaceted work of ASHAs and AWWs as a visual of a ‘woman with many arms’, as shared by the participants during S4, and (right) shows the frontline health workers’ interaction with a pregnant woman, where the HN is ‘outside’ the network of JHAs, ASHAs, and AWWs.

active in the area. In the urban area (S3) the Anganwadi centre consisted of two frontline health workers (JH6, AW5). This urban configuration helped us to explore the perceptions and limitations caused by the absence of the ASHA worker in this centre. Participants were invited to talk about the services they provide and describe each other roles from their own perspectives. Discussions also touched upon the coordination needs and challenges identified by them in relation to their work practices and the public health infrastructure. Following on this, participants discussed the process of exchanging information (or lack of it) between them and the healthcare system (see Figure 2-right), and the socio-technical artefacts involved in their work practices (see Figure 2-left).

3.3.4 S5: A Visit to the Taluk Health Center and Additional Data. Under the PMSMA scheme, a camp is organized at the Taluk Health Center (THC) on the 9th of every month. This was taken as an opportunity to visit the hospital and observe additional community interactions. Notes and observations were taken during the visit around the sequence of events, conversations, and visitors and their interaction with the system and we again used sketching and mapping activities to visualize these accounts. Consent was taken from the doctor and the staff. In addition, we interviewed two ASHA workers, a pregnant woman, and a family member of the pregnant women at the hospital, that helped us to corroborate findings and enabled us to continue exploring health services at the THC, and the practices and existing perceptions between frontline health workers and the community.

3.3.5 Secondary Data from an Interview study with Community Households. As part of the main project, we also engaged with 27 households (19 pregnant women and 8 young nursing mothers) through an interview study investigating the everyday challenges of women and caregivers in pregnancy care in the same rural (12 households) and semi-urban (15 households) areas of Channapatna. The HNs served as key informants during the project and helped us to identify the households as part of their data collection practices during household visits. In this paper, we only draw on data from this study that highlights the interactions and challenges between the households and frontline health workers. A detailed description of the interview study with households on everyday challenges of Indian women in pregnancy care is outside the scope of this paper and will be reported separately. Household visits and the semi-structured interviews lasted for about 45 minutes to one hour and were conducted in Urdu and Kannada. These interviews were also aided by sketching and mapping activities (a day in the life and the pregnancy journey). For this study, we only draw

on data coming from the pregnancy journey (see Figure 3) as this activity clearly shows navigation and mobility challenges interacting with public and private healthcare services, perceived roles of frontline health workers, and public health schemes in practice.

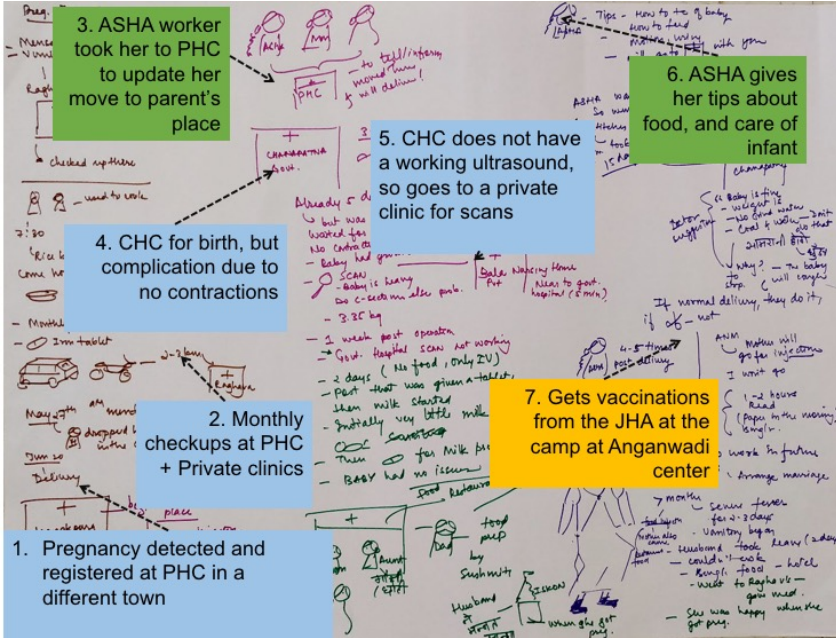


Fig. 3. A woman’s pregnancy journey and interactions with the healthcare infrastructure.

3.4 Data Analysis

Four researchers (three local and one international) participated in the analysis. The recordings were transcribed, translated from Hindi/Kannada to English and combined with the notes for an inductive thematic analysis [25]. We started familiarizing ourselves with the collected material, and then conducted two separate rounds (2 researchers in each round) before we merged the analysis. We iteratively reviewed the transcripts and generated materials (e.g., sketches) to identify emerging themes making constant comparison among the two teams. Initial examples of coding were “registering on the MCTS system”, “overlapping roles shaping working relationships”, “the complexity of high-risk pregnancies”, “lack of financial incentives”. An important consideration was to identify the invisible work that supports frontline health work, everyday challenges and interactions within the healthcare infrastructure as we continued discussing, revisiting and grouping data into themes. We re-arranged overarching themes, and these were further informed and contextualized by frontline health workers participating in the project and the local team of researchers using storyboards (see Figure 4). All members of the research team provided feedback on the final themes.

4 FINDINGS: INVISIBLE WORK OF MAINTENANCE IN COMMUNITY HEALTH

In contrast to previous CSCW and HCI research in community health in India that has studied a particular type of frontline health workers (i.e., ASHAs) [35, 54–56, 137] and community volunteers [67, 90, 93], we encountered a network of human infrastructure (ASHAs, JHAs, AWWs, HNs) as the

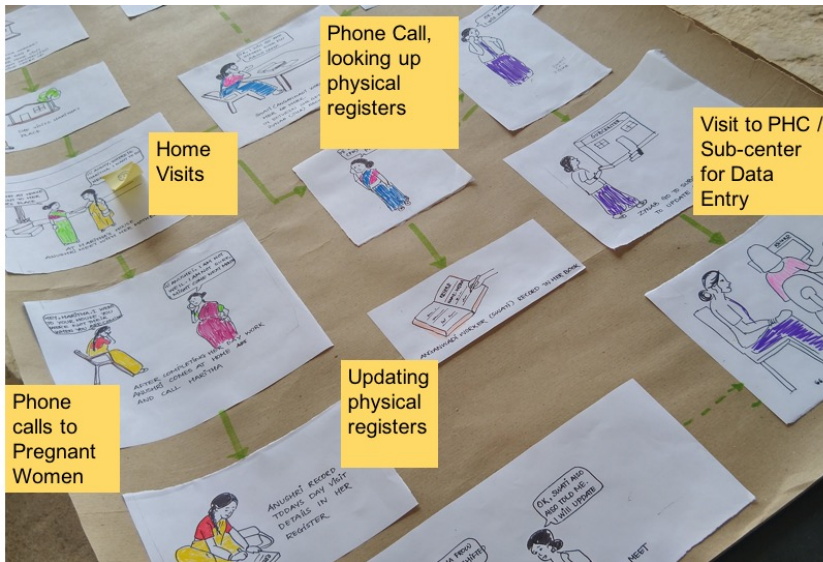


Fig. 4. A storyboard of the different touch-points from a pregnant woman interacting with the human infrastructure in community health throughout her pregnancy journey.

social system [108] supporting frontline health work. Our findings show how these multiple types of frontline workers faced numerous challenges in carrying out their work due to their overlapping job roles, low financial incentives, information and communication breakdowns and the invisible efforts they undertook to make community health infrastructures work. These efforts maintaining community health infrastructures often remain invisible, and their voices are “largely unheard” [88], for both, the ministries and governmental agencies of public health, as well as design and policy initiatives. In the following, we present the invisible work of maintenance that frontline health workers undertake beyond their prescribed job responsibilities dealing with everyday challenges while caring for their communities, their social work/home relationships and for themselves.

4.1 Making Care Infrastructure Work through different Maintenance Practices

Frontline health workers spent a lot of their efforts dealing with distributed and fragmented data infrastructures, while anticipating and upkeeping the ad-hoc nature of caring for pregnant women.

4.1.1 Maintaining Data Infrastructures: Inputting, Translating, Mending, Repairing, Reconciling. AWWs or ASHA workers or both, based on who is active in a particular locality, conduct periodic surveys of households in their designated areas and collect a set of basic information usually for the public health system at the state or national level, linked to disease prevention and surveillance. Information collected through the surveys by the JHAs and ASHA workers are entered onto the MCTS digital portal by data-entry personnel at the PHC. However, digital data entry adds to the labor of the frontline health workers as they have to either wait for the data-entry personnel to do it on their time, or find extra time to do it on their own, which is not part of their job roles.

“If we give this month’s data, it’ll be entered only in the next month. But if we complain about it, it will appear as if we are gossiping. Since the past two years I have entered the data myself rather than giving it to them. I store the MCTS data on my phone [taking images of field notes from ‘daily diaries’ used during field visits]. Weekly or monthly,

whenever I'm free I go and enter data and finish the work. I don't leave it [the work] for them [data entry personnel], I manage everything myself." – JHA (S3JH6)

Inputting data as a workaround (data entry to the digital portal by themselves) adds extra work to frontline health workers that is very time-consuming with limited resources to support them. For example, the same JHA (S3JH6) further mentioned how, data entry is *"too heavy [a burden]. We can't even sit whenever we want and enter the data [due to shortage of computers and hectic field work]. Even when we find time, we get tired just after 10 minutes"*. This example highlights the complexity of data work [15, 79] in community health [55] as tiring work bringing attention to the lack of social and material arrangements (data entry personnel delaying registration, not enough computers with Internet) to maintain community care infrastructures.

Additional language barriers make the situation more complex. In contrast to Hindi-speaking north India where a study reported that ASHAs recorded data in Hindi or English [55], in the Southern states data is captured in the language of the state which then has to be translated to English during digital data entry. Our study shows how frontline health workers collected data in Kannada that added some extra work.

"Entering data into the computer is difficult because everything is in English, but everyone here has studied in Kannada medium. We know a little bit so we guess, estimate and fill in information. If the application enables us to enter data in Kannada, one can always ask for help and fill in. But data entry is complicated. These people in the government [people who design and build the MCTS portal] are also little complicated." – JHA (S3JH6)

This example shows how frontline health workers engage in translation work which is not a simple or straightforward task as *translating* is a situated practice [149] that involves many different tasks (e.g., editing, correcting, making guesses) to fill in the data. Frontline health workers also do extra work while mending the gaps in the MCTS system due to missing information or losing Thai cards. A 'Thai Card' is a "comprehensive mother and child registration booklet" used as a "person-centered" artifact to document, track and promote care services for pregnant women, young mothers and infants [29]. Losing these cards not only mean pregnant women stop having financial benefits (e.g., through coupons attached to the card), but also frontline health workers missing out on entering their information into the MCTS system. Frontline health workers revealed a number of strategies to mend these gaps aiming to restore the working order. These strategies included making copies of Thai cards and giving them to pregnant women who have lost their cards, replacing the unique numbers on the cards using 'whiteners' and rewriting on it the assigned number. While photocopied cards cannot be used to avail financial benefits, they helped collecting and restoring data for the MCTS system as a temporal patchwork for material losses.

Repairing information breakdowns also add extra work especially when multiple actors are involved. For example, an ASHA worker needs to be present for every meeting and community visits done by doctors or JHAs (e.g., during immunizations camps). However, we found that many ASHA workers were informed quite late (on the previous evening). An ASHA worker (S4A5) stated, *"We have to attend the camps [at Anganwadi center] or be there whenever the doctor comes for a visit. But we usually don't get to know when they will come, and we get a call just before they visit."* Even though camps are planned in advance, unanticipated changes can occur in the schedules of the doctor or JHAs. ASHA workers discussed that they could not accommodate last minute camps or visits as they would have to shift their focus away from their planned and committed care tasks e.g., home visits, counselling. As a result, camps or visits did not reach many people as the community might not have been able to attend due to a short notice.

While the JHA and ASHA workers have access to a data entry portal, the Anganwadi workers did not have any access as they belong to the MWCD. AWWs maintain their data in a physical

book/register named as ‘Record of Services offered for Pregnant Women and Nursing Mothers’. This record is kept at the Anganwadi center, which is a physical place, or ‘courtyard’, for rural childcare (see Figure 1). In this case, updating physical registers also added extra work to their daily routines. In particular, the movement of pregnant women to their parents’ homes leads to variance in data increasing the risk of “data breakages” [94] and requiring data reconciliation.

“We keep removing and adding pregnant women from our lists depending on newcomers or the ones who have moved [to their mother’s house]. Because of that a difference [in information] shows up ‘here and there’. I have to record an entry even if someone [a pregnant woman] is coming here [in that locality] just for a while.” – AWW (S4AW6)

Reconciling data in physical and digital registers are important as for example tracking relocations would help delivering services (e.g., nutritional food, vaccinations, etc.) to the right people. However, maintaining multiple data-registers make this work more complex. AWWs and JHAs maintain physical registers individually with about 25-35 data entry columns. While a JHA (S3JH6) explained that they “write down only the things that are required” in their physical registers, an ASHA worker (S2A1) questioned the relevance of this data as “data just goes into the system and no action is taken upon it by the government”. The overlap in data recording not only leads to duplicated efforts but also affects data accuracy and completeness of the data [54].

4.1.2 Anticipating and Upkeeping Ad-hoc Care Activities for their Communities. Our study brought forward multiple instances of the frontline health workers turning the data collection practices into opportunities to perform other care-related activities, anticipating and planning for ad-hoc care demands. Anticipation helps with figuring out what actions to take in time [3] as these practices are “employed to navigate daily life and to sustain relations, the practices which are at the heart of social transformation long before we are able to name it as such” [91]. One such instance is how frontline health workers piggybacked on the activity of conducting disease surveys to also get a sense of the pregnant women and anticipate their health and wellbeing needs and associated risks.

“When I conduct a Larva survey [survey conducted to map the spread of Dengue and Malaria mosquitos], I collect information about pregnancy care. I cannot specifically visit over and over again for a single purpose. Once we go to a household, we see everything. It could be what is in their fridge, how they cook, about drinking water usage, about their growth patterns. If there is a pregnant woman in the house we check about their nutritional and food, and about their decisions/preparedness for the delivery. We counsel them about the facilities that are available, about the tests that need to be done in the PHC monthly. If it is a case of high-risk pregnancy, we advise them when they should come to the hospital for the camp. If it is a nursing mother, we talk about feeding practices, about the baby’s cleanliness, baby’s sleeping patterns, how they should look after that baby, and so on. This way if we go to one house, we collect all these details and write it down.” – JHA (S5JH6)

ASHAs and AWWs workers conduct what is called a ‘line-listing’ of pregnant women with the purpose of registering them into the MCTS system and disburse the Thai card. The line-listing is reconfigured as a practice that enables not only data collection about pregnant women in the locality, but also for ‘reaching out’ to provide other care activities.

“First, we [ASHAs] go for household visits and see if there are any pregnant ladies and tell them to apply for Thai card... When we do this, we also tell them to do a UPT [Urine Pregnancy Test], by offering the test kits we have. If they are willing, we do the test at home with it. If not, we take them [to PHC] and get it done.” – ASHA (S4A5)

Anticipatory work also took place when a JHA (S3JH6) reconfigured home visits based on the density of population aiming to perform complementary tasks: “I work with four Anganwadi workers.

Monday to Thursday, I go to one area each day. The rest two days, I dedicate my time to visit places which have a higher population.” Frontline health workers perform anticipatory work that helps foreseeing needs, demands, risks and respond accordingly. Such practices of anticipation enable the frontline health workers to become aware of any potential health issues in their localities, decide a proper preventive course of action (e.g., blood or urine test, counselling, etc.). They even make sure the action is carried out by taking women to the PHC for consultation. However, these anticipatory practices are not enough for ad-hoc demands where frontline health workers have to do extra work that is often stressful. One particular situation is managing high-risk pregnancies (e.g., women older than 35 years, high or low weight, diabetes, hyperthyroidism, prior pregnancies with c-section births, low hemoglobin levels, etc.). Pregnancy complications involve women’s physical, social and emotional labor when seeking clinical help, needing extra support from frontline health workers. A JHA mentioned, *“they [ASHA workers] will know what to expect in complicated situations and based on their experience they suggest solutions”* (S3JH6).

Managing ad-hoc situations often requires frontline health workers to accompany pregnant women aiming to mend the gaps in the healthcare infrastructure and make the journey of the pregnant women smoother. A recent survey study in the northern state of Uttar Pradesh shows that ASHAs spent a large amount of their time accompanying women for delivery or checkups [117]. In our study, we found that ASHAs, JHAs and AWWs would accompany pregnant women to the healthcare facilities especially in case of an emergency. An ASHA (S2A1) stated *“during emergencies, when doctors are not available at government facilities, like in the evenings, we [ASHAs and/or JHAs] decide to go to Mandya hospital [the district level tertiary hospital] with the patients.”* While it is mostly the ASHAs and JHAs who accompany the pregnant women, in occasions where an ASHA worker is not present or active in a locality, an AWW would do this extra task, *“If someone comes and says there’s nobody [to go with them] then I go with them to the hospital visit”* (S4AW6). Such ad-hoc demand requires quick working out of alternative arrangements facilitated by their experience, availability of resources, and how well networked they are in the local area. However, it is not always possible to create and sustain alternative arrangements resulting in unintended consequences as commented by an ASHA worker (S4A5).

“There was one case where I had taken a woman for delivery; it was a c-section case at the Channapatna hospital [THC]. That day however the sister [JHA] was not there, otherwise probably she could have managed things. The pregnant woman’s blood pressure had gone high because of which we had to go to Mandya [to the district tertiary hospital, as per doctor’s recommendation at the THC]. We had to stay in Mandya for 3 days. I couldn’t locate the sister [JHA] at that time and the high blood pressure of the pregnant woman was difficult to manage.” – ASHA (S4A5)

Ad-hoc demands managing high-risk pregnancies together with the lack of human infrastructure as the JHA was on leave without a substitute for the day. The lack of resources to treat high blood pressure at the THC, make the situation more complex adding extra ‘unplanned’ work to the ASHA worker leaving behind their own families for days.

4.2 Maintaining Relationships

Frontline health workers performed extra work while navigating social relations and caring for their communities. Firstly, they had to work out their inter-relationships among the situated human infrastructure (JHAs, ASHAs and AWWs) to support work coordination and create a support network for each other. Secondly, frontline workers had to build relationships with the pregnant women and their families, often taking on roles of educators and mediators managing the values and perceptions the communities hold of them, and going beyond their prescribed job roles.

4.2.1 Reworking Inter-Network Relationships within the Human Infrastructure. Frontline health workers engage in extra work to make the network of human infrastructure come and act together while caring for the pregnant women and their families. The overlapping job responsibilities shape the working relation between frontline health workers as it is influenced by the existing power relations and norms. Aligned with [56], we observed that JHAs are perceived at a higher level in both urban and rural areas. For example, the JHA is the main contact point between clinical settings (PHC, THC) in the system (see Figure 1) and other frontline health workers (ASHAs and AWWs) follow their instructions. An ASHA (S4A5) stated, "*Sister [JHA] tells us everything so we don't make any mistakes*". This hierarchy was also perceived and accepted by the community as another ASHA worker (S4A1) stated, "*I ask the nurse [JHA] to speak to the husbands and convince them [for family planning and other sensitive issues]*".

Furthermore, the total absence of one of the frontline health workers in the area means not only a disruption in the unspoken power hierarchy but also that the other frontline health workers in the area have to share the extra workload. In areas where JHAs were not present we observed a change in the power relations as the ASHAs were in a dominating role over the AWWs even though they are both at the same lower level. In one of the focus group (S4) where the JHA was not present, we observed how the AWW (S4AW6) was looking for approval from the ASHA before replying to questions, while the ASHA worker sometimes cut off opinions of the AWW mid-sentence, bringing attention to the misalignment of stances and the need to reworking relationships [31]. We also observed that the position of the ASHA worker was left permanently unoccupied in some areas, which led to increase in the workload for AWWs and JHAs. In these cases, the role of the ASHAs was often taken up by JHAs directly (urban area: U5) or by the AWW who would coordinate with the JHA of the area (rural area: R2).

"I do Larva surveys and distribution of Oral Re-hydration Solution (ORS), which is ASHA worker's job. Also, motivate people to undergo sterilization procedure for family planning. Just because... [ASHA worker is not present] we cannot leave it [the care work]" – AWW (S3AW5)

In session S3, a JHA (S3JH6) also mentioned how she performed some of the jobs of the missing ASHA worker in her locality that she perceived to be of value for the wellbeing of the community, such as counselling and talking to households, and collecting data through surveys with the help of the AWW.

"We [JHA and AWW] speak over the phone and decide for so and so date for the immunization camp and announce it in the nearest mosque. Regarding surveys too she [AWW] helps if I don't know anything. In the beginning when I joined, she helped a lot, I did not know anything about the areas or have any contact with the pregnant women in the locality. She had only introduced me to everyone. Sometimes the pregnant women don't know the address to our hospital, then we call them here [Anganwadi center] and talk to them." – JHA (S3JH6)

Maintaining good interpersonal relations among the different frontline health workers is key to the social functioning of the human infrastructure. However, personal familiarities between two of the three frontline health workers within an area also led to breakdowns and frictions when they were unable to bring their stances into alignment. For example, in some areas the JHA was already well versed and in a good working relation with the Anganwadi worker and have established a communication channel without including the ASHA worker. An Anganwadi worker (S4AW6) mentioned, "*I call her [JHA] sometimes when any pregnant woman informs me that she is due for vaccination. She [JHA] calls me sometimes and asks me to go and check on someone [to the home]"* Although the Anganwadi worker supports the work of JHAs by reaching out to the community,

this communication bypasses the ASHA workers who are directly responsible for the home visits in these areas. We also found out that the introduction of a new actor brings potential resistance and frictions. A hierarchy about the division of labor emerged in session 4 when we discussed the possibility of having the privately operating Health Navigators (HNs) to support frontline work practices. While the ASHA worker (S4A5) was not positive and appeared reluctant to embrace the idea, mentioning “*we do all our work properly, there is no need for more [people]*”, the Anganwadi worker (S4AW6) seemed more positive and welcoming of this potential change.

“If she [HN- S4HN1] asks us how she can help us, we can suggest things to her. If she will listen to us, then we can tell her things to do. When she goes to houses [during the visits that HN does as part of her private community health work], she can help us to identify the pregnant women, and maybe also do the tests [UPT]” – AWW (S4AW6)

The frontline health workers’ perceptions about the value of offering free services versus paying for the same services often contribute to these frictions, challenging the working relations of the human infrastructure.

4.2.2 Reworking Roles to Manage Community Values and Perceptions. Our study also shows how personal values, expectations, and community perceptions shape the invisible work of frontline health workers who often take the roles of educators and mediators between the community and the healthcare infrastructure. Frontline health workers perceived that the Department of Health expects them to increase their workload to deal with the lack of personnel on the ground, and hence did not wish to officially complain about the extra work they do. A JHA (S3JH6) stated, “*No its not part of my job role, I don’t have to do the work they [ASHA] do. But we can’t say that to the health department, when they come to inspect.*” It was not just the ‘fear’ of an inspection, but her sense of responsibility, “*in doing so, I’m also helping the community.*” Another ASHA (S2A1) believed that the work she does for the community gives her ‘man ki shanti’ –peace of mind.

Our study shows how frontline health workers care about their communities through different acts of kindness, moral choices and taking-on extra caregiving tasks. A touching example is the case of an Anganwadi worker (S1AW1) who went beyond her responsibilities and engaged in restoration work [67] caring for a family affected with HIV in her locality. When a couple confided that they could be HIV positive, she took them to different hospitals in the nearest town for testing while maintaining their privacy. She separately accompanied their two young children and got them tested, and their tests came out negative. The AWW commented “*I had to hide this trip from the community, as there is a strong stigma attached with HIV, and people get shocked that children also have to be tested*”. After the couple passed away, the AWW applied for their death certificates, registered the children under an educational scholarship scheme, and continues to help and look after the children as she “*has a strong desire to do something for those children*”.

Frontline health workers are social actors working within community systems [117, 138] and their extra caregiving tasks are shaped not only by their personal values and motivation to do their jobs, but also to gain prominence and receive appreciation and respect by the community, beyond their salary and monetary incentives.

“We are not doing it for money. But for the respect they [the community] give us. We do our work thinking that we are doing good for somebody, we get peace of mind due to it. They respect us... Not as much as doctors but in our areas, we have more respect.” – ASHA (S2A1)

This ASHA worker previously engaged with the community as a HN. We found a tension between the HNs who charge a nominal fee for home-based services of blood sugar monitoring, and the ASHAs who do not charge money but get incentives from the government. The ASHAs perceived

to have a higher status and respect in the community than HNs, as they offer 'free' services to the community, while HNs charge a nominal subscription fee.

The acts of care that go beyond the prescribed job roles and incentive structures also shape the perception of the frontline health workers in the community helping to establish more familiarity and trust between the actors. Even so, frontline health workers often had to deal with these relational dynamics by building trust in often controversial moments of care. For example, there were rumors in a particular community that the vaccines provided by the government should not be trusted and that the frontline workers were using infected needles. To allay the anxieties and mistrust due to such rumors the frontline workers spent a great deal of their time having multiple meetings with community leaders, demonstrating and explaining how the vaccines work.

4.3 Invisible Work for Maintaining Themselves

Frontline health workers (ASHAs and AWWs) perform extra work towards maintaining themselves, namely tracking their activities and actively seeking financial incentives, along with boundary work trying to balance work and life activities. The public health system works based on incentives for the ASHAs. To receive these incentives, ASHAs need to complete the data entry in the system as described above. To get the registrations done, ASHAs create additional socio-technical arrangements such as accompanying women to the hospital. However, these strategies are challenged by existing socioeconomic and cultural practices. Accompanying women to the THC for a sterilization procedure as part of family planning is one of the care tasks performed by the ASHAs getting 100 rupees for each procedure but spending more than half on public transport.

"We accompany the women [to the THC for the procedure] in the morning.... We get 50 rupees, if we do everything for the 'patient' and send them in the auto rickshaw back to their homes. And then when we go and get it [details about the procedure] entered in the data center, we get 50 rupees. And we spend almost 60 rupees to come and go from our homes sometimes [laughs]." – ASHA (S2A1)

Getting reimbursed for travel expenses involves submission of signed bills from transport providers (mostly informal auto rickshaws) and often the ASHAs don't bother to claim these costs due to the extra efforts involved in getting the invoices signed by the auto rickshaw driver. Sometimes they also pay for the transport of poor women, *"Not for all, we pay only for those who are really poor pregnant women"* (S2A1). This can lead to a loss of money for the ASHAs. We also found instances where ASHAs left their jobs due to non-payment of stipends and incentives for a period of more than a year. In session 2 when we asked the ASHAs why some areas did not have an active ASHA worker, one of them mentioned:

"They have left the job. ASHA workers who had joined with us have also left because money stopped coming. Not even a rupee had come in the first year of our service. Some people who did not want to put in efforts without benefits, left [the job]" – ASHA (S2A1)

In Karnataka, according to the National Health Mission each ASHA in rural areas gets 300 Indian rupees and each ASHA in urban areas gets 200 Indian rupees for every institutional delivery, which is one of the largest amounts of incentive. When a pregnant woman moves to another location (e.g., parent's home), the ASHA at the new location gets the benefit of this incentive, and the subsequent incentives are linked to post-birth vaccinations.

"That [movement of women] causes a lot of loss for us. From here we would have helped them to get vaccinations and other things [first two trimesters] but once they move, they utilize services from the [PHC] village they shifted to, and the incentives go to those ASHAs... We can't do anything about it, Thyai Card is on their [women] name only... The

ASHA there gets registered in the system [MCTS] as the ASHA for the pregnant woman, so they get the benefits for that and not me.” – ASHA (S4A5)

To track and secure her earned incentives, an ASHA expressed, *“We do our own line-listing. We have to keep our own records, so that I know how much incentives I am getting” (S2A2)*. The ASHAs maintain this record and use it to claim incentives at the THC after birth, as they must provide detailed data of the mother and child to receive incentives.

In addition, frontline health workers have to maintain personal boundaries, particularly to not let their care work affect their family life. The different acts of caring increases the community expectations leading to contradictory pressures on the frontline health workers. For example, frontline health workers accompanied some pregnant women without any monetary and family support to private clinics, and also provided counseling on the phones, beyond working hours, and sometimes late at night too. A JHA said that the pregnant women, *“call them [JHA] saying that they are having pain and ask them where they should go. In those times, I guide them over a call” (S3JH6)*. A phone call also enables the community to reach out for help anytime as, *“We would have told them [pregnant women] to call when they are having any trouble”* and in cases of emergency such as, *“their water broke or if they feel pain in the night, they call us.”* Calls are also used to provide counselling to pregnant women and household members.

“For the people who don’t know how to read or the ones who don’t have time to read, I have given counsel over the phone and asked them to look for things on the mobile. I tell them there is a lot of information about healthcare on the phone itself so look it up.” – AWW (S4AW6)

However, constant availability on the phone is difficult to maintain as frontline health workers also have their families and social life. To maintain the social order across different social worlds, frontline health workers engaged in boundary work [1] and developed strategies to manage the intersection of the social worlds (home and work) and the community expectations about their availability. For example, a JHA (S1JH1) used two phones, one is a feature phone that she brings to the field during community visits only for calls, and a smartphone at home for WhatsApp messaging and social media apps to communicate and interact with family and friends. After a couple of incidents being disturbed late at night by women and their families who video-called on WhatsApp, the JHA now only shares her feature phone number, as she considers it is less intrusive for offering advice rather than receiving video calls outside working hours.

5 DISCUSSION: TOWARDS MAINTENANCE-CENTERED DESIGN

Our study highlights key socio-technical elements (e.g., incentives, physical/digital data registers, transportation, mobile phones, MTCS system, etc.) that shape the everyday experiences of frontline health workers and call for attention to the invisible work of maintenance that sustain community health infrastructures. Given the current trend to address public health challenges through digital health [89] and the increasing focus on data-driven approaches [15, 24, 79, 90], our study shows how existing technologies [35, 90, 137] do not fully support frontline health work in community health. Our study extends existing research investigating the invisible work and the human infrastructure that is highly intertwined with the heterogeneous elements of community health infrastructures, and still remain poorly understood in CSCW and HCI research in community health [67, 93].

5.1 Making Maintenance Practices Visible Enough for Legitimation

Our study unpacks the invisible work that frontline health workers do through a number of maintenance practices by mending, repairing, anticipating, adapting, creating and shaping different infrastructural arrangements across multiple human and non-human entities including people

(e.g., the community, AWWs, HNs, ASHAs, JHAs), places (e.g., households, Anganwadi centres, PHC, THC), and physical and digital resources (e.g., Thai Card, MCTS, physical registers, mobile phones). Our study shows how frontline health workers took additional responsibilities on top of their job requirements and made adjustments according to the local circumstances through for example anticipating practices [3] by lobbying pregnant women or distributing tasks among other frontline health workers. Even though frontline health workers were aware that they were doing work that goes beyond their job description, they were ‘okay’ rendering visible caring [73, 106] as a shared value, where maintenance in community health means caring not only for things [104] but also of the people, the community and the overall care infrastructure [34, 37, 73, 108].

To maintain the material and social order, frontline health workers engage in invisible repair work by “re-ordering people and their assumptions about a work setting” [50]. Frontline health workers spent a lot of time inputting, mending, translating and reconciling multiple data registers outside working hours that are not logged, auto rickshaw rides that are not compensated, efforts rearranging visits and calls to help women navigate across private and public services.

Making these maintenance practices more visible [127] will bring them to the front stage [128] and at the centre of community health. While mobile technology can help frontline health workers to establish legitimacy within their communities [98] and the healthcare system [56], it can also offer opportunities to support the invisible work of maintenance. For example, a mobile platform could be designed to enhance rickshaw local services to issue digital receipts that can help frontline health workers to claim back their expenses, or an app to help them track and reflect on the work they do beyond job’s descriptions. Future research can investigate data integration practices [15] across multiple socio-technical systems in community health and the design of technologies to aid frontline health workers maintaining data infrastructures (inputting, translating, mending, repairing, reconciling) beyond data collection [90].

While rendering maintenance work more visible it redirects attention to different forms of articulation work to support the material and social order in community health, and design should pay special attention to the negotiation of visibility as “not all work must be made visible” [122]. For example, tracking benefits or any maintenance practice that might cause distress should be visible to frontline health workers to help them regain control over their own accountability. Designing for maintainability requires making maintenance practices just visible enough for legitimation while keeping discretion to avoid unwanted surveillance [119] and flexibility to support the ad hoc nature of articulation work [41] across multiple frontline health workers in community settings. In addition, design efforts could also focus on enabling frontline health workers to collectively negotiate their roles and responsibilities with the government drawing inspiration from Turkopticon [53].

5.2 Reconciling Multiple Perspectives, Values and Expectations

Our empirical account of the maintenance work brings attention to the multiple perspectives, values and interdependences between people, systems and sociocultural practices that might enable or inhibit how care infrastructures work. Aligned with [56], our study shows how the JHAs are recognized as having a high social status within the community and the human infrastructure rendering their maintenance practices more visible, while ASHAs, AWWs, and HNs tend to lean to a lower status. When conflicts arise due to differences in social status, values, and expectations [122], frontline health workers coped with unforeseen changes through tacit agreements influenced by the social status as well as establishing different communication channels using mobile phones.

In particular, AWWs were always ready to follow instructions from the JHAs and the ASHAs even though their work belongs to a different minister. Similar to health care managers [87], frontline health workers perform visible and less visible maintenance work dealing with conflicts by making or adapting compromises, what Jagd has named as “justification work” [58], as compromises need

to be “created, solidified, and justified” [87]. For instance, JHAs and AWWs took extra work to compensate for not having an ASHA worker in her area taking extra responsibilities, or staying longer time performing data entry, or deciding to give their phone numbers to pregnant women or even paying for women’s transport.

In cases of conflicting perspectives such as dominating stances or too restrictive arrangements, the values and expectations from multiple stakeholders in community health must be reconciled and articulated [31, 43]. Reconciling infrastructural incompatibilities would require an equitable negotiation of conflicts [48] by promoting a flexible and fair division of labour [31] among frontline health workers. An intrinsic part of the reconciliation process that keeps frontline health workers functioning is without doubt the emotional labour to manage the distributed nature of maintenance practices “as an expression of care” [106]. Caring for their communities requires balancing and managing “reactions to conflicts” [48] with themselves to avoid stress and burnout and with others to avoid missing camps, consultations, or women’s deterioration of health. One way to deal with conflicts could be through the use of the Anganwadi centre to bring frontline health workers (public and private) to collectively discuss and produce constructive compromises [87] to help cultivate the social support system through different socio-material modes of togetherness [36]. Here, technology can also offer opportunities to support conflict management, motivation and confidence building, and emotional management [72].

5.3 The Need for Coordination Mechanisms in Community Health

Our study shows how maintenance practices are challenged by the distribution and heterogeneity of the human infrastructure where information exchange is often not formalized increasing the complexity of articulation work [41] in community health. The articulation undertaken through maintenance practices in community health often show an unpredictable flow of activities that require ad hoc decision-making, planning and coordination and even workarounds (e.g., inputting data to the digital portal) to keep the material and social order across different social worlds.

In our study it became evident that frontline health workers lacked tools to help them manage unforeseen changes to make adjustments to their daily schedules and to support coordination, except for the way they used the mobile phone. Mobile phones acted as an infrastructural entity [24, 139] supporting ad-hoc and in-situ coordination and information exchange regarding meetings, camps, or emergency situations helping frontline health workers to quickly create and shape arrangements. In some occasions, a number of cross-boundary communication and information breakdowns took place when frontline health workers were not able to achieve awareness of the work or their fellows, leaving some frontline health workers waiting for days or even left out from the communication exchange. Thus, there is a need to support the social, temporal and spatial awareness of maintenance work practices to re-establish the ordering of information and practices to prevent and deal with infrastructural misalignments in community health [139].

While the Thai Card provides an overview of the pregnancy journey including women’s interactions with public and private healthcare services acting not only as an infrastructural artefact [139] but also as a potential boundary object [22, 43], it has not reached its overall potential in practice. There are opportunities to reimagine the Thai card as a coordination mechanism [111] to facilitate the exchange of information within and beyond the boundaries of women’s home. For example, it can register the names of the frontline health workers that have provided health services so that this information can be still available even after the relocation of pregnant women to avoid for example the loss of incentives.

To manage boundary work at the intersections of different social worlds between home and work and avoid last minute calls, would require support for scheduling and time-management skills [31, 43, 48]. To complement WhatsApp chats, shared calendars [18] can also be explored to support

the scheduling and coordination of community health activities among the different frontline health workers and even with the communities. To avoid misalignments and cross-boundary breakdowns, a good alternative to explore is expanding the use of context-mediated social awareness [11] from the hospital to community health settings. One way to achieve this is by designing mobile shared workspaces to support frontline health workers with on-demand context-aware information [84]. On-demand collaboration needs an awareness of user's reachability [74] and caching and synchronization mechanisms [142] to support synchronous and asynchronous planning and work coordination, enabling frontline health workers to decide when and with whom to share information. Also, Anganwadi centres can provide Internet connectivity so support synchronization periodically when frontline health workers gather together at the centre.

5.4 From Maintainers to System Builders

Our findings clearly show the essential role of frontline health workers as maintainers [73] dealing with the disparities of community health infrastructures, going beyond promoting health towards maintaining data infrastructures (inputting, translating, mending, repairing, reconciling), sustaining relationships within the network of frontline health workers and within the community through different acts of caring or anticipating and upkeeping ad-hoc care activities (e.g., accompanying women, paying for transport, etc.). In both the Global North and South, the role of the maintainers has been undervalued and often overlooked as they are "seen only as the people who carry out the repairs—not very much thought is given to all the work it takes to keep everything running" [38]. Over the years many technologies for community health have been designed to support the roles of educators and mediators of care services focusing on training and work performance [9, 35, 40, 62, 137, 141]. However, these have often overlooked the essential role of frontline health workers as the "link between social and material forms of order" [50] in community health.

To enact the educator and mediator roles and perform routine work, frontline health workers engage in maintenance practices and ongoing negotiations to reconfigure and reestablish the social and material order across multiple heterogeneous elements (human and non-human) of care infrastructures. Aligned with current efforts to reimagine the role of the maintainers [38, 73, 105], we find Law's notion of "system builders" [68] to be appealing to describe the maintenance and caring efforts of frontline health workers. For example, a fundamental problem of system builders is "how to juxtapose and relate heterogeneous elements together such that they stay in place and are not disassociated by other actors in the environment in the course of the inevitable struggles—whether these are social or physical or some mix of the two" [68]. This characterizes exactly the everyday efforts of frontline health workers adapting and reshaping heterogeneous and distributed arrangements of care infrastructures through their bodies [50] by negotiating different stakeholder's needs, norms, expectations and sociomaterial arrangements in context.

Previous research in healthcare has used the notion of "heterogeneous engineer" [103], a type of system builders [68], to call for attention to the active role of users negotiating multiple perspectives while designing sustainable information systems in healthcare [103]. Conceptualizing frontline health workers as system builders can help provide a "new image" [38], establish legitimacy [56] and raise their profile recognizing their maintenance practices and caring efforts bringing these nuances to the front stage of design rather than being in the background. As such, the role of frontline health workers should be seen as performative [103] and acted out and highly influenced by the sociocultural context and the network of infrastructural arrangements, rather than being considered only as infomediaries and intermediaries of health services [54]. Designing interventions in community health should recognize and value the crucial role of frontline health workers as system builders to promote their active participation throughout the design process [51].

5.5 Limitations

One of the main limitations of our study is the class and caste positionality of the research team and the participants. The members of the research team in India belong to an upper-middle socio-economic class and belong to caste communities that are deemed ‘upper’ (dominant castes) in the socio-cultural hierarchy that pervades India. This position has shaped the way we framed the study and the analysis of the data. As a way to reconcile with the privileges of the research team, we engaged with community stakeholders both the frontline health workers and pregnant women earlier in the research framing and analysis processes [8]. However, it is challenging to explicitly conduct a caste-based recruitment of study participants, particularly when the study is led by researchers belonging to the dominant castes. Nonetheless, we followed the best practices to continuously involve frontline health workers in iterative feedback loops to validate the data and its interpretation with the help of our local collaborator MAYA Health. Some of the collaborators from MAYA belong to the oppressed castes but this was not brought up in the planning and carrying out of the study, as caste is not explicitly talked about and yet operates as part of everyday life routines across India. Caste is a complex concept that influences public health in India in multiple ways [76], yet how it influences frontline health work needs further investigation [59, 117, 138].

While a recent study shows how ASHAs from a lower caste might have restricted access to households [117], another study shows no relationship or effect of caste in relation to the ASHAs home visits [113]. Another recent study shows that low caste AWWs spent less time on feeding and paper register work than higher caste AWWs but are more likely to spend the expected amount of time doing home visits than general caste AWWs [59]. Working with MAYA, we are currently in the process of sharing the research findings with the communities within the area of our study in a form and language that is relevant and appropriate. Our future work includes understanding how caste dynamics influence frontline health work as well as co-designing digital health technologies to support the work of maintenance in community health.

6 CONCLUSION

In this paper, we investigated the everyday challenges, experiences and invisible work practices that frontline health workers do to support and maintain community health infrastructures. Through the notion of maintenance and articulation work, our study calls for attention to the social and material dimensions of maintenance practices highlighting the vital and crucial role of frontline health workers not only as maintainers but also as system builders of community health infrastructures. For instance, ASHAs and AWWs are currently involved in the door-to-door surveillance and contact tracing of Covid-19 as part of the Indian state’s response to the pandemic [14]. However, these unprecedented circumstances have also brought to the fore the unfulfilled demands (e.g., low salaries, reductions and payment of work-related travels) of ASHA workers and the fragility of the public healthcare system [14, 102]. We discussed how understanding the visibility and invisibility of maintenance work practices and reconciling multiple perspectives, values and expectations in community health are crucial to inform the development of policies, tools and interventions to support frontline health workers. In particular, our study calls for attention to the need of coordination mechanisms in community health settings and suggest moving towards maintenance-centered design as a strategy to identify opportunities for technology design by giving careful consideration to the socio-technical elements that shape maintenance work in practice.

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