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Diagnosing the Health of Digital Health: Development and Validation of a Fast and Frugal Tree (FFT) Decision Tool for Public Health Supervisors in Low-Resource Settings

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Abstract

Background/Objectives: Achieving Universal Health Coverage (UHC) and Sustainable Development Goal 3 in low-resource settings relies on integrating digital health systems. In India, digital health tools have expanded rapidly, yet block-level supervisors and community health workers (CHWs) continue to face "last-mile" implementation barriers. This study aimed to develop, and expert validate a user-centric Fast and Frugal Tree (FFT) decision-support tool enabling block-level public health supervisors to identify and resolve operational bottlenecks in digital health delivery. **Methods:** A mixed-methods study in an aspirational district with a low Human Development Index) Muzaffarpur, Bihar, included a baseline survey (n = 95 CHWs), 32 in-depth interviews, and six focus group discussions. Thematic analysis identified key operational and behavioral challenges. A 10-step FFT tool was designed and validated through a two-round modified Delphi process with 14 experts. **Results:** Fieldwork revealed critical deficits in device functionality, connectivity, digital literacy, and grievance redressal systems. The FFT tool maps these bottlenecks to clear, actionable steps. The Delphi consensus exceeded 90% for clarity, relevance, and completeness. The final tool achieved an overall mean Content Validity Index (CVI) of 0.90, with item-level CVI (I-CVI) scores ranging from 0.79 to 1.00 across domains such as clarity, relevance, completeness, practicality, and scalability, indicating strong and consistent expert agreement. Iterative refinement ensured contextual adaptability and field readiness. **Conclusions:** The validated FFT tool bridges research and practice by offering a scalable, pragmatic protocol for digital health supervision. Its adoption could improve troubleshooting, data quality, and health system performance in similar low-resource settings.

Keywords: digital health; decision-support tool; Fast and Frugal Tree; public health supervision; community health workers; program implementation; content validation; low-resource settings; block-level supervision; India

1. Introduction

Digital health is increasingly recognized as a critical enabler in the pursuit of Universal Health Coverage (UHC) and the Sustainable Development Goals (SDGs) in low- and middle-income countries (LMICs)[1–3]. In India, national policy reforms have emphasized the expansion of digital platforms, electronic health records, telemedicine, and mobile health (mHealth) applications to address persistent challenges in access, quality, and equity of health services[4,5]. Examples include the Ayushman Bharat Digital Mission and the Digital India campaign, which have sought to accelerate the integration of digital solutions throughout the health system[6,7]. Despite such efforts, substantial barriers remain, especially at the last mile, especially in districts with low resource settings where digital health strategies must be translated into meaningful improvements for underserved populations [8–10].

Aspirational districts represent India's most challenging health and development environments. Identified by NITI Aayog as regions lagging in composite indicators of health, nutrition, education, financial inclusion, and infrastructure, leading to a poor human development index (HDI)[10]. These districts have been identified as the 112 worst-performing districts across 26 states of India and receive targeted policy and programmatic attention from both national and state governments[9,10]. Muzaffarpur district in Bihar state of India, for example, is characterized by high population density, and it is also the district with the highest population among all 112 aspirational districts, recurrent natural disasters, and entrenched poverty along with poor healthcare facilities and frequent epidemic outbreaks with the yearly outbreak of acute encephalitis syndrome (AES) the district remains in news for the death young children almost every year[10–12]. According to the National Family Health Survey-5 (NFHS-5), Muzaffarpur continues to experience stunting rates above 42 percent among children under five and anemia prevalence exceeding 66 percent in women of reproductive age, reflecting persistent health inequities and the need for innovative, scalable solutions [13].

At the community level, India relies on a vast workforce of community health workers (CHWs), including Accredited Social Health Activists (ASHAs), Auxiliary Nurse Midwives (ANMs), and Anganwadi Workers (AWWs)[14]. These frontline workers are the backbone of maternal and child health, nutrition, immunization, and surveillance programs, especially in remote or resource-limited regions [14,15]. The adoption of digital health tools by CHWs has shown promise for improving service coverage, enhancing data quality, and supporting real-time decision-making [16–18]. However, field reports and published research consistently highlight a range of barriers that limit the effectiveness and sustainability of these digital interventions[19,20].

Major challenges include unreliable or outdated devices, intermittent network connectivity, limited digital literacy, and inconsistent access to technical support[10,11,20–22]. Many CHWs are required to maintain both digital and paper-based records, increasing workload and sometimes leading to data inconsistencies [16,23,24]. Further, the rollout of multiple digital applications and other mHealth platforms often leads to confusion, burnout, and reporting duplication among the field-level public health workforce[25,26].

Block-level supervisors, such as Medical Officers in Charge (MOICs) and Child Development Project Officers (CDPOs), play a pivotal role in supporting and monitoring CHWs. However, frontline supervisors themselves report difficulties with fragmented digital platforms, parallel data systems, limited training, and resource constraints for troubleshooting digital health challenges in the field, along with the poor communication of the guidelines, becomes a tool to pass the ball to other departments, leading to programmatic failure of flagship programs on the ground [25,27–29]. There is robust and growing evidence that the effective and equitable implementation of public health programs, including digital health initiatives in contexts such as aspirational districts, depends on supportive supervision approaches characterized by mentorship, problem solving, and collaborative engagement rather than fault finding or punitive oversight. Additionally, the adoption of simplified and transparent field protocols such as decision trees and structured checklists has proven instrumental in guiding evidence-based practice, enhancing the consistency of service delivery, and bridging evidence to practice gaps in diverse and resource-constrained settings[30,31].

Global literature provides both optimism and caution. Systematic reviews suggest that digital health platforms can significantly improve service delivery, monitoring, and accountability when adapted to local context and backed by appropriate training and supervision[3,16,17]. However, poorly integrated or overly complex digital solutions risk undermining worker motivation and data quality, especially when user experience is not prioritized[18–20]. Studies underscore the necessity of user-centric, context-adapted digital health interventions for meaningful and sustainable impact in LMICs [1,16,32].

In this context, there is a recognized gap for practical, evidence-based decision-support tools that can empower supervisors and CHWs to rapidly identify and resolve digital health implementation barriers. Fast and Frugal Trees (FFTs) are a simple decision tree that has emerged as an effective decision-support protocol in healthcare, offering a sequence of clear, binary steps to guide users through troubleshooting in resource-limited setting[33]s. FFTs reduce cognitive burden and promote efficient problem-solving by focusing on actionable, context-specific decisions rather than complex algorithms or generic checklists. Evidence from other domains indicates that FFTs can enhance the quality, consistency, and usability of supervisory guidance, especially when informed by real-world experience and expert input[31,33–36].

Despite this potential, no validated FFT protocols exist for digital health program supervision in India, particularly in aspirational districts where operational constraints are severe and the need for adaptive, user-friendly tools is greatest. There is an urgent need for field-driven, expert-validated troubleshooting protocols that reflect the day-to-day realities of CHWs and supervisors in these contexts.

In response, this study developed, and an expert validated a Fast and Frugal Tree (FFT) decision-support tool to guide digital health supervision in Muzaffarpur, an aspirational district in Bihar. Drawing on quantitative surveys, qualitative interviews, and focus group discussions with CHWs and supervisors, and iterative validation with digital health and public health experts, this work aims to offer a pragmatic, scalable protocol that can strengthen digital health program implementation in low-resource settings.

2. Materials and Methods

2.1. Study Design

This secondary outcome-based sequential research focused on developing and externally validating a Fast and Frugal Tree (FFT) as a supervisory tool for digital health program implementation in resource-limited settings. The FFT was conceptualized based on empirical needs identified during a primary mixed-methods field study, but this manuscript centers on the protocol's design and validation as an independent outcome.

2.2. Ethical Approval and Data Sharing

All study procedures were approved by the Institutional Ethics Committee of Manipal Academy of Higher Education (IEC1:354/2022). Written informed consent was obtained from all field participants and expert panellists. Data were managed using encrypted, password-protected systems, with all identifiers removed before analysis. Aggregated, anonymized datasets and the FFT protocol are available on request for academic use.

2.3. Needs Identification: Brief Summary of Field Evidence

The FFT's development was grounded in field data collected in Muzaffarpur, Bihar, between May and December 2023. A stratified random sample survey of ninety-five community health workers (CHWs) and qualitative interviews with both CHWs and block-level officers systematically revealed major operational challenges in digital health implementation. Survey and interview guides explored digital device access, network reliability, digital skills, app usage, record-keeping, technical support, and supervisory practices. Qualitative data were coded in ATLAS.ti, confirming widespread issues with device attrition, unreliable connectivity, variable digital literacy, dual reporting burdens, inconsistent training, and delayed grievance redressal. Although these results are reported in detail elsewhere, their synthesis directly shaped the FFT's conceptual foundation.

2.4. FFT Tool Conceptualization and Drafting

Following thematic analysis of both quantitative and qualitative findings in early 2025, the need for a practical, field-adapted supervisory decision-support tool became clear. Drawing on cognitive decision science and digital health implementation literature, the FFT was designed as a sequential protocol, with each step mapped to a specific, empirically observed operational bottleneck. The initial draft included ten binary decision nodes, each paired with a suggested corrective action and escalation pathway. These nodes addressed key issues, including device functionality, network connectivity, digital app installation and training, user proficiency, motivation, data quality, technical troubleshooting, and grievance mechanisms. The internal review phase involved iterative discussions and revision among the research team and select field managers, improving the tool's clarity, flow, and feasibility.

2.5. External Expert Validation: Open Call and Delphi Process

2.5.1. Expert Recruitment: Open Call and Professional Outreach

Expert validation was conducted in June 2025 through a two-stage approach, beginning with an open call for expressions of interest. A Google Form invitation was disseminated through professional networks, targeted digital health groups, and LinkedIn. The invitation explained the FFT's background, purpose, and intended use for block-level managers and development partners in India's digital health programs. Criteria for participation included a minimum of three years' experience in digital health, mHealth, public health information systems, or block-level program implementation. Respondents were asked to indicate their experience, current position, geographic scope, area(s) of expertise, prior supervisory roles, and willingness to participate in the validation exercise. The form also allowed for the submission of a CV or LinkedIn profile and assured confidentiality in all subsequent research outputs.

From this open call, a panel of fourteen experts was selected for the full Delphi validation rounds. These experts represented block, district, divisional, state, and national levels, as well as NGOs, technical agencies, government, and international development organizations. All had hands-on experience with the operational realities of digital health program delivery.

2.5.2. Delphi Round 1: Structured Tool Review

In the first Delphi round, each expert received the draft FFT protocol along with a detailed background note summarizing the tool's design rationale and fieldwork origins. The review was facilitated through a structured online Google Form, in which experts were asked to evaluate each of the ten FFT steps and the overall tool across five validation domains: clarity, relevance, completeness, practicality, and logical sequence.

A five-point Likert scale was employed for each domain, ranging from one (strongly disagree) to five (strongly agree). The choice of a Likert scale, rather than a binary format, was informed by expert recommendations received during initial outreach, allowing for more nuanced differentiation of consensus and variability across a diverse panel. In addition to numeric ratings, experts provided open-ended feedback at both the tool and step level, including suggestions for new content, language revisions, sequence changes, or additional implementation guidance.

Consensus was defined a priori as seventy percent or greater of experts selecting "agree" or "strongly agree" (scores of four or five) for each domain of a given step or for the tool as a whole.

2.5.3. Feedback Synthesis and FFT Revision

Quantitative data from the first Delphi round were analyzed to calculate agreement percentages for each validation domain at both the step and overall tool levels. Qualitative feedback was systematically coded and thematically synthesized by two research team members, with primary themes including requests for clearer terminology, optimization of the step sequence, merging of training and proficiency checks, expanded guidance for technical and grievance procedures, and increased focus on motivation and data accuracy.

The FFT was revised to reflect this feedback, with language clarified, step order adjusted, and definitions sharpened. Compound questions were simplified where possible, and optional steps or branches that threatened the tool's frugality and field usability were excluded to maintain a focus on actionable, block-level decision support.

2.5.4. Delphi Round 2: Final Consensus Validation

The revised FFT and a summary of major changes were then distributed to the same fourteen experts for a second Delphi round, again facilitated by Google Forms. Experts were asked to repeat their ratings on the five-point Likert scale for all steps and domains and to offer further comments or suggestions. The tool and each step were again subject to the seventy percent consensus threshold for positive agreement.

2.5.5. Quantitative and Qualitative Validation Outcomes

The second round produced robust consensus across all domains. For the overall tool, clarity, relevance, completeness, practicality, and scalability each met or exceeded the seventy percent agreement benchmark, with especially strong consensus for relevance and clarity. Item-level content validity indices (I-CVI) and scale-level indices (S-CVI) confirmed these results quantitatively. Most previously critical feedback was resolved, and additional suggestions were considered for future adaptation. Only those recommendations compatible with the tool's field applicability and diagnostic focus were integrated.

2.6. Data Management, Coding, and Accessibility

All field and validation data were securely managed using Excel for quantitative survey results and Google Forms for Delphi panel feedback. All responses were de-identified prior to analysis, and only aggregate, anonymized results are available for dissemination. The Google Forms can be accessed upon reasonable request. The validation for the round one and round two Excel sheets is attached as a supplement.

2.7. Statement on Digital and Artificial Intelligence Tools

No generative artificial intelligence or large language models were used for study design, protocol development, or data analysis. Grammarly and large language model-based editing tools were used only for language, grammar, and scientific clarity.

3. Results

The development and validation of the Fast and Frugal Tree (FFT) digital health decision-support tool were driven by a robust mixed-methods approach. This section presents a granular account of the validation process, beginning with the composition and profile of the expert panel, and proceeding through the iterative two-round Delphi process. The section concludes with a comprehensive analysis of both quantitative content validity indices and qualitative expert feedback, culminating in the final validated FFT instrument.

3.1. Expert Validation Panel: Composition and Depth

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External content validation was anchored by a purposively selected expert panel of 14 distinguished subject-matter experts, ranging from the block level to the national level. These individuals were selected for their extensive and practical experience in digital health, mHealth, health information systems, and field-level program implementation within the Indian and broader South Asian public health ecosystems. The panel's collective experience ranged from three to over twenty-five years, encompassing senior program managers, state-level coordinators, technical specialists, government consultants, nutrition officers, and technology officers. To ensure that the FFT would be broadly applicable, experts were drawn from a diverse set of organizational backgrounds, including governmental and public sector bodies, international and national NGOs, United Nations agencies, academic institutions, and private health technology enterprises.

A majority of the panel had direct experience with last-mile implementation, having supervised community health workers (CHWs) and managed digital health programs in both rural and urban settings. The composition guaranteed that feedback would be both theoretically informed and grounded in real-world, block-level operational challenges (Table 1).

Table 1. Anonymized Profile of the Expert Validation Panel (n = 14).

Expert ID	Role Description	Organization Type	Geographic Base	Experience (Years)	Key Expertise	Field/Block Experience
E1	Senior Program Manager	National NGO	Western India	>8	Digital health, HIS	Direct implementation
E2	Program Officer	International NGO	India + South Asia	3–5	Digital health, mHealth	Direct implementation
E3	Block Health Manager	Government	North India	5–8	Block management	Block management
E4	State Program Manager	Maternal Health NGO	Western India	5–8	mHealth, HIS	Block management
E5	Senior Specialist	State Tech Partner NGO	India/Fiji	5–8	Digital health, HIS	Block management
E6	Senior Program Manager	National Foundation	East India	>8	HIS	Direct implementation
E7	Senior Specialist	Government Tech Partner	North India	5–8	HIS, block management	Block management
E8	Consultant	UN Agency	Northeast India	>8	HIS, block management	Block management
E9	Health and Climate Fellow	NGO	East India	3–5	mHealth, HIS	Block management
E10	Nutrition Officer	International Agency	National HQ	>8	Digital health, HIS	Block management
E11	Project Coordinator	International NGO	North India	>8	Digital health, HIS	Block management

E12	State Officer	Government Tech Partner	North India	3–5	Block managemen t	Supervision
E13	Chief Technology Officer	Health Tech Firm	Nepal/Indi a	5–8	mHealth, HIS	Supervision
E14	District Coordinato r	State Health Mission	North India	3–5	Block managemen t	Supervision

3.2. The Delphi Validation Process: Quantitative and Qualitative Insights

The FFT validation employed a two-round modified Delphi process, ensuring structured expert engagement and iterative tool refinement. This process combined quantitative assessment using Content Validity Indices (CVI) with deep qualitative feedback, generating a holistic validation trajectory.

3.2.1. Round 1: Establishing the Diagnostic Baseline

3.2.1.1. Quantitative Analysis: Scale- and Item-Level Content Validity

In the initial Delphi round, 14 public health/digital health experts independently evaluated a 10-step Fast and Frugal Tree (FFT) prototype, which contained 55 distinct decision items. Each item was rated for clarity, relevance, completeness, practicality, and its logical position ("At right step number") using a five-point Likert scale. For quantitative analysis, Item-Level Content Validity Indices (I-CVI) and two Scale-Level indices (S-CVI/Ave and S-CVI/UA) were computed using a binary coding system, where "quite relevant" and "highly relevant" responses were scored as agreement.

The aggregate results reflected a moderately strong but improvable tool. The mean scale-level agreement (S-CVI/Ave) across all items was 0.819, exceeding the minimum threshold for acceptability but below the widely recognized excellence standard of 0.90. Universal agreement (S-CVI/UA), defined as the proportion of items achieving unanimous expert endorsement, was particularly low at 0.09, with only 5 out of 55 items receiving perfect consensus.

A closer look at the item-level data revealed that 14 items failed to meet the pre-specified I-CVI cutoff of 0.78. Most of these low-scoring items clustered within the "completeness" and "correct step order" domains, while items assessing "relevance" were rated highly across the board. This pattern indicated that, while there was consensus on the essential content areas, there was disagreement over how comprehensively items covered those areas and whether they were positioned optimally within the decision sequence.

3.2.1.2. Qualitative Analysis: Thematic Synthesis of Expert Critique

Expert commentary provided further insight into these findings. Several panellists highlighted the need for clearer, more objective language in the FFT items. Suggestions included separating multi-part questions, simplifying complex verification steps, and adapting specific criteria to be context-sensitive, such as replacing fixed timeframes with more adaptable expressions like "n days."

Some experts noted that steps related to grievance management and supervisor self-efficacy needed clearer differentiation between user and supervisor responsibilities, and questioned their sequencing within the decision flow. There was broad consensus that digital literacy, user motivation, and troubleshooting for technical issues warranted greater depth and more context-specific guidance.

Selected remarks from experts included:

- "The most important barrier, according to me, would be untrained CHWs. If they are not proficient, have poor digital literacy, or even if all other resources are available, the output and impact will be poor."

- "Motivation should be checked objectively, and the regular use of the app can be verified by digital records. Steps 5 and 6 can be swapped depending on field testing outcomes."
- "Language barrier is not purely a technical problem and should be integrated with proficiency checks."
- "Grievance redressal timelines should be flexible; seven days may not be realistic in all settings."

These comments reinforced the need for the subsequent round of Delphi validation, with a focus on revision and consensus-building.

3.2.2. Round 2: Iterative Refinement and Consensus Building

3.2.2.1. Tool Revision and Expert Re-Evaluation

Responding to the diagnostic feedback from Round 1, the research team undertook substantial revisions of the FFT tool. All items failing the I-CVI threshold were reworded or reorganized. Recommendations from the expert panel were systematically integrated, including clearer phrasing, more logical sequencing, context-adaptive guidance, and greater operational detail. The revised FFT was then subjected to a second round of expert review.

3.2.2.2. Quantitative Outcomes: Substantial Improvement in Validity Indices

The results from Round 2 demonstrated marked improvement in the tool's content validity. The mean scale-level agreement (S-CVI/Ave) rose to 0.901, surpassing the criterion for excellent content validity. The proportion of items receiving perfect agreement (S-CVI/UA) also increased, with 16 items now rated as relevant by all panellists.

Crucially, every one of the 55 items in the revised tool achieved an I-CVI of at least 0.786, with most items scoring substantially higher. Notably, previously problematic items showed substantial gains following revision; for example, the completeness item at Step 3 improved from 0.643 to 1.00, and scalability at Step 5 rose from 0.571 to 0.857. Items addressing logical sequence also saw notable improvement.

3.2.2.3. Qualitative Outcomes: Affirmation and Recommendations for Implementation

Qualitative feedback from Round 2 was overwhelmingly positive. Experts praised the revised FFT as "clear, quick to use," "field-useful," and "fit for scale-up, especially in aspirational blocks." Many recognized the tool's potential to facilitate supervisory visits and frontline troubleshooting in block and field settings. Remaining comments focused on practical nuances for implementation, such as workflow integration and the adaptability of the tool to local conditions.

Panellists' affirmations included:

- "The FFT is now clear and highly useful for both block-level and higher-level field visits. The self-check and grievance steps add value. It is fit for scale-up."
- "For supervisors, this is a practical self-assessment tool to reflect on their preparedness and the adequacy of resources. For development partners, it identifies gaps for targeted capacity building."

Minor suggestions for further refinement persisted, particularly regarding the adaptation of certain steps for specific contexts and the need for field-based piloting by the government agencies or the development partners working in the field, so as to address any residual ambiguity in workflow or operational guidance. These recommendations highlight the importance of moving toward real-world implementation research.

3.3. The Final Validated Fast and Frugal Tree (FFT)

The culmination of this rigorous two-round process is a validated, user-centric, final 10-step FFT, presented in Table 2. Each step poses a binary question mapped to operational bottlenecks, with immediate, actionable pathways for "No" responses. The last step serves as a self-efficacy check for block staff.

Table 2. The Final 10-Step FFT Tool for Block-Level Digital Health Troubleshooting.

Step	Supervisor Question	If Yes	If No	Suggestive Actions (Examples)
1	Is a functional smartphone or tablet available with the CHW?	Go to Step 2	Exit & Act	Provide spare/repair, and audit devices
2	Does the device have a functional internet connection?	Go to Step 3	Exit & Act	Switch networks, offline forms, and recharge
3	Are all apps installed, and has the CHW received recent training?	Go to Step 4	Exit & Act	Install apps; schedule training
4	Is the CHW proficient in all digital applications?	Go to Step 5	Exit & Act	Assign mentor; refresher training
5	Is the CHW motivated and satisfied with digital tools?	Go to Step 6	Exit & Act	Motivational workshops, recognition
6	Are all applications working without technical issues?	Go to Step 7	Exit & Act	IT ticketing: escalate issues
7	Is the data fully updated for the last 14 days?	Go to Step 8	Exit & Act	Data review: align paper/digital records
8	Is there a time-bound grievance redressal system?	Go to Step 9	Exit & Act	Implement a simple ticketing system
9	Are grievances resolved within agreed-upon days?	Go to Step 10	Exit & Act	Review in meetings; escalate systemic issues
10*	Are resources at the block level adequate (self-efficacy)?	Review regularly	Exit & Act	Self-assess resource gaps; escalate if needed

* Step 10 can be optional.

3.4. Synthesis: Overall Patterns and Implications

- Quantitative Synthesis: The FFT moved from a baseline of basic acceptability to robust excellence, with all items validated at I-CVI ≥ 0.78, S-CVI/Ave = 0.901, and substantial gains in S-CVI/UA.
- Qualitative Synthesis: Thematic analysis highlighted recurring strengths (clarity, practical value, contextual fit) and residual challenges (workflow nuances, adaptation flexibility). Panelists'

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insights drove targeted revisions, resulting in a tool that is both technically sound and field realistic.

4. Discussion

This study presents the development and expert validation of a Fast and Frugal Tree (FFT) decision-support tool for block-level digital health troubleshooting in India, addressing a critical gap in translating digital health strategy into operational practice in low-resource settings. The FFT's pragmatic, user-centered design provides a concrete response to persistent last-mile bottlenecks that have been consistently documented in India and other low- and middle-income countries (LMICs), but which have rarely been operationalized into actionable supervisory tools.

4.1. Synthesis with Previous Literature

The findings of this study confirm and extend a substantial body of literature highlighting the persistent challenges encountered by community health workers (CHWs) and block-level managers at the intersection of digital health policy and field-level implementation. Multiple studies have described recurring problems, including device attrition, unreliable network connectivity, variable digital literacy, dual reporting requirements, and insufficient training. These issues continue to undermine the effectiveness of digital health programs and are well recognized both in India and globally[17,18,29,37].

The Muzaffarpur findings mirror national and international patterns, indicating that even where robust digital health policy environments exist, the success of these programs depends heavily on day-to-day operational realities. The literature consistently demonstrates that digital interventions such as the Poshan Tracker, ANMOL, and similar platforms in Africa and Southeast Asia frequently introduce parallel systems and fragmented workflows rather than producing the intended efficiencies[3,16,38–40]. The FFT's core logic, which prompts immediate and context-specific action for commonly encountered bottlenecks, directly addresses this fragmentation. It provides a rare, field-validated solution that integrates device, network, human, and systemic factors into a unified supervisory tool[22,24,41].

4.2. Advances in Decision-Support for Digital Health

The FFT tool builds on and advances existing frameworks for digital health supervision. Previous approaches have often relied on checklists, digital readiness indexes, or multi-step protocols, but these tools tend to be either overly generic, insufficiently adapted to the local context, or too complex for routine use by block-level supervisors[27,42,43]. By drawing on the Fast and Frugal Tree methodology, which is rooted in decision science and has demonstrated effectiveness for rapid judgments in resource-constrained environments, the FFT achieves a unique balance of comprehensiveness and usability and can provide the desired user acceptance for tiresome task managing processes followed by the block level officials leading to poor quality of supervision and data availability[33,44–46].

The use of a modified Delphi consensus process, resulting in a mean item-level content validity index of 0.90, exceeds established standards for tool validation in health research[47,48]. The FFT's binary logic and explicit linkage of each step to a real-world corrective action overcome a major limitation of earlier algorithms and checklists: the lack of operational granularity and practical guidance for supervisors under field conditions[27,29,36].

4.3. Practical Relevance and Usability

A central strength of the FFT is its modularity and adaptability. The iterative feedback process with the expert panel ensured that the steps, their sequence, and the recommended actions could be customized for different programmatic and geographic contexts. The inclusion of flexible timeframes, attention to language barriers, and integration of motivational and self-efficacy checks reflect an

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application of behavioral science and address operational nuances highlighted in prior research [1,49–52]. Such features are seldom present in other published toolkits, marking the FFT as both innovative and highly responsive to frontline realities.

Moreover, the explicit focus on motivation and satisfaction, along with the provision for self-efficacy assessment at the block level, represents a significant advance over conventional decision trees, which have historically addressed only structural or technical barriers. These additions are supported by technology adoption and behavior change models, which show that perceived usefulness, ease of use, and organizational support are as critical as infrastructure in determining the uptake of digital health tools[3,41,42,53].

4.4. Comparison with National and Global Initiatives

This work contributes to the ongoing discourse about digital health supervision tools in India and internationally. Recent government and partner initiatives, such as digital health operational guidelines and the deployment of supervisory dashboards, have acknowledged the importance of field-level troubleshooting but have yet to operationalize this recognition in ways that are both actionable and scalable for block-level managers [1,52,54,55]. The FFT, as validated in this study, provides a concrete potential solution, with consensus from practitioners across sectors and regions, making it ready for rapid piloting and scale-up.

Globally, guidance from the World Health Organization (WHO) emphasizes the need for practical, user-driven implementation frameworks but stops short of prescribing detailed, actionable tools for supervisors or CHWs [1,25,32,56]. Recent research from Africa, Latin America, and South Asia continues to call for operational research on supervisory algorithms and real-world troubleshooting protocols [18,21,39,57–59]. The FFT directly addresses this gap, offering a reproducible model for LMICs seeking to strengthen digital health implementation at the ground level.

4.5. Strengths and Limitations

The major strength of this study lies in its rigorous mixed-methods approach, which combines a baseline survey, in-depth qualitative inquiry, and expert panel consensus. This triangulation enhances the credibility, transferability, and practical utility of the FFT, ensuring that it reflects both measurable gaps and lived experiences [33,36,60]. The study’s embedding within ongoing programmatic realities in aspirational districts with low resource availability increases its external validity and relevance for other high-priority districts.

However, several limitations must be acknowledged. While the Delphi panel was diverse and national in scope, the validation process did not include many international experts or states with radically different health system architectures. Adaptation may therefore be required for some contexts. Furthermore, the FFT’s performance under field conditions, including its sensitivity, specificity, and real-world usability, has yet to be assessed through operational pilots, which can be planned as a next step but were outside the scope of this research. Finally, although the tool’s stepwise logic is designed for block-level supervisors, some steps, such as grievance resolution and self-efficacy assessment, may require additional customization or supplementary guidance for use by state-level or non-health actors.

4.6. Implementation, Scalability, and Policy Implications

The FFT’s modular design supports multiple modes of deployment, including as a paper checklist, laminated card, or digital dashboard module, making it appropriate for both immediate adoption and long-term integration. This flexibility aligns with global recommendations for iterative adaptation, enabling phased introduction and contextual learning[3,61,62]. The FFT’s structure allows for ongoing evolution as feedback from pilots and field testing can directly inform future refinements and digital transformation efforts.

At the policy level, the FFT offers a standardized, actionable protocol that fills a crucial gap between high-level digital health strategies and the often fragmented and ad hoc supervisory practices observed in block and district programs[1,5,55] . By equipping supervisors with a protocol that supports proactive problem-solving, the tool has the potential to strengthen data quality and user engagement. The explicit attention to motivational and behavioral determinants of technology use, which is rarely found in existing decision-support models, also allows for integration with wider organizational development and health system strengthening efforts. As India continues to expand digital health initiatives under the Ayushman Bharat Digital Mission (ABDM) and similar programs, tools like the FFT are likely to be essential for sustainable and scalable success.

4.7. Directions for Future Research

The expert validation of the FFT marks a significant advance, but further operational research is needed to evaluate its performance, impact, and user satisfaction in real-world conditions. Key next steps include pilot deployment in diverse districts to assess usability, time burden, and acceptability among supervisors and CHWs, measurement of impact on data quality, grievance resolution, and program efficiency compared to current supervisory practice, and adaptation and digital integration with state governments and partners, including links to dashboard systems and automated alerts. Research should also explore the impact of motivational and self-efficacy checks on technology adoption and workforce morale, and undertake comparative studies in other LMICs to assess transferability and generate cross-contextual learning[16,18,22,25]. Additionally, future versions may incorporate artificial intelligence or machine learning analytics for automated prioritization of field support, but such innovations must retain the FFT's operational simplicity[63–68].

5. Conclusions

This study demonstrates the development of a rigorous, expert-validated Fast and Frugal Tree (FFT) decision support tool designed to address persistent operational barriers to digital health implementation in low-resource Indian settings. By synthesizing quantitative and qualitative evidence from block level supervisors and community health workers in an aspirational district, the FFT provides a practical and user centric protocol for identifying and resolving the common bottlenecks, such as device attrition, poor connectivity, digital illiteracy, dual reporting, and limited grievance redressal, that routinely hinder effective digital health delivery.

The Delphi process ensured that the FFT is both evidence-informed and field-adapted, with consensus exceeding international standards for content validity. Unlike conventional supervisory checklists or readiness indexes, the FFT explicitly integrates motivational and self-efficacy checks, reflecting current evidence that sustainable digital health adoption requires attention to behavioral as well as technical determinants.

The tool's modular design and adaptability make it suitable for phased implementation and iterative refinement in varied contexts, supporting India's broader digital health ambitions under programs such as the Ayushman Bharat Digital Mission. Its explicit and actionable steps enable supervisors to move beyond fault-finding toward a supportive, problem-solving role that can improve program performance, data quality, and worker engagement.

However, the FFT's long-term impact depends on further piloting by the competent authorities, integration into routine workflows, and ongoing adaptation in response to field realities. The study's limitations, including the need for wider contextual validation and operational research, point toward future directions, including impact evaluation, digital integration, and potential cross-country adaptation.

In conclusion, the FFT addresses a critical "missing middle" in digital health supervision, offering a pragmatic, scalable, and evidence-based tool for bridging policy and practice. If implemented with fidelity to its user-centric principles, it can play a vital role in advancing equitable and effective digital health systems in India and other low and middle-income countries.

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Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, File F1: Detailed Content Validation Results from Delphi Round 1; File F2: Detailed Content Validation Results from Delphi Round 2.

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Abbreviations

The following abbreviations are used in this manuscript:

Abbreviation	Full Form
AES	Acute Encephalitis Syndrome
ANM	Auxiliary Nurse Midwife
ASHA	Accredited Social Health Activist
AWW	Anganwadi Worker
CDPO	Child Development Project Officer
CHW	Community Health Worker
CVI	Content Validity Index
FFT	Fast and Frugal Tree
HDI	Human Development Index
HIS	Health Information Systems
ICDS	Integrated Child Development Services
IEC	Institutional Ethics Committee
I-CVI	Item-level Content Validity Index
LMICs	Low- and Middle-Income Countries
mHealth	Mobile Health
MOIC	Medical Officer In Charge

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NGO	Non-Governmental Organization
NFHS-5	National Family Health Survey-5
S-CVI	Scale-level Content Validity Index
S-CVI/Ave	Scale-level Content Validity Index (Average)
S-CVI/UA	Scale-level Content Validity Index (Universal Agreement)
SDG	Sustainable Development Goal
UHC	Universal Health Coverage
UN	United Nations
WHO	World Health Organization

References

1. World Health Organization *WHO-Global Strategy on Digital Health 2020-2025*; 2021; ISBN 9789240020924.
2. Bank, W. *Ayushman Bharat Digital Mission's Integrated Digital Health Ecosystem Is the Foundation of Universal Citizen-Centered Health Care in India*;
3. Labrique, A.B.; Wadhwani, C.; Williams, K.A.; Lamptey, P.; Hesp, C.; Luk, R.; Aerts, A. Best Practices in Scaling Digital Health in Low and Middle Income Countries. **2018**, 1–8.
4. Welfare, M. of H. and F. *National Health Policy India 2017*; 2017;
5. National Health Authority (NHA), I. ABDM Handbook Ayushman Bharat Digital Mission 2021, 1–67.
6. National Health Authority (NHA), I. *Ayushman Bharat Digital Mission Draft Health Data Management Policy 2022*; 2022;
7. Sharma, R.S.; Rohatgi, A.; Jain, S.; Singh, D. The Ayushman Bharat Digital Mission (ABDM): Making of India's Digital Health Story. *CSI Transactions on ICT* **2023**, *11*, 3–9, doi:10.1007/s40012-023-00375-0.
8. Sarin, E.; Bisht, N.; Mohanty, J.S.; Chandra Joshi, N.; Kumar, A.; Dey, S.; Kumar, H. Putting the Local Back into Planning-Experiences and Perceptions of State and District Health Functionaries of Seven Aspirational Districts in India on an Innovative Planning Capacity Building Approach. *International Journal of Health Planning and Management* **2021**, *36*, 2248–2262, doi:10.1002/hpm.3290.
9. Bhatia, V.; Rath, R.; Singh, A. Developing the Underdeveloped: Aspirational Districts Program from Public Health Point of View. *Indian Journal of Community and Family Medicine* **2018**, *4*, 1–3, doi:10.4103/2395-2113.251433.
10. NITI Aayog *Transformation of Aspirational Districts Baseline Ranking Report by NITI Aayog*; 2018;
11. Malaviya, P.; Picado, A.; Hasker, E.; Ostyn, B.; Kansal, S.; Singh, R.P.; Shankar, R.; Boelaert, M.; Sundar, S. Health & Demographic Surveillance System Profile: The Muzaffarpur-Tmrc Health and Demographic Surveillance System. *Int J Epidemiol* **2014**, *43*, 1450–1457, doi:10.1093/IJE/DYU178.
12. Government of India *District Census Handbook Muzaffarpur 2011*; 2011;
13. Ministry of Health and Family Welfare *NFHS 5 District Fact Sheet Muzaffarpur Bihar*; Muzaffarpur, 2021;
14. Kalne, P.S.; Kalne, P.S.; Mehendale, A.M. Acknowledging the Role of Community Health Workers in Providing Essential Healthcare Services in Rural India-A Review. *Cureus* **2022**, *14*, 1–7, doi:10.7759/cureus.29372.
15. Nadella, P.; Subramanian, S. V.; Roman-Urrestarazu, A. The Impact of Community Health Workers on Antenatal and Infant Health in India: A Cross-Sectional Study. *SSM Popul Health* **2021**, *15*, 100872, doi:10.1016/j.ssmph.2021.100872.
16. Blondino, C.T.; Knoepflmacher, A.; Johnson, I.; Fox, C.; Friedman, L. The Use and Potential Impact of Digital Health Tools at the Community Level: Results from a Multi-Country Survey of Community Health Workers. *BMC Public Health* **2024**, *24*, 1–14, doi:10.1186/s12889-024-18062-3.
17. Feroz, A.S.; Khoja, A.; Saleem, S. Equipping Community Health Workers with Digital Tools for Pandemic Response in LMICs. *Archives of Public Health* **2021**, *79*, 10–13, doi:10.1186/s13690-020-00513-z.
18. Owoyemi, A.; Osuchukwu, J.I.; Azubuike, C.; Ikpe, R.K.; Nwachukwu, B.C.; Akinde, C.B.; Biokoro, G.W.; Ajose, A.B.; Nwokoma, E.I.; Mfon, N.E.; et al. Digital Solutions for Community and Primary Health Workers: Lessons From Implementations in Africa. *Front Digit Health* **2022**, *4*, 1–9, doi:10.3389/fdgth.2022.876957.

19. Verdezoto, N.; Bagalkot, N.; Akbar, S.Z.; Sharma, S.; Mackintosh, N.; Harrington, D.; Griffiths, P. The Invisible Work of Maintenance in Community Health: Challenges and Opportunities for Digital Health in Supporting Frontline Health Workers in Karnataka, South India. *Proc ACM Hum Comput Interact* **2021**, *5*, 1–31, doi:10.1145/3449165.
20. Pgdha, V.K.; Chaudhary, S.; Sharma, A.K. Challenges in Implementing Digital Health Services in Rural India. *J Int Soc Telemed eHealth* **2023**, *11*, 1–5, doi:10.29086/JISfTeH.11.e3.
21. Gadsden, T.; Mabunda, S.A.; Palagyi, A.; Maharani, A.; Sujarwoto, S.; Baddeley, M.; Jan, S. Performance-Based Incentives and Community Health Workers' Outputs, a Systematic Review. *Bull World Health Organ* **2021**, *99*, 805–818, doi:10.2471/BLT.20.285218.
22. Borges do Nascimento, I.J.; Abdulazeem, H.; Vasanthan, L.T.; Martinez, E.Z.; Zucoloto, M.L.; Østengaard, L.; Azzopardi-Muscat, N.; Zapata, T.; Novillo-Ortiz, D. Barriers and Facilitators to Utilizing Digital Health Technologies by Healthcare Professionals. *NPJ Digit Med* **2023**, *6*, 1–28, doi:10.1038/s41746-023-00899-4.
23. Siyam, A.; Ir, P.; York, D.; Antwi, J.; Amponsah, F.; Rambique, O.; Funzamo, C.; Azeez, A.; Mboera, L.; Kumalija, C.J.; et al. The Burden of Recording and Reporting Health Data in Primary Health Care Facilities in Five Low- and Lower-Middle Income Countries. *BMC Health Serv Res* **2021**, *21*, 1–9, doi:10.1186/s12913-021-06652-5.
24. Borges do Nascimento, I.J.; Abdulazeem, H.M.; Vasanthan, L.T.; Martinez, E.Z.; Zucoloto, M.L.; Østengaard, L.; Azzopardi-Muscat, N.; Zapata, T.; Novillo-Ortiz, D. The Global Effect of Digital Health Technologies on Health Workers' Competencies and Health Workplace: An Umbrella Review of Systematic Reviews and Lexical-Based and Sentence-Based Meta-Analysis. *Lancet Digit Health* **2023**, *5*, e534–e544, doi:10.1016/S2589-7500(23)00092-4.
25. World Health Organization *WHO Guideline on Health Policy and System Support to Optimize Community Health Worker Programmes*; WHO, 2015; Vol. 16; ISBN 0123456789.
26. Hilty, D.M.; Armstrong, C.M.; Smout, S.A.; Crawford, A.; Maheu, M.M.; Drude, K.P.; Chan, S.; Yellowlees, P.M.; Krupinski, E.A. Findings and Guidelines on Provider Technology, Fatigue, and Well-Being: Scoping Review. *J Med Internet Res* **2022**, *24*, 1–15, doi:10.2196/34451.
27. Bosch-Capblanch, X.; Liaqat, S.; Garner, P. Managerial Supervision to Improve Primary Health Care in Low- and Middle-Income Countries. *Cochrane Database of Systematic Reviews* **2011**, *2019*, doi:10.1002/14651858.CD006413.pub2.
28. Rashmi Kundapur, Sumit Aggarwal, Rakhal Gaitonde, Anusha Rashmi, L.S.G.; Bavaskar, Arvind Pandey, Y. Challenges Faced by Frontline Health Managers during the Implementation of COVID-19 Related Policies in India: A Qualitative Analysis. *Indian Journal of Medical Research* **2023**, 21–27, doi:DOI: 10.4103/ijmr.ijmr_206_22.
29. Vikas Bhatia, Preetam Mahajan, Swayam P. Parida, S.B.; Sahoo, S.S. Challenges in Supervision, Monitoring, and Reporting in Anemia Programme Implementation in Odisha, India: A Qualitative Process Documentation. *J Family Med Prim Care* **2019**, *8*, 1365–1369, doi:10.4103/jfmpc.jfmpc_68_19.
30. Karuga, R.N.; Mireku, M.; Muturi, N.; McCollum, R.; Vallieres, F.; Kumar, M.; Taegtmeyer, M.; Otiso, L. Supportive Supervision of Close-to-Community Providers of Health Care: Findings from Action Research Conducted in Two Counties in Kenya. *PLoS One* **2019**, *14*, 1–19, doi:10.1371/journal.pone.0216444.
31. Wolfenden, L.; Williams, C.M.; Kingsland, M.; Yoong, S.L.; Nathan, N.; Sutherland, R.; Wiggers, J. Improving the Impact of Public Health Service Delivery and Research: A Decision Tree to Aid Evidence-Based Public Health Practice and Research. *Aust N Z J Public Health* **2020**, *44*, 331–332, doi:10.1111/1753-6405.13023.
32. World Health Organization *WHO Guideline Recommendations on Digital Interventions for Health System Strengthening*; 2019; Vol. 2;.
33. Gigerenzer, G.; Kurzenhauser, S. Fast and Frugal Heuristics In Medical Decision Making. *Science and Medicine in Dialogue* 2024, 3–16.
34. Martignon, L.; Katsikopoulos, K. V.; Woike, J.K. Categorization with Limited Resources: A Family of Simple Heuristics. *J Math Psychol* **2008**, *52*, 352–361, doi:10.1016/j.jmp.2008.04.003.
35. Bonner, G. Decision Making for Health Care Professionals: Use of Decision Trees within the Community Mental Health Setting. *J Adv Nurs* **2001**, *35*, 349–356, doi:10.1046/j.1365-2648.2001.01851.x.

36. Martignon, L.; Erickson, T.; Viale, R. Transparent, Simple and Robust Fast-and-Frugal Trees and Their Construction. *Frontiers in Human Dynamics* **2022**, *4*, doi:10.3389/fhumd.2022.790033.
37. John, A.; Nisbett, N.; Barnett, I.; Avula, R.; Menon, P. Factors Influencing the Performance of Community Health Workers: A Qualitative Study of Anganwadi Workers from Bihar, India. *PLoS One* **2020**, *15*, 1–17, doi:10.1371/journal.pone.0242460.
38. Singh, S.; Miller, E.; Closser, S. Nurturing Transformative Local Structures of Multisectoral Collaboration for Primary Health Care: Qualitative Insights from Select States in India. *BMC Health Serv Res* **2024**, *24*, 1–15, doi:10.1186/s12913-024-11002-2.
39. Braun, R.; Catalani, C.; Wimbush, J.; Israelski, D. Community Health Workers and Mobile Technology: A Systematic Review of the Literature. *PLoS One* **2013**, *8*, 4–9, doi:10.1371/journal.pone.0065772.
40. Singh, N.S.; Scott, K.; George, A.; Lefevre, A.E.; Ved, R. A Tale of "Politics and Stars Aligning": Analysing the Sustainability of Scaled up Digital Tools for Front-Line Health Workers in India. *BMJ Glob Health* **2021**, *6*, 1–14, doi:10.1136/bmjgh-2021-005041.
41. Parajuli, R.; Bohara, D.; KC, M.; Shanmuganathan, S.; Mistry, S.K.; Yadav, U.N. Challenges and Opportunities for Implementing Digital Health Interventions in Nepal: A Rapid Review. *Front Digit Health* **2022**, *4*, 1–14, doi:10.3389/fdgth.2022.861019.
42. Temsah, M.-H.; Aljamaan, F.; Malki, K.H.; Alhasan, K.; Altamimi, I.; Aljarbou, R.; Bazuhair, F.; Alsubaihin, A.; Abdulmajeed, N.; Alshahrani, F.S.; et al. ChatGPT and the Future of Digital Health: A Study on Healthcare Workers' Perceptions and Expectations. *Healthcare* **2023**, *11*, 1–14, doi:10.3390/healthcare11131812.
43. Woods, L.; Eden, R.; Macklin, S.; Krivit, J.; Duncan, R.; Murray, H.; Donovan, R.; Sullivan, C. Strengthening Rural Healthcare Outcomes through Digital Health: Qualitative Multi-Site Case Study. *BMC Health Serv Res* **2024**, *24*, doi:10.1186/s12913-024-11402-4.
44. Venkatesh, V.; Morris, M.G.; Davis, G.B.; Davis, F.D. User Acceptance of Information Technology: Toward a Unified View. *MIS Q* **2003**, *27*, 425–478, doi:10.2307/30036540.
45. Arvind Pandey*, Nandini Roy**, R.B. and R.M.M. Health Information System in India: Issues of Data Availability and Quality. *Demogr India* **2010**, *39*, 11–128.
46. Meghani, A.; Rodríguez, D.C.; Peters, D.H.; Bennett, S. Understanding Reasons for and Strategic Responses to Administrative Health Data Misreporting in an Indian State. *Health Policy Plan* **2023**, *38*, 150–160, doi:10.1093/heapol/czac065.
47. Yusoff, M.S.B. ABC of Content Validation and Content Validity Index Calculation. *Education in Medicine Journal* **2019**, *11*, 49–54, doi:10.21315/eimj2019.11.2.6.
48. Denise F. Polit; Cheryl Tatano Bec The Content Validity Index: Are You Sure You Know What's Being Reported? Critique and Recommendations. *Res Nurs Health* **2006**, 489–497, doi:10.1002/nur.
49. Min, H.; Li, J.; Di, M.; Huang, S.; Sun, X.; Li, T.; Wu, Y. Factors Influencing the Continuance Intention of the Women's Health WeChat Public Account: An Integrated Model of UTAUT2 and HBM. *Front Public Health* **2024**, *12*, 1–12, doi:10.3389/fpubh.2024.1348673.
50. Gudi, N.; Lakiang, T.; Pattanshetty, S.; Sarbadhikari, S.N.; John, O. Challenges and Prospects in India's Digital Health Journey. *Indian J Public Health* **2021**, *65*, 209–212, doi:10.4103/ijph.IJPH_1446_20.
51. Kostkova, P. Grand Challenges in Digital Health. *Front Public Health* **2015**, *3*, 1, doi:10.3389/FPUBH.2015.00134.
52. Cometto, G.; Ford, N.; Pfaffman-Zambruni, J.; Akl, E.A.; Lehmann, U.; McPake, B.; Ballard, M.; Kok, M.; Najafizada, M.; Olaniran, A.; et al. Health Policy and System Support to Optimise Community Health Worker Programmes: An Abridged WHO Guideline. *Lancet Glob Health* **2018**, *6*, e1397–e1404, doi:10.1016/S2214-109X(18)30482-0.
53. Okolo, C.T.; Kamath, S. It Cannot Do All of My Work: Community Healthworker Perceptions of Ai-Enabled Mobile Health Applications in Rural India. In Proceedings of the Conference on Human Factors in Computing Systems - Proceedings; 2021; pp. 1–20.
54. Ministry of Health and Family Welfare (MoHFW) *An E-Booklet on IT Initiatives of NHM*; 2023;
55. Ministry of Women and Child Development [MoWCD] *Mission Saksham Anganwadi and Poshan 2.0 - Scheme Guidelines 2022*; 2022;

 doi:10.20944/preprints202507.0873.v1

56. World Health Organisation *Digital Transformation Handbook for Primary Health Care Optimizing Person-Centred Point of Service Systems*; 2024; ISBN 9789240093362.
57. D'Elia, A.; Gabbay, M.; Rodgers, S.; Kierans, C.; Jones, E.; Durrani, I.; Thomas, A.; Frith, L. Artificial Intelligence and Health Inequities in Primary Care: A Systematic Scoping Review and Framework. *Fam Med Community Health* **2022**, *10*, 1–10, doi:10.1136/fmch-2022-001670.
58. Rahimi, S.A.; Légaré, F.; Sharma, G.; Archambault, P.; Zomahoun, H.T.V.; Chandavong, S.; Rheault, N.; Wong, S.T.; Langlois, L.; Couturier, Y.; et al. Application of Artificial Intelligence in Community-Based Primary Health Care: Systematic Scoping Review and Critical Appraisal. *J Med Internet Res* **2021**, *23*, 1–19, doi:10.2196/29839.
59. Ahmed, S.; Chase, L.E.; Wagnild, J.; Akhter, N.; Sturridge, S.; Clarke, A.; Chowdhary, P.; Mukami, D.; Kasim, A.; Hampshire, K. Community Health Workers and Health Equity in Low- and Middle-Income Countries: Systematic Review and Recommendations for Policy and Practice. *Int J Equity Health* **2022**, *21*, 1–30, doi:10.1186/s12939-021-01615-y.
60. Braun, V.; Clarke, V. Using Thematic Analysis in Psychology; In Qualittaive Research in Psychology. *Uwe Bristol* **2006**, *3*, 77–101.
61. Masis, L.; Gichaga, A.; Zerayacob, T.; Lu, C.; Perry, H.B. Community Health Workers at the Dawn of a New Era: 4. Programme Financing. *Health Res Policy Syst* **2021**, *19*, 1–18, doi:10.1186/s12961-021-00751-9.
62. Woods, L.; Martin, P.; Khor, J.; Guthrie, L.; Sullivan, C. The Right Care in the Right Place: A Scoping Review of Digital Health Education and Training for Rural Healthcare Workers. *BMC Health Serv Res* **2024**, *24*, 1–12, doi:10.1186/s12913-024-11313-4.
63. Rodrigues, S.M.; Kanduri, A.; Nyamathi, A.; Dutt, N.; Khargonekar, P.; Rahmani, A.M. Digital Health-Enabled Community-Centered Care: Scalable Model to Empower Future Community Health Workers Using Human-in-the-Loop Artificial Intelligence. *JMIR Form Res* **2022**, *6*, 1–15, doi:10.2196/29535.
64. Chettri, S.K.; Deka, R.K.; Saikia, M.J. Bridging the Gap in the Adoption of Trustworthy AI in Indian Healthcare: Challenges and Opportunities. *AI (MDPI Switzerland)* **2025**, *6*, 1–18, doi:10.3390/ai6010010.
65. Cossy-Gantner, A.; Germann, S.; Schwalbe, N.R.; Wahl, B. Artificial Intelligence (AI) and Global Health: How Can AI Contribute to Health in Resource-Poor Settings? *BMJ Glob Health* **2018**, *3*, 1–7, doi:10.1136/bmjgh-2018-000798.
66. Wibowo, M.F.; Pyle, A.; Lim, E.; Ohde, J.W.; Liu, N.; Karlström, J. Insights Into the Current and Future State of AI Adoption Within Health Systems in Southeast Asia: Cross-Sectional Qualitative Study. *J Med Internet Res* **2025**, *27*, 1–16, doi:10.2196/71591.
67. WHO TEAM Digital Health and Innovation (DHI), M.D. and D. (MDD) *Generating Evidence for Artificial Intelligence-Based Medical Devices: A Framework for Training, Validation and Evaluation*; 2021; ISBN ISBN: 9789240038462.
68. World Health Organization *Ethics and Governance of Artificial Intelligence for Health. Guidance on Large Multi-Modal Models*; 2024; ISBN 9789240029200.