

Enhancing Government-Citizen Interaction: Bridging Service Gaps through Digital Design Solutions in Bihar, India

Authors:

1. **Rishabh Aryan**, M.Des (UX), School of Design, DIT University, Dehradun (Uttarakhand, India).
2. **Abdul Kalam**, Assistant Professor, School of Design, DIT University, Dehradun (Uttarakhand, India).

Corresponding Author: Abdul Kalam, Assistant Professor, School of Design, DIT University, Dehradun (Uttarakhand, India).

Email ID: abdul.kalam@dituniversity.edu.in

Accepted: 26/06/2024

Published: 18/07/2024

Author(s) Retains the Copyrights of This Article

Abstract

In the rapidly evolving landscape of public administration, leveraging digital design solutions is imperative to foster transparent, accountable, and inclusive governance. This study, titled "Enhancing Government-Citizen Interaction: Bridging Service Gaps through Digital Design Solutions in Bihar, India," investigates the potential of utilizing digital tools and user-centered design principles to mitigate deep-seated public service delivery constraints. Bihar faces significant administrative hurdles, characterized by inadequate infrastructure, low

digital literacy, bureaucratic inefficiencies, and a pronounced rural-urban digital divide that often excludes marginalized communities.

Adopting a descriptive and exploratory mixed-methods approach, the research combines qualitative and quantitative methodologies—including structured surveys, stakeholder interviews, focus group discussions, and document analysis. To illustrate the practical flow of public service networks on the ground, the study utilizes Social Network Analysis (SNA) within a case study focused on the state's agricultural sector. By interviewing 111 key informants across six districts, the network mapping evaluates how administrative figures—such as District Agricultural Officers, Block Agricultural Officers, and village-level advisors (*Krishi Salahakars*)—control, transmit, and utilize critical information.

The findings reveal that while bureaucratic hierarchies can be time-consuming and prone to information lag, the penetration of mobile communication technologies successfully expedites service responsiveness by bypassing unnecessary administrative layers. Furthermore, network dynamics vary heavily by district, indicating that a one-size-fits-all digital strategy is ineffective. Based on these insights, the study proposes actionable policy frameworks rooted in Human-Centered Design (HCD). It recommends formalizing grassroots workers as central information nodes, modernizing dissemination channels using mobile and video tools, upgrading personnel skills, and creating localized digital repositories in vernacular languages. Ultimately, this research provides a strategic blueprint for policymakers to minimize service delivery gaps, optimize digital interaction, and enhance overall public trust in governance.

Keywords: *Digital Governance / E-Governance, Public Service Delivery, Human-Centered Design (HCD), User-Centered Design, Social Network Analysis (SNA), Government-Citizen Interaction, Digital Divide, Bihar Public Administration, Social Knowledge Networks (SKNs), Information Dissemination.*

CHAPTER -1

INTRODUCTION

1.1 Introduction

In the rapidly evolving landscape of governance and public administration, the integration of digital design solutions has emerged as a transformative force, particularly in regions grappling with socio-economic challenges. Bihar, one of India's most populous and historically significant states, stands at a critical juncture where bridging service gaps through innovative technological interventions are not just desirable but imperative. "Enhancing Government-Citizen Interaction: Bridging Service Gaps through Digital Design Solutions in Bihar, India" delves into the potential and practicalities of leveraging digital tools to foster more effective, transparent, and inclusive governance. Bihar's unique demographic and developmental context presents both challenges and opportunities for digital transformation. Despite notable progress in recent years, the state continues to face significant hurdles in public service delivery, ranging from inefficiencies in administrative processes to limited access to essential services in rural areas. This has often resulted in a disconnect between the government and its citizens, undermining trust and hampering development efforts.

This study explores how strategic implementation of digital design solutions can address these service gaps, enhance communication, and promote citizen engagement. By analyzing existing initiatives and proposing new frameworks, it aims to illustrate how digital innovations can be harnessed to streamline government functions, improve service delivery, and ultimately, bridge the divide between the government and the people it serves. Through case studies, stakeholder interviews, and comparative analyses, the research provides a comprehensive overview of the current state of digital governance in Bihar and offers actionable insights for policymakers and practitioners aiming to foster a more connected and responsive administrative ecosystem.

1.1.1 Enhancing Government-Citizen Interaction

Enhancing government-citizen interaction through digital platforms is a transformative approach that fosters greater transparency, accountability, and efficiency in public service delivery. Digital platforms, such as websites, mobile applications, and social media, allow governments to engage directly with citizens, offering an accessible and convenient way to

access services, provide feedback, and participate in decision-making processes. These interactions can take various forms, from online consultations and surveys to real-time updates on government activities and services. For instance, e-governance portals enable citizens to apply for permits, pay taxes, and request public records without needing to visit government offices, significantly reducing bureaucratic red tape and wait times. Social media platforms also play a crucial role by providing a channel for immediate communication and feedback, enhancing public trust and government responsiveness. Moreover, digital interaction ensures inclusivity by reaching marginalized communities who may have limited access to traditional government services. By adopting a citizen-centric approach, governments can better understand and address the needs and concerns of their populations, ultimately fostering a more engaged and informed citizenry.

1.1.2 The Evolution of Digital Technologies in Public Administration

The evolution of digital technologies in public administration has revolutionized how governments operate and deliver services. Initially, the integration of information technology in the public sector involved the basic computerization of records and internal communications. However, the rapid advancement of digital technologies such as the internet, cloud computing, and mobile applications has paved the way for more sophisticated e-governance solutions. Governments worldwide now utilize online portals to provide a wide range of services, from tax filing and business registrations to health and social services, all accessible to citizens anytime and anywhere. The introduction of big data analytics allows for the collection and analysis of vast amounts of data to inform policy decisions and improve service delivery. Moreover, artificial intelligence and machine learning enable predictive analytics and the automation of routine tasks, enhancing efficiency and reducing human error. Blockchain technology offers secure and transparent ways to manage public records and transactions, furthering trust in government processes. The ongoing evolution of these technologies continues to transform public administration, making it more transparent, efficient, and responsive to the needs of citizens.

1.1.3 Current Challenges in Government Service Delivery: Insights from Bihar

Bihar, one of India's most populous states, faces significant challenges in delivering effective government services. Despite various initiatives aimed at improving public administration, the state grapples with inadequate infrastructure, low levels of digital literacy, and pervasive bureaucratic inefficiencies. Many rural areas in Bihar lack reliable internet connectivity, severely limiting access to e-governance services. This digital divide means that a large portion of the population remains excluded from the benefits of digital government initiatives. Additionally, corruption and bureaucratic red tape continue to impede service delivery, making it difficult for citizens to obtain essential documents and services in a timely manner. The shortage of skilled personnel to manage and operate digital platforms is another critical issue, leading to inconsistent implementation of digital initiatives. The COVID-19 pandemic has further highlighted these challenges, underscoring the urgent need for robust digital infrastructure and effective service delivery mechanisms. Addressing these issues requires a multifaceted approach, including significant investment in digital infrastructure, comprehensive digital literacy programs, and reforms to streamline bureaucratic processes. Insights from Bihar illustrate the complex interplay of factors that can hinder effective government service delivery and emphasize the need for tailored solutions that consider local contexts and challenges.

1.1.4 Harnessing Digital Design Solutions for Public Service Improvement

Harnessing digital design solutions can significantly enhance public services by making them more user-friendly, accessible, and efficient. Digital design focuses on creating intuitive interfaces and seamless user experiences, ensuring that services meet the needs of all citizens. This approach involves applying principles of user-centered design, where services are developed based on user feedback and behavior. For instance, mobile-friendly websites and applications allow citizens to access government services on the go, enhancing convenience and accessibility. Interactive platforms can provide personalized assistance, reducing the need for in-person visits and long wait times. Employing data analytics helps identify service bottlenecks and optimize processes. Estonia's e-Residency program exemplifies successful digital design, providing a user-friendly platform for global entrepreneurs to establish and manage businesses remotely. By prioritizing user experience, governments can increase citizen engagement, satisfaction, and trust in public services. Ultimately, digital design

solutions play a crucial role in modernizing public administration and delivering services that are efficient, inclusive, and responsive to citizen needs.



1.1.5 Exemplary Case Studies: Digital Initiatives Impacting Bihar

Bihar has seen several digital initiatives aimed at improving public service delivery, with mixed success. One notable example is the e-District project, designed to provide government services electronically to citizens, including certificates and licenses. Despite initial challenges, the project has streamlined many processes, reducing the time and effort required for citizens to access services. Another significant initiative is the Bihar Public Grievance Redressal System (BPGRS), an online platform allowing citizens to file complaints and track their resolution. This has enhanced transparency and accountability in addressing public grievances. Additionally, the state government has implemented digital literacy programs to bridge the digital divide, although the impact has been limited due to infrastructure constraints. The Digital Health Mission in Bihar aims to improve healthcare delivery through telemedicine and digital health records, offering a glimpse into the potential of digital initiatives. These case studies highlight both the successes and challenges in implementing digital solutions in Bihar, emphasizing the need for continuous improvement and adaptation to local contexts.

1.1.6 Human-Centered Design Principles in Government Services

Human-centered design (HCD) principles in government services prioritize the needs, experiences, and feedback of citizens in the development and implementation of public services. This approach involves empathizing with users, defining their needs, ideating solutions, prototyping, and testing iteratively. HCD ensures that services are accessible, efficient, and user-friendly, enhancing citizen satisfaction and engagement. For instance, involving citizens in the design process through surveys, focus groups, and usability testing can reveal pain points and areas for improvement. The redesign of the UK's Government Digital Service (GDS) exemplifies successful application of HCD, resulting in a more intuitive and accessible platform for accessing various public services. By focusing on the user experience, HCD minimizes barriers to access and promotes inclusivity, particularly for marginalized and vulnerable populations. Governments adopting HCD principles can create more responsive, transparent, and effective services, ultimately fostering greater public trust and participation in governance.

1.1.7 Proposed Policy Frameworks for Advancing Digital Governance

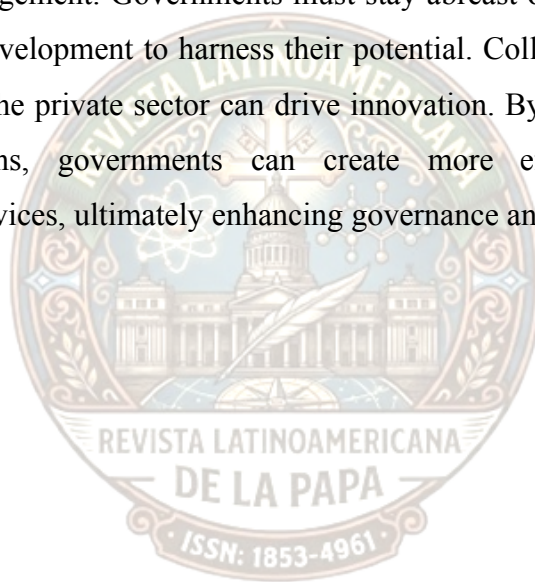
Advancing digital governance requires robust policy frameworks that address infrastructure, digital literacy, security, and inclusivity. Key components include establishing a comprehensive digital infrastructure, ensuring high-speed internet access, particularly in rural and underserved areas. Policies must promote digital literacy through education and training programs, enabling citizens to effectively use digital services. Data security and privacy are paramount, necessitating stringent regulations and safeguards to protect citizens' information. Inclusivity should be a core principle, ensuring that digital services are accessible to all, including the elderly, disabled, and those with limited technological access. Interoperability standards should be set to ensure seamless integration of various government services and platforms. Encouraging public-private partnerships can drive innovation and investment in digital technologies. Additionally, continuous evaluation and feedback mechanisms are essential to adapt and improve digital services. By implementing these policy frameworks, governments can create a more efficient, transparent, and inclusive digital governance landscape, enhancing overall public service delivery and citizen engagement.

1.1.8 Navigating Ethical and Legal Frontiers in Digital Public Services

Navigating the ethical and legal frontiers in digital public services involves addressing issues related to privacy, data security, equity, and accountability. Governments must ensure that digital services respect citizens' privacy rights and adhere to data protection laws, such as GDPR in the European Union. Ethical considerations include preventing digital exclusion by ensuring services are accessible to all citizens, regardless of socio-economic status, disability, or digital literacy. Transparent algorithms and decision-making processes are crucial to maintain trust and prevent bias in automated systems. Legal frameworks must be updated to address emerging challenges, such as cybersecurity threats and the misuse of personal data. Public consultations and stakeholder engagement are essential to develop policies that reflect societal values and ethical standards. Regular audits and oversight mechanisms can help ensure compliance with ethical and legal standards. By proactively addressing these issues, governments can build trust in digital services and create a fair, secure, and inclusive digital public service environment.

1.1.9 Anticipating Future Innovations in Digital Governance

Anticipating future innovations in digital governance involves recognizing emerging technologies and trends that can further enhance public service delivery. Artificial intelligence (AI) and machine learning will likely play a significant role in predictive analytics, personalized services, and automated decision-making. Blockchain technology promises increased transparency, security, and efficiency in government transactions and record-keeping. The Internet of Things (IoT) can enhance urban management through smart city initiatives, improving infrastructure, transportation, and public safety. 5G technology will enable faster, more reliable internet connections, facilitating advanced digital services and remote work capabilities. Virtual and augmented reality (VR/AR) can transform education, training, and public engagement. Governments must stay abreast of these advancements and invest in research and development to harness their potential. Collaborating with technology experts, academia, and the private sector can drive innovation. By proactively preparing for these future innovations, governments can create more efficient, responsive, and citizen-centric digital services, ultimately enhancing governance and public trust.



1.2 Problem Statement

Bihar, a populous state in India, faces substantial hurdles in delivering efficient government services to its citizens. Despite various initiatives, the state grapples with inadequate infrastructure, low digital literacy, and bureaucratic inefficiencies, which significantly hinder service delivery. Rural areas are particularly affected by a digital divide, where limited internet connectivity restricts access to e-governance services. This situation exacerbates issues like corruption, delays in service provision, and overall citizen dissatisfaction. Additionally, the shortage of skilled personnel to manage digital platforms compounds the problem. Therefore, the central issue is how to enhance government-citizen interaction and bridge these service gaps using digital design solutions. Leveraging digital technologies and user-centered design principles has the potential to transform public service delivery in Bihar, making it more accessible, transparent, and efficient.



1.3 Research Objective

The primary objective of this research is to explore and evaluate how digital design solutions can enhance government-citizen interaction and bridge service gaps in Bihar, India. Specifically, the study aims to:

1. Identify the current challenges and limitations in government service delivery in Bihar.
2. Assess the potential of digital design solutions to address these challenges and improve service accessibility, efficiency, and transparency.
3. Examine successful case studies of digital initiatives in Bihar and other comparable regions to identify best practices.
4. Develop a framework for implementing digital design solutions in Bihar's public administration to enhance citizen engagement and satisfaction.



1.4 Research Questions

To achieve the research objective, the following research questions will be addressed:

1. What are the primary challenges faced by citizens in accessing government services in Bihar?
2. How can digital design solutions be utilized to improve the accessibility and efficiency of these services?
3. What are the successful examples of digital initiatives in Bihar or similar contexts that have effectively bridged service gaps?
4. What framework can be developed to implement digital design solutions in Bihar's public administration?
5. How can user-centered design principles be integrated into the development and deployment of these digital solutions?



1.5 Hypothesis of the Study

The study will test the following hypotheses:

H01: Implementing digital design solutions will significantly enhance the accessibility of government services in Bihar.

H02: Digital design solutions will improve the efficiency of service delivery in Bihar's public administration.

H03: Applying user-centered design principles in developing digital solutions will increase citizen satisfaction and trust in government services in Bihar.

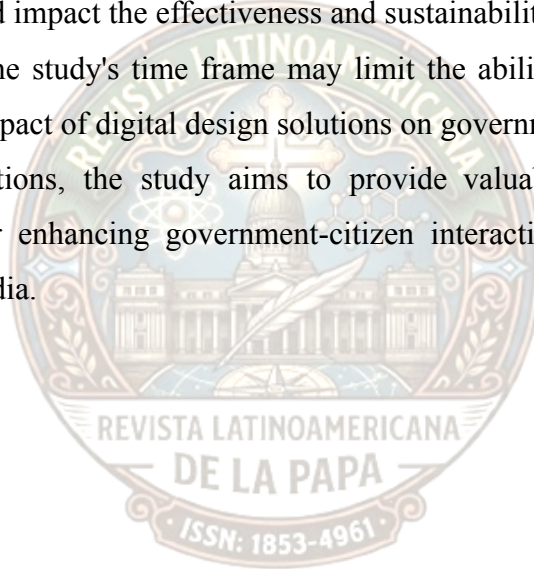
H04: Successful digital initiatives from other regions can be adapted and implemented effectively in Bihar to bridge service gaps.



1.6 Limitations of the Study

The study acknowledges several limitations that may impact the findings and conclusions:

1. **Data Availability:** Limited availability and reliability of data on government service delivery and digital infrastructure in Bihar may affect the comprehensiveness of the analysis.
2. **Regional Specificity:** The unique socio-economic and cultural context of Bihar may limit the generalizability of the findings to other regions or states.
3. **Technological Constraints:** The current technological infrastructure and resources available in Bihar may constrain the implementation of digital solutions.
4. **Resistance to Change:** Resistance from government officials and citizens to adopt new digital solutions could impact the effectiveness and sustainability of these initiatives.
5. **Time Constraints:** The study's time frame may limit the ability to conduct longitudinal assessments of the impact of digital design solutions on government-citizen interaction.
6. Despite these limitations, the study aims to provide valuable insights and practical recommendations for enhancing government-citizen interaction through digital design solutions in Bihar, India.



CHAPTER 2

LITERATURE REVIEW

2.1 Related Research Studies

Athique and Zhang (2020) examine "E-government and citizen satisfaction in developing countries: A case study of India" in *Information Systems Frontiers*. Their study investigates the impact of e-government initiatives on citizen satisfaction in India, highlighting the role of digital governance in enhancing public service delivery and governance effectiveness. In "E-governance and service delivery in India: A state-of-the-art review" (Gupta & Jana, 2018), published in the *International Journal of Public Sector Management*, Gupta and Jana provide a comprehensive review of e-governance practices and service delivery mechanisms in India. They analyze the evolution, challenges, and advancements in leveraging ICTs for improving governance outcomes across various sectors.

Baruah and Bhuyan (2016) conduct a review titled "Land records management system: A review of existing practices and future directions" in the *International Journal of Computer Applications*. Their review critically examines existing practices in land records management systems, emphasizing technological advancements and future directions for improving efficiency and transparency in land administration. In their study published in *World Development*, Bhagat and Nagarajan (2018) delve into the intricate relationship between land titling, land records, access to finance, and rural development outcomes in India. They emphasize the crucial role of secure land tenure facilitated by effective land titling systems in promoting economic development and social equity in rural areas. In his study published in *Land Use Policy*, Roy (2020) provides a detailed analysis of the challenges and opportunities in land record management in West Bengal, India. The research specifically examines the complexities and inefficiencies within the state's land administration system, highlighting issues such as outdated paper-based records, inconsistent data quality, and administrative bottlenecks that hinder effective governance and transparency.

Agarwal, Dey, and Kohli (2017) present "Digital transformation for rural development: A conceptual framework and empirical analysis from India" in *Information Technology for*

Development. Their work introduces a framework that explores how digital transformation can drive rural development in India, emphasizing both theoretical underpinnings and practical insights gained from empirical analysis. The study underscores the potential of digital technologies to empower rural communities, improve access to services, and foster economic growth.

Gavali and Patadia (2021) conduct a systematic review titled "Impact of digital technologies on rural livelihoods in developing countries" in Sustainability. Their review synthesizes existing literature to evaluate how digital technologies have influenced rural livelihoods in developing nations. They identify key trends, challenges, and opportunities associated with digital interventions, providing a comprehensive overview of the field and suggesting avenues for future research and policy.

Cao, Zhao, and Li (2019) propose "A user-centered design approach for promoting technology adoption in rural areas" in Sustainability. They advocate for a user-centered design methodology tailored to rural contexts, aiming to enhance the adoption and effectiveness of technology solutions in addressing rural development challenges. The study emphasizes the importance of understanding local needs and preferences to design more inclusive and impactful technological interventions.

Eswaran and Rai (2017) examine "E-governance and its challenges in India" in the International Journal of Information Technology and Management. Their study addresses the complexities and obstacles associated with implementing e-governance initiatives in India, focusing on issues such as infrastructure, institutional readiness, and citizen engagement. They highlight the need for adaptive strategies to overcome these challenges and leverage technology for effective governance.

Goyal and Mittal (2018) delve into "Challenges in implementation and adoption of e-governance in India" in the International Journal of Computer Applications. They analyze specific barriers hindering the widespread adoption of e-governance practices in India, including technological constraints, bureaucratic resistance, and inadequate stakeholder

collaboration. Their research underscores the importance of addressing these challenges to achieve comprehensive e-governance reforms.

Ahmed and Tiwari (2020) critically analyze "Land administration reforms in India: A critical analysis of the use of information technology" in Land Use Policy. They assess the role of information technology in facilitating land administration reforms in India, evaluating its impact on transparency, efficiency, and equity in land governance. Their study provides insights into the complexities of integrating IT solutions into land administration systems and proposes recommendations for policy and practice improvements.

Yuan, Shen, and Gong (2018) examine "Land administration systems and their modernization in developing countries: A comparative study" published in Land Use Policy. Their comparative analysis delves into the challenges and opportunities associated with modernizing land administration systems in developing countries. By drawing parallels across different contexts, they provide insights into strategies that can facilitate effective land governance and sustainable development.

Richard Heeks (2018) in "Digital inclusion: Conceptualizing the problem of user inequalities in the digital age," published in Social Science Computer Review, addresses the issue of digital inequality. He conceptualizes how disparities in access, skills, and usage of digital technologies create social and economic divides, thereby hindering inclusive development in the digital era. Heeks argues for policies and interventions that can mitigate these inequalities and promote equitable digital inclusion.

Alajarmeh (2021) conducted an exploratory cross-country study aimed at evaluating the accessibility of public health websites. This study delved into how well these websites cater to users with diverse accessibility needs, highlighting areas where improvements are necessary to enhance usability and inclusivity in accessing health-related information online.

Sik-Lanyi and Orban-Mihalyko (2019) focused on assessing the usability of European health-related websites through comprehensive accessibility testing. Their research aimed to identify specific barriers that users may encounter when navigating these websites, proposing strategies to make them more accessible and user-friendly.

Ross et al. (2017) approached the assessment of mobile application accessibility within the framework of epidemiology. Their study examined a large-scale sample of mobile applications designed for healthcare purposes, aiming to understand how well these apps accommodate users with disabilities and what measures can be taken to improve their accessibility.

Vazquez et al. (2018) reviewed e-health interventions targeted at adults and aging populations with intellectual disabilities. Their comprehensive analysis highlighted various digital health solutions tailored to meet the specific needs of these user groups, emphasizing the potential benefits and challenges associated with implementing such interventions.

Jones et al. (2018) provided a critical analysis of the current landscape of mobile healthcare applications for individuals with disabilities. Their study identified existing gaps in accessibility and functionality, pointing out areas for future research and development to better meet the healthcare needs of people with disabilities through mobile technology.

Yu et al. (2019) conducted a study on an mHealth (mobile health) application designed for users with dexterity impairments. Their research focused on evaluating the accessibility features of the app, aiming to enhance usability for individuals facing challenges with fine motor skills, thus improving their ability to engage with digital health tools effectively.

Patrick et al. (2020) explored the use of technology and social media among adult patients with intellectual and/or developmental disabilities. Their study investigated how these individuals utilize digital platforms for social interaction, information access, and support, highlighting both opportunities and challenges in leveraging technology for inclusive social participation.

Jones et al. (2018) presented findings from a preliminary survey on mobile healthcare and its impact on people with disabilities. Their research, published in Springer Verlag, examined the current state of mobile health technologies in addressing the healthcare needs of individuals with disabilities, identifying gaps and proposing recommendations for future development and implementation strategies.

De Oliveira et al. (2016) evaluated the accessibility of smart home technologies for users with visual disabilities, focusing on open-source mobile applications for home automation. Their study, conducted at the Federal University of Lavras, Brazil, assessed the usability and effectiveness of these technologies in enhancing independent living and accessibility for visually impaired individuals within their home environments.

David (2013) explored the concept of internalized oppression within marginalized groups in the context of psychology. His work, published by Springer Publishing Company, delves into the psychological processes through which individuals from marginalized backgrounds internalize societal prejudices and its impact on their self-perception and well-being.

Mheta and Mashamba-Thompson (2017) outlined a scoping review protocol focusing on barriers and facilitators affecting access to maternal health services for women with disabilities. Their systematic review aimed to identify key factors influencing healthcare access and delivery for this vulnerable population, informing strategies to improve maternal health outcomes through inclusive healthcare policies and practices.

Chiwandire and Vincent (2017) conducted a study focusing on wheelchair users' access and exclusion within South African higher education institutions. Published in the African Journal of Disability, their research explored the barriers faced by wheelchair users in accessing educational facilities and the broader implications for inclusive education policies in South Africa.

The United Nations (2007) adopted the Convention on the Rights of Persons with Disabilities (CRPD), emphasizing the rights and dignity of individuals with disabilities globally. This international treaty outlines principles for non-discrimination, accessibility, and full inclusion in all aspects of society, including healthcare, education, employment, and political participation.

Brett et al. (2014) conducted a systematic review on the impact of patient and public involvement in health and social care research. Published in Health Expectations, their study mapped the contributions of patient and public involvement to research design,

implementation, and outcomes, highlighting its importance in promoting patient-centered approaches and enhancing the relevance and quality of research in healthcare settings.

Williams and Moore (2011) discussed the concept of universal design in biomedical research, emphasizing the inclusion of persons with disabilities in mainstream research studies. Their work, published in *Science Translational Medicine*, advocates for the incorporation of universal design principles to ensure that research methodologies and outcomes are accessible and relevant to individuals with disabilities, thereby promoting equity and inclusivity in biomedical research practices.

Rios et al. (2016) explored methods for conducting accessible research by actively involving people with disabilities in public health, epidemiological, and outcomes studies. Their study, published in the *American Journal of Public Health*, emphasized the importance of inclusive research practices to ensure that the perspectives and needs of individuals with disabilities are adequately represented in health-related studies. By incorporating accessible research methods, such as inclusive recruitment strategies and adaptive data collection techniques, the authors aimed to enhance the validity and relevance of public health research for individuals with disabilities.

Johansson et al. (2015) investigated user participation in the context of mental and cognitive disabilities, as presented in the proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility (ASSETS '15). Their research focused on understanding the challenges and opportunities for involving users with mental and cognitive disabilities in the design and evaluation of accessible technologies. The study highlighted strategies to promote meaningful user engagement and ensure that technology solutions meet the diverse needs of this user group.

Poli et al. (2019) developed a research tool designed to measure non-participation among older adults in digital health research. Published in *BMC Public Health*, their study aimed to address barriers that prevent older individuals from participating in digital health studies, such as technological literacy, access to digital devices, and concerns about privacy and data security. The research tool provided insights into reasons for non-participation, enabling

researchers to develop more inclusive and accessible recruitment strategies for digital health interventions targeting older populations.

Carroll et al. (2018) proposed a study protocol focused on enabling participation among disabled young people in health-related research. Published in BMC Public Health, their protocol outlined methods to facilitate the involvement of disabled youth in research processes, ensuring their voices are heard and their unique perspectives are integrated into health promotion initiatives and policy development. By employing inclusive and participatory research approaches, the study aimed to empower disabled youth to actively contribute to discussions on health issues affecting their community.

Peters et al. (2020) contributed a chapter on scoping reviews in the JBI Manual for Evidence Synthesis. Published by The Joanna Briggs Institute, this chapter provides comprehensive guidance on conducting scoping reviews, emphasizing their utility in mapping the extent and nature of research evidence on a particular topic. The chapter outlines the methodological framework, including protocol development, search strategy formulation, study selection criteria, data extraction methods, and synthesis approaches. It serves as a practical resource for researchers and practitioners seeking to undertake scoping reviews to inform healthcare practice and policy.

Ouzzani et al. (2016) introduced Rayyan, a web and mobile application designed for systematic reviews. Published in Systematic Reviews, their study highlights Rayyan's functionality in facilitating the systematic review process by enabling efficient screening, selection, and organization of research studies. The application supports collaboration among reviewers, enhances transparency in review procedures, and streamlines data management, thereby improving the rigor and reproducibility of systematic reviews across various disciplines.

Peters et al. (2015) provided guidance on conducting systematic scoping reviews in the International Journal of Evidence-Based Healthcare. Their article offers a methodological framework for researchers to conduct systematic scoping reviews effectively. It emphasizes the importance of clearly defining research questions, selecting appropriate study designs,

conducting comprehensive literature searches, and synthesizing findings to identify gaps in evidence and inform future research directions. The guidance aims to enhance the methodological rigor and transparency of scoping review processes in evidence synthesis.

DeForte et al. (2020) conducted a focus group study to assess the usability of a mobile app designed to improve literacy among children with hearing impairment. Published in JMIR Human Factors, their research involved engaging end-users, including children with hearing impairment and their caregivers, to evaluate the app's usability, functionality, and user interface design. The study identified usability challenges and preferences among the target user group, providing insights to enhance the app's accessibility and effectiveness in supporting literacy development for children with hearing impairment.

Hill and Breslin (2016) refined an asynchronous telerehabilitation platform for speech-language pathology in a study published in Frontiers in Human Neuroscience. They employed an iterative design process involving end-users, such as speech-language pathologists and patients, to enhance the platform's usability, functionality, and user experience. The study emphasized the importance of user-centered design principles in developing telerehabilitation technologies, aiming to optimize communication and therapeutic outcomes for individuals receiving speech-language pathology services remotely.

Kerkhof et al. (2017) conducted a study published in the Journal of Rehabilitation and Assistive Technologies Engineering to identify user requirements for selecting apps aimed at people with mild dementia. The researchers focused on enabling meaningful activities and self-management through app functionalities. They employed qualitative methods to gather insights from users, caregivers, and healthcare professionals, aiming to enhance the usability and effectiveness of dementia apps. The study's findings contribute to the development of user-centered apps that support cognitive and functional abilities among individuals with mild dementia.

Lu et al. (2017) developed and evaluated a cognitive training game for older people, published in Frontiers in Psychology. Their research utilized a design-based approach to

create a game specifically tailored to enhance cognitive functions in older adults. The study incorporated user feedback and iterative design principles to optimize game mechanics and user interface elements. Evaluation outcomes highlighted improvements in cognitive performance and user engagement, underscoring the game's potential as a non-pharmacological intervention for cognitive health in aging populations.

Malu and Findlater (2016) presented a paper at the 10th EAI International Conference on Pervasive Computing Technologies for Healthcare, focusing on accessible health and fitness tracking for individuals with mobility impairments. Their research addressed barriers faced by users with mobility impairments in accessing and using health and fitness tracking apps. The study proposed design considerations and accessibility guidelines to improve app usability and functionality, aiming to promote active lifestyles and health monitoring among people with mobility limitations.

Winberg et al. (2017) explored the utilization of apps for health management among individuals with multiple sclerosis, Parkinson's disease, and stroke, published in *Studies in Health Technology and Informatics*. Their research identified barriers and facilitators influencing app adoption and usage in clinical settings. The study involved qualitative interviews and surveys with patients and healthcare providers to assess app functionalities, usability issues, and perceived benefits. Findings highlighted the importance of personalized app features and healthcare professional support in enhancing app engagement and health outcomes for chronic disease management.

Zafeiridi et al. (2018) conducted a mixed-methods evaluation of the CAREGIVERSPRO-MMD, a web-based platform designed for people with memory problems and their caregivers. Published in *JMIR Formative Research*, the study aimed to assess the usability of the platform through qualitative and quantitative methods. The research included user feedback, usability testing, and surveys to evaluate user satisfaction, functionality, and effectiveness in supporting memory care management. Findings highlighted the platform's utility in enhancing caregiver support and user engagement, emphasizing the importance of user-centered design in digital health solutions for memory-related issues.

Madrigal-Cadavid et al. (2020) developed a mobile app providing drug information tailored for people with visual impairments, published in Research in Social and Administrative Pharmacy. The study focused on the app's design and development to address accessibility challenges faced by visually impaired users in accessing essential drug information. Utilizing user-centered design principles, the research incorporated feedback from visually impaired individuals to optimize app features such as voice navigation, text-to-speech functionality, and screen reader compatibility. Evaluation outcomes underscored the app's effectiveness in improving medication management and accessibility for visually impaired users.

Singanamalla et al. (2019) presented PocketATM at the 10th International Conference on Information and Communication Technologies and Development. Their research aimed to enhance ATM accessibility for people with disabilities in India through understanding user needs and optimizing ATM design. The study employed participatory design methods and user feedback to identify accessibility barriers and propose solutions, including tactile interfaces, audio cues, and improved navigation features. The findings highlighted the importance of inclusive design in promoting financial inclusion and accessibility for diverse user groups in digital banking services.

Zhou et al. (2020) conducted a qualitative single-subject study published in JMIR Mhealth Uhealth, focusing on making self-management mobile health apps accessible to people with disabilities. The research aimed to identify usability challenges and preferences of users with disabilities in using self-management apps. Through in-depth interviews and usability testing, the study explored user experiences, accessibility barriers, and design recommendations to improve app accessibility and user engagement. Findings emphasized the need for accessible design features, such as customizable interfaces and assistive technology integration, to enhance app usability and support self-management among users with disabilities.

Thirumalai et al. (2018) developed and evaluated TEAMS, a tailored telerehabilitation mHealth app for individuals with multiple sclerosis (MS). Published in JMIR Mhealth Uhealth, the study employed a participant-centered approach to app development and usability testing. Researchers collaborated with MS patients and healthcare providers to co-design app functionalities, including exercise programs, symptom tracking, and remote

monitoring capabilities. Evaluation outcomes highlighted the app's effectiveness in improving adherence to exercise regimens, enhancing patient-provider communication, and promoting self-management among individuals with MS.

Bhattacharjya et al. (2019) assessed the usability and consistency of mRehab, a mobile rehabilitation system integrating smartphone technology and 3D printing. Published in the Journal of NeuroEngineering and Rehabilitation, the study focused on evaluating the system's usability through user testing and clinical assessments. Researchers collaborated with rehabilitation specialists and users to customize device interfaces, optimize functionality, and assess rehabilitation outcomes. Findings underscored the system's potential in enhancing rehabilitation therapies, personalized treatment plans, and patient engagement through innovative technology solutions.

Groussard et al. (2018) explored the development and evaluation of mobile services for individuals with head injuries from a participatory design perspective. Published in Neuropsychological Rehabilitation, the study emphasized involving users throughout the design process to ensure the relevance and usability of mobile services. Researchers collaborated with individuals with head injuries, caregivers, and healthcare professionals to co-design and evaluate mobile applications addressing cognitive rehabilitation, daily living support, and social interaction. Findings highlighted the importance of user engagement in enhancing app acceptance, usability, and effectiveness in supporting individuals with head injuries in daily activities and rehabilitation.

Furberg et al. (2018) developed a digital decision support tool aimed at enhancing decisional capacity for clinical trial consent processes. Published in JMIR Research Protocols, the study focused on designing and evaluating the tool's effectiveness in improving understanding and decision-making among potential clinical trial participants. Researchers employed a user-centered approach, integrating feedback from stakeholders, including patients, caregivers, and healthcare providers, to optimize tool features such as multimedia content, interactive modules, and decision aids. Evaluation outcomes underscored the tool's potential to empower individuals in making informed decisions about clinical trial participation, highlighting its role in enhancing health literacy and informed consent processes.

Lazar et al. (2018) detailed the co-design process of a smartphone app designed to help individuals with Down syndrome manage their nutritional habits. Published in the Journal of Usability Studies, the study utilized a participatory approach involving individuals with Down syndrome, caregivers, and nutrition experts in app development and evaluation. Researchers focused on addressing user needs and preferences through iterative design cycles, incorporating features such as personalized dietary recommendations, meal tracking, and health education resources. Evaluation findings highlighted positive user experiences, improved nutritional awareness, and enhanced self-management capabilities among individuals with Down syndrome using the app.

Ferati et al. (2018) applied a participatory design approach to Internet of Things (IoT) technology by co-designing a smart shower for people with disabilities. Published in the book "Universal Access in Human-Computer Interaction," the study emphasized collaboration with users, caregivers, and accessibility experts to create an inclusive IoT solution. Researchers integrated customizable features, remote control capabilities, and sensory feedback mechanisms into the smart shower design to accommodate diverse user needs and preferences. Evaluation outcomes underscored the smart shower's effectiveness in promoting independence, comfort, and accessibility for individuals with disabilities in daily hygiene routines.

Blair and Abdullah (2019) investigated the needs and challenges of using conversational agents (CAs) for deaf older adults. Presented at the Conference Companion Publication of the 2019 ACM Conference on Computer Supported Cooperative Work and Social Computing, the study explored user interactions with CAs and identified barriers such as speech recognition limitations, language preferences, and accessibility concerns. Researchers engaged deaf older adults and assistive technology experts to address usability issues and enhance CA functionalities for improved communication, social interaction, and accessibility in digital environments. These summaries provide insights into each study's objectives, methodologies, key findings, and contributions to advancing research and practice in digital health interventions, decision support tools, assistive technologies, IoT applications, and accessibility solutions for diverse user populations.

Lam MY et al. (2015) explored perceptions of technology and its therapeutic applications for individuals with hemiparesis, based on findings from adult and pediatric focus groups. Published in JMIR Rehabilitation and Assistive Technologies, the study aimed to understand user perspectives on technology use in therapeutic contexts. Researchers conducted focus groups involving adults and children with hemiparesis, caregivers, and healthcare professionals. They explored attitudes towards technology, its perceived benefits, barriers to adoption, and preferences for therapeutic applications. Key themes included usability concerns, motivation for technology use, expectations for therapy outcomes, and suggestions for improving technology relevance and effectiveness in rehabilitation settings.

Glaser NJ et al. (2017) focused on the formative design of "Epilepsy Journey," a web-based executive functioning intervention for adolescents with epilepsy. Published in the Journal of Formative Design in Learning, the study aimed to develop an interactive intervention targeting executive function deficits in adolescents with epilepsy. Researchers employed iterative design processes involving epilepsy specialists, educators, and adolescents to refine intervention components, including goal-setting tools, cognitive exercises, and educational resources. Evaluation highlighted the intervention's potential in supporting self-management skills, enhancing medication adherence, and improving quality of life among adolescents with epilepsy through tailored, accessible digital interventions.

Albouys-Perrois J et al. (2018) advanced towards a multisensory augmented reality (AR) map for blind and low vision individuals. Presented at the CHI Conference on Human Factors in Computing Systems, the study focused on developing an inclusive AR navigation tool using multisensory feedback. Researchers collaborated with blind and low vision users, AR developers, and accessibility experts to integrate auditory, tactile, and haptic cues into the AR map interface. Evaluation emphasized user-centered design principles, including usability testing, to enhance navigation accuracy, spatial awareness, and independence for blind and low vision individuals in indoor and outdoor environments.

Stearns L et al. (2018) designed an augmented reality (AR) magnification aid tailored for low vision users. Presented at the ACM SIGACCESS Conference on Computers and Accessibility, the study aimed to improve visual acuity and task performance through AR

technology. Researchers engaged low vision users, optometrists, and AR specialists in iterative design cycles to optimize magnification algorithms, user interface elements, and interaction techniques. Evaluation outcomes highlighted the aid's effectiveness in enhancing reading speed, visual comfort, and task completion for individuals with varying degrees of visual impairment in real-world settings.

Daveler B et al. (2015) focused on participatory design and validation of a mobility enhancement robotic wheelchair. Published in the Journal of Rehabilitation Research and Development, the study aimed to co-design a robotic wheelchair with end-users, caregivers, and rehabilitation professionals. Researchers integrated user feedback to enhance wheelchair mobility, safety features, and user interface accessibility. Evaluation emphasized usability testing and user trials to validate the wheelchair's effectiveness in improving independence, maneuverability, and user satisfaction among individuals with mobility impairments.

Leporini B et al. (2018) explored home automation solutions for independent living in the context of accessible technologies. Presented at the Internet of Accessible Things conference, the study aimed to enhance home environments for individuals with disabilities through IoT technologies. Researchers collaborated with accessibility experts, smart home developers, and end-users to design inclusive IoT applications for home automation. Key features included voice-controlled devices, environmental sensors, and adaptive lighting systems to promote autonomy, safety, and comfort for individuals with diverse disabilities in home settings.

Kim WJ et al. (2018) studied the impact of UX design guidelines on information accessibility for visually impaired users in mobile health apps. Presented at the IEEE International Conference on Bioinformatics and Biomedicine, the study aimed to enhance user experience (UX) by implementing accessibility features. Researchers evaluated the effectiveness of design guidelines, including text-to-speech functionality, screen reader compatibility, and high contrast interfaces. User testing involved visually impaired participants to assess navigation efficiency, information comprehension, and overall usability improvements in mobile health applications. Findings emphasized the importance of

inclusive UX design in promoting equitable access to health information and services for visually impaired users.

Arnott J et al. (2018) explored the involvement of people with cognitive and communication impairments in mobile health app design. Presented at the ACM SIGACCESS Conference on Computers and Accessibility, the study focused on participatory design methods to ensure app accessibility. Researchers collaborated with individuals with diverse cognitive disabilities, caregivers, and app developers to co-create inclusive design features. The process included usability testing, iterative feedback loops, and interface adjustments to enhance app usability and accessibility. Findings highlighted the significance of user engagement in improving app functionality, navigation clarity, and information comprehension for individuals with cognitive impairments.

Schmutz S et al. (2018) investigated the effects of accessible website design on nondisabled users, considering age and device as moderating factors. Published in *Ergonomics*, the study examined how inclusive design practices impact user experience across different demographic groups. Researchers conducted usability tests with nondisabled participants using varied devices (e.g., desktops, tablets, smartphones) to evaluate interface accessibility, navigation efficiency, and content comprehension. Results indicated age-related differences in usability perceptions, emphasizing the need for adaptable design strategies to accommodate diverse user preferences and device capabilities in digital environments.

Horton S, Sloan D. (2014) discussed accessibility in practice through a process-driven approach in inclusive designing. Published in "Inclusive Designing," the chapter outlined methodologies for integrating accessibility into design processes. Authors emphasized systematic approaches to identify, prioritize, and implement inclusive design features across digital platforms. Case studies and practical guidelines highlighted the benefits of proactive accessibility planning, including improved user engagement, compliance with accessibility standards, and enhanced usability for individuals with disabilities. The framework advocated for collaboration among designers, developers, and accessibility experts to foster inclusive digital environments.

Fuglerud KS (2014) addressed the challenges of diversity in ICT through inclusive design practices. Published by the University of Oslo, Faculty of Humanities, the report explored theoretical perspectives and practical implications of designing inclusive ICT solutions. The study emphasized user diversity, including age, disability, and cultural backgrounds, as critical factors influencing design decisions. Authors advocated for inclusive design methodologies that prioritize user participation, usability testing, and continuous feedback to ensure equitable access and usability of ICT products across diverse user groups.

Van der Kleij R et al. (2019) explored eHealth in primary care, focusing on concepts, conditions, and challenges. Published in the European Journal of General Practice, this review highlighted the integration of electronic health technologies in primary healthcare settings. The article discussed key concepts such as telehealth, electronic health records (EHRs), and patient portals, examining their potential benefits and challenges in improving healthcare delivery. Authors emphasized the importance of infrastructure, patient-provider communication, and privacy concerns as critical factors influencing the implementation and effectiveness of eHealth solutions in primary care.

Were MC et al. (2019) presented a systematic approach to equity assessment for digital health interventions, using mobile personal health records as a case example. Published in the Journal of the American Medical Informatics Association, the study focused on assessing disparities in access, adoption, and outcomes of digital health technologies. Researchers applied equity-focused evaluation frameworks to identify barriers and facilitators impacting underserved populations' utilization of mobile health records. Findings underscored the need for inclusive design, culturally competent interventions, and policy initiatives to mitigate digital health disparities and promote equitable access to healthcare information.

Veinot TC et al. (2018) critically examined the unintended consequences of informatics interventions on healthcare inequality. Published in the Journal of the American Medical Informatics Association, the article discussed how well-intentioned informatics initiatives may exacerbate disparities among vulnerable populations. The study reviewed empirical evidence and theoretical frameworks to explore factors contributing to digital divides, including technology access, literacy, and socio-economic disparities. Authors advocated for

ethical considerations, user-centered design, and equity-oriented policies to mitigate unintended consequences and foster inclusive healthcare innovation.



2.2 Research Gap

While efforts are being made to enhance government-citizen interaction through digital design solutions in Bihar, India, there is a notable gap in understanding the specific challenges and opportunities for bridging service gaps effectively. There is limited empirical research that systematically evaluates the impact of digital design solutions on improving government service delivery and citizen engagement in Bihar. Additionally, there is a need for studies that explore the barriers hindering the adoption of digital platforms by diverse segments of the population, including marginalized communities. Addressing these gaps could provide valuable insights for policymakers and practitioners aiming to optimize digital strategies for more inclusive and effective governance in Bihar.



CHAPTER-3

RESEARCH METHODOLOGY

In this chapter, the research methodology employed to investigate and address the topic of enhancing government-citizen interaction through digital design solutions in Bihar, India, is elucidated. The chapter outlines the research approach, design, data collection methods, sampling strategy, and data analysis techniques utilized to achieve the research objectives effectively.

3.1 Research Approach

The research adopts a mixed-methods approach to comprehensively explore and understand the dynamics of government-citizen interaction in Bihar. This approach combines qualitative and quantitative methods to capture diverse perspectives, experiences, and data related to digital design solutions aimed at bridging service gaps. Qualitative methods are employed to delve into the nuances of citizen experiences and perceptions, while quantitative methods facilitate the measurement and analysis of key variables and trends.

3.2 Research Design

The research design is primarily exploratory and descriptive, aiming to uncover insights into the current state of government-citizen interaction in Bihar and the potential impact of digital design solutions. It involves both cross-sectional and longitudinal components, allowing for a holistic examination of the phenomenon over time and across different contexts within the state.

3.3 Data Collection Methods

Multiple data collection methods are employed to gather comprehensive and rich data:

Surveys: Structured surveys are conducted to gather quantitative data on citizen perceptions, satisfaction levels, and preferences regarding government services and digital interfaces.

Interviews: In-depth interviews with key stakeholders including government officials, digital designers, and citizens are conducted to explore qualitative aspects such as challenges, opportunities, and specific needs related to enhancing interaction through digital solutions.

Focus Groups: Focus group discussions are organized with diverse groups of citizens to elicit collective insights, opinions, and suggestions on improving government-citizen interaction through digital platforms.

Document Analysis: Existing documents, reports, policies, and case studies related to digital initiatives and government service delivery in Bihar are analyzed to provide contextual background and supplementary data.

Sampling Strategy

The sampling strategy is purposive and stratified to ensure representation across various demographic, socio-economic, and geographic segments within Bihar. Participants are selected based on their relevance to the study objectives and their potential to provide insightful perspectives on government-citizen interaction and digital solutions.

3.4 Data Analysis Techniques

Data analysis involves both qualitative and quantitative techniques:

Qualitative Analysis: Thematic analysis is employed to identify recurring themes, patterns, and categories from interviews, focus groups, and document analysis. NVivo or similar software may be used to facilitate data coding and theme identification.

Quantitative Analysis: Statistical techniques such as descriptive statistics, correlation analysis, and regression analysis are applied to analyze survey data and quantify relationships between variables related to citizen satisfaction, digital interface effectiveness, and service delivery gaps.

3.5 Ethical Considerations

Ethical guidelines and protocols are strictly followed throughout the research process to ensure confidentiality, informed consent, and respect for participants' rights. All data collected is anonymized and securely stored to protect participants' privacy.



CHAPTER-4**ANALYSIS AND DATA INTERPRETATION****4.1 Social Knowledge Networks**

Studying Social Knowledge Networks in Bihar's Agriculture Sector involves exploring innovative approaches to disseminating agricultural advancements in a region traditionally reliant on one-way communication from experts to farmers. Embracing the Agricultural Innovation System (AIS), this collaborative framework integrates farmers, government agencies, and private businesses into a cohesive network where information flows dynamically. Unlike conventional approaches, AIS fosters a social knowledge network characterized by interconnectedness among these diverse groups, facilitating the evolution and dissemination of agricultural information. While existing studies in India underscore the efficacy of AIS, specific research tailored to Bihar is crucial. Such studies aim to meticulously map the involved groups, delineate their interactions with farmers, and scrutinize network structures to identify pivotal information sharers. By pinpointing barriers obstructing information flow within these networks, researchers can uncover opportunities to enhance the adoption of new technologies and practices among Bihar's farmers. Ultimately, this nuanced understanding of social knowledge networks equips policymakers and practitioners with tailored strategies to bolster agricultural development and resilience in Bihar.

The theoretical framework for this study draws on seminal works (Borgatti and Everett, 2006; Freeman, 1979; Landherr et al., 2010) examining network structures and characteristics. Hermans et al. (2013) emphasize the significance of actor affiliations over individual capabilities and roles within innovation systems, a perspective highly relevant to Agricultural Information Systems (AIS). In Bihar's context, understanding the network of actors and their interactions is pivotal for assessing the efficacy of the innovation system (Van Mierlo et al., 2010). This study focuses on identifying key informants and information sources within Bihar's agricultural sector, highlighting their interconnected relationships. The hypothetical network model (depicted in Figure 4.1) represents these actors (A_i) and their linkages (E_j),

essential for comprehending the dynamics influencing the dissemination of agricultural knowledge and technologies.

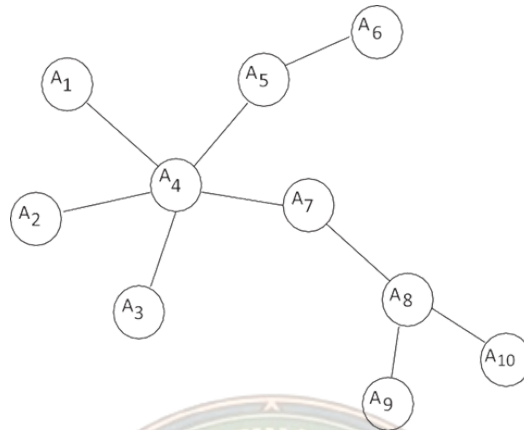


Figure 4.1: Hypothetical network

In the specific context of Bihar, a one-sided (undirected) network analysis reveals that Actor A4 maintains connections with a larger number of other actors, indicating a higher degree of connectivity. Conversely, Actor A7, despite having fewer connections, occupies a pivotal position between two distinct sub-networks within the agricultural information system. A7's centrality is highlighted by its shorter distance to other actors, implying fewer intermediaries are needed for information flow. This underscores the critical role of linkages and the strategic positioning of actors within Bihar's network. Identifying these central actors is essential for optimizing the dissemination of agricultural technologies, ensuring efficient and effective knowledge exchange across the network. This approach is grounded in the principles of social network analysis and guided our framework for understanding and assessing the network structure in Bihar. This research project focused on understanding the flow of agricultural information among farmers in Bihar, India. Bihar is a state with rich natural resources but struggles with low productivity and weak governmental support for agriculture. Researchers examined how information travels between various groups involved in agriculture, including government agencies, private businesses, and individual farmers. To map these information networks, they interviewed 111 key informants across 6 districts in

Bihar. These informants were people in important positions who connect with farmers on agricultural matters, such as government extension workers, agricultural scientists, and even progressive farmers themselves. The researchers interviewed these key informants throughout the entire network, from village level representatives all the way up to officials in the state capital. The interviews conducted as part of this study provided valuable insights into the existing social and knowledge systems within Bihar's agricultural sector. These systems encompassed a diverse range of stakeholders, each playing crucial roles in the dissemination and exchange of agricultural information. By analyzing these networks, the study aimed to uncover their structural characteristics and the dynamics of relationships among different actors.

Understanding these social and knowledge networks is pivotal for identifying the prominent channels of communication and information exchange across various geographical locations within Bihar. The study revealed that these channels are often influenced and governed by similar structures imposed by state or central government agencies. This uniformity in governance ensures consistency in how agricultural information flows through different levels of the administrative hierarchy, from grassroots extension workers to higher-level decision-makers. The research highlighted that while the general framework of communication channels may be similar across different locations within Bihar, the effectiveness and efficiency of these channels can vary significantly. Factors such as geographical disparities, socio-economic conditions, and infrastructural limitations can influence how information travels and is utilized by farmers and other stakeholders.

By mapping these networks and understanding their intricacies, the study aimed to provide valuable insights for policymakers and agricultural development practitioners. It underscored the importance of optimizing these communication channels to enhance the dissemination of critical agricultural information, thereby improving productivity, sustainability, and livelihoods across rural Bihar. The study emphasized the need for tailored approaches that consider local contexts and challenges while leveraging existing social and knowledge networks to foster inclusive agricultural development in Bihar.

Analytical tools

In this study, Social Network Analysis (SNA) was employed as a methodological approach to analyze and depict the Social Knowledge Networks (SKNs) among key informants across six districts in Bihar. SNA is a robust methodology used to map and understand the relationships and interactions among actors (nodes) within a specific social context (Borgatti et al., 2009; Clark, 2006). The analysis focused on identifying key informants and their relationships with various information sources, shedding light on how agricultural knowledge is disseminated and accessed in the region. Network maps were generated to visually represent these relationships, where actors (nodes) are connected by lines or arrows to indicate the flow of information. The maps, created using tools such as Netdraw, incorporated attribute data to distinguish actors based on their roles or positions within the network (Bartholomay and Chazdon, 2011). Nodes positioned centrally in the network are considered more influential or important in terms of information dissemination, while those on the periphery or isolated play smaller roles.

Attributes of the actors, such as their roles as District Agricultural Officers, Block Agricultural Officers, Kisan Salahakars, or representatives from NGOs and research institutions, were crucial in characterizing the network. This characterization helped in understanding which actors served as major sources of agricultural knowledge and how they were interconnected within the network. Centrality measures were employed to quantitatively assess the importance of nodes within the network. These measures included Degree centrality, which indicates the number of direct connections a node has; Betweenness centrality, measuring a node's influence over the flow of information between other nodes; Closeness centrality, assessing how quickly a node can access information from others; and Eigenvector centrality, which considers a node's connections to other well-connected nodes (Freeman, 1979; Borgatti, 2005).

These centrality measures provide insights into the key players within the SKN, highlighting nodes that are pivotal in information dissemination due to their high connectivity and influence. For instance, nodes with high Degree centrality may be trusted sources of information, while those with high Betweenness centrality may act as bridges between different sub-networks within Bihar's agricultural information system. The application of SNA and centrality measures in this study facilitated a comprehensive understanding of

Bihar's agricultural knowledge networks. By revealing the structure, characteristics, and dynamics of these networks, the study aimed to inform strategies for enhancing the dissemination of agricultural technologies and practices, ultimately contributing to improved agricultural outcomes in the region.

$$\sigma D(x) = \sum_{i=1}^n a_{ix}, \quad (1)$$

Closeness centrality in network analysis quantifies how central a node is based on its average distance to all other nodes in the network. It reflects the efficiency of a node in spreading information or influence throughout the network. Nodes with higher closeness centrality have shorter average paths to other nodes, indicating that they can disseminate information more quickly and efficiently across the network. It is defined as the reciprocal of the sum of its shortest path distances to all other nodes in the network (Freeman, 1979, as cited in Landherr, Friedl, and Heidemann, 2010)

$$\sigma C(x) = \frac{1}{\sum_{i=1}^n d_G(x, i)}, \quad (2)$$

In simpler terms, closeness centrality measures how quickly information originating from a node can reach all other nodes in the network. Nodes with high closeness centrality are well-positioned to efficiently communicate or disseminate information because they require fewer steps to interact with other nodes. Understanding closeness centrality is crucial in various applications such as identifying key individuals in social networks for effective communication strategies, determining critical infrastructure nodes in transportation or utility networks, and optimizing information flow in organizational or technological networks.

where σC is the closeness centrality for node x ; d_G is a number of edges in the geodesics linking nodes i to j .

$$\sigma B(x) = \sum_i^n \sum_{<j}^n b_{ij}(x), \quad (3)$$

Betweenness centrality in network analysis quantifies the extent to which a node acts as a bridge along the shortest paths between pairs of other nodes in the network. It measures the control or influence a node exerts over the flow of information or resources between other nodes. Nodes with high betweenness centrality are strategically positioned as intermediaries that can control or facilitate communication between different parts of the network.

$$b_{ij}(x) = \frac{g_{ij}(x)}{g_{ij}}, \quad (4)$$

In simpler terms, betweenness centrality identifies nodes that occupy critical positions in the network's structure, enabling them to control the flow of information or resources. Nodes with high betweenness centrality are important in maintaining efficient communication and cohesion within the network. They can act as brokers or gatekeepers, influencing how information spreads and facilitating collaboration between different parts of the network.

Understanding betweenness centrality helps in various applications such as identifying influential individuals in social networks, optimizing infrastructure networks by locating critical nodes for efficient transportation or communication, and enhancing organizational effectiveness by managing key connectors in information flow.

$$\lambda e_i = \sum_j R_{ij} e_j, \quad (5)$$

where R is the matrix of relationship; e is the eigenvalue of R; λ is the associated eigenvalue, it should be a constant to have a non-zero solution

4.2 Bihar's agricultural information network

The study investigates the roles of key informants within Bihar's agricultural information network, aiming to understand how various actors contribute to the dissemination of agricultural knowledge and technologies. Bihar, despite its abundant natural resources, faces challenges like low productivity and inadequate institutional support (Joshi, Tripathi, and Gautam, 2012). The network includes government agencies, cooperatives, NGOs, Krishi

Vigyan Kendras (KVKs), private input dealers, service providers/progressive farmers, and members of panchayats, each playing distinct roles in information dissemination. Government officials from the Department of Agriculture constitute a significant portion of key informants, responsible for policy formulation and implementation. Progressive farmers, comprising the second-largest group, act as crucial intermediaries between formal institutions and farmers, sharing information on agricultural practices and technologies. Their role extends to demonstrating technologies and conducting field trials, which enhances their credibility among fellow farmers. Other key informants include private input dealers supplying agricultural inputs, service providers offering farming services, and panchayat members facilitating local governance and communication channels.

The study employed a structured questionnaire administered to 111 key informants across six districts in Bihar, namely Begusarai, Samastipur, Vaishali, Lakhisarai, Arah, and Buxar. Key informants were identified through a snowball sampling method, starting with focus group discussions and expanding to include individuals pivotal within their respective communities. The data collected focused on the flow of information among actors, types of information exchanged, communication frequencies, and modes of dissemination. Social Network Analysis (SNA) was utilized to visualize and analyze the network, depicting nodes as key informants and edges as connections or information pathways. Centrality measures such as degree centrality (number of connections), betweenness centrality (control over information flow), closeness centrality (accessibility within the network), and eigenvalue centrality (importance based on connections) were calculated to identify influential actors and key pathways for information dissemination.

Findings highlighted government officials and KVKs as central actors due to their extensive connections and roles in policy-making and technology dissemination. Progressive farmers emerged as pivotal intermediaries bridging the gap between formal institutions and grassroots farmers, facilitating technology adoption and influencing agricultural practices. The study underscores challenges such as limited infrastructure and bureaucratic hurdles impacting information dissemination efficiency. However, opportunities lie in strengthening partnerships among government agencies, NGOs, and private stakeholders to enhance agricultural extension services and improve farmer access to timely and relevant information.

Future research directions include longitudinal studies to track network changes over time, exploring digital technology integration for enhanced connectivity, and providing evidence-based policy recommendations to bolster Bihar's agricultural information network and promote sustainable agricultural development.

Table 4.1: Classification and Roles of Key Informants in Agricultural Information Networks

Key Informants Classification	In Percent (N = 111)
Type of Institution	
Government	36.9 (41)
Cooperatives and NGO	9.0 (10)
KVK	3.6 (4)
Private Input Dealers	10.8 (12)
Service Providers and Progressive Farmers	28.8 (32)
Member of Panchayat	10.8 (12)
Roles of Key Actors in Network	
Create Information	6.3 (7)
Intermediary to Pass Information	82.9 (92)
Utilize Information	86.5 (96)
Multiple Role as Intermediary and Utilizer	
Government	87.8

Cooperatives and NGO	80
KVK	0
Private Input Dealers	25
Service Providers and Progressive Farmers	43.8
Member of Panchayat	91.7
Total	64.9

In the study, the roles and contributions of key informants within Bihar's agricultural information network are delineated across various categories. The majority of interviewed actors serve as intermediaries (82.9%) and utilizers (86.5%) of information, highlighting their crucial role in disseminating and applying agricultural knowledge. These intermediaries are predominantly found at the block level, within Krishi Vigyan Kendras (KVKs), and among NGOs, underscoring their pivotal position in the information transmission chain. A smaller subset of actors (6.3%) are identified as creators of information, primarily at the state government and block levels. These individuals initiate and generate new agricultural insights and practices, which are then disseminated through the network. Notably, only one service provider in Vaishali district assumes the dual role of creating and transmitting information, leveraging their status as a progressive farmer to share firsthand field observations and experimental results with fellow villagers.

A distinct group of key informants (19 respondents) are solely categorized as utilizers of information, relying on the knowledge disseminated through the network without actively participating in its creation or further transmission. Conversely, thirteen respondents, primarily comprising input dealers, exclusively function as intermediaries, facilitating the distribution of agricultural inputs but not contributing to new information creation. 64.9% of respondents play a dual role as both intermediaries and utilizers of information, exemplifying their multifaceted involvement in the agricultural information ecosystem in Bihar. This nuanced categorization highlights the complex dynamics within the network, where actors

assume diverse roles based on their institutional affiliations and operational contexts, ultimately influencing the flow and utilization of agricultural knowledge across the state.

In this study, the focus is on understanding the intricate information networks within Bihar's agricultural sector, specifically how key actors interact and facilitate the creation, transmission, and utilization of agricultural information. The data collected from respondents, who were asked to identify teams, individuals, and organizations they engage with in their roles, provides insights into these network dynamics across different districts. The findings are visually represented through network maps (Figures 2–7), which depict the connections and relationships between various actors and institutions within each district. These maps highlight distinct patterns and differences across districts, offering a comprehensive view of how information flows within the agricultural information ecosystem in Bihar.

Across all districts, government institutions exhibit strong internal networking, particularly among similar government entities. However, interactions between government institutions and non-governmental sources are limited. Notably, Krishi Salahakars, who are directly engaged with farmers, demonstrate robust connections with private input dealers but less interaction with other government actors. Key government entities such as District Agricultural Officers (DAOs), Block Development Officers (BAOs), Agricultural Coordinators (ACs), and Krishi Melas emerge as pivotal information sources within the networks of most respondents. The network maps reveal minimal direct interaction between farmers and various actors and institutions. This suggests a limited feedback loop from farmers back into the agricultural information system. This aspect raises important questions about the effectiveness of information dissemination and the integration of farmer perspectives in decision-making processes. The legends used in the network maps (detailed in Table 4.2) and the actor abbreviations (listed in Table 4.3) provide clarity on the roles and affiliations of each actor within the network. These visual representations, coupled with qualitative data on interactions and information flows, contribute to a deeper understanding of the complex dynamics shaping Bihar's agricultural information networks.

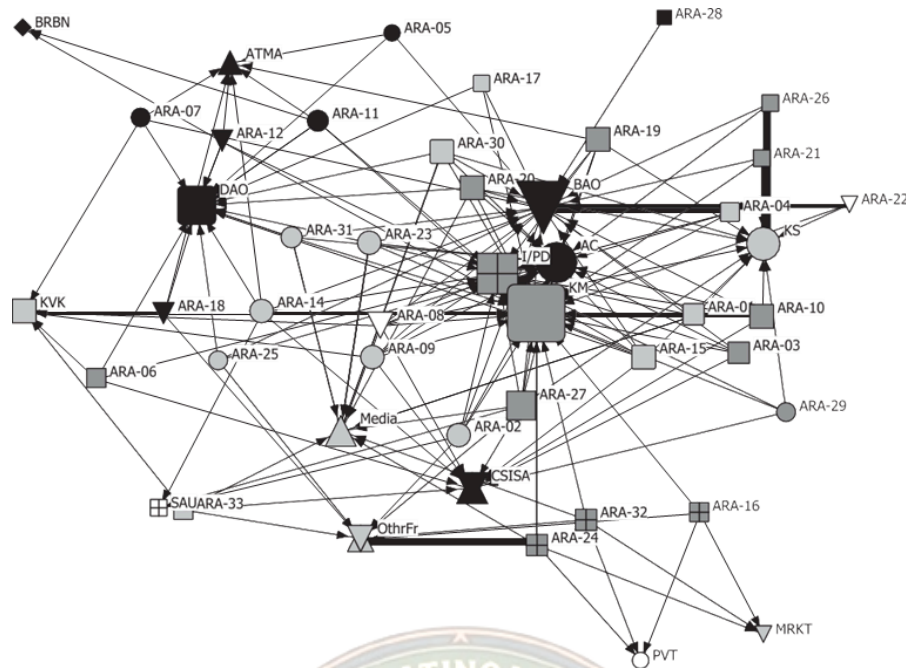


Figure 4.2: Agricultural knowledge network map in Ara district (N = 33)

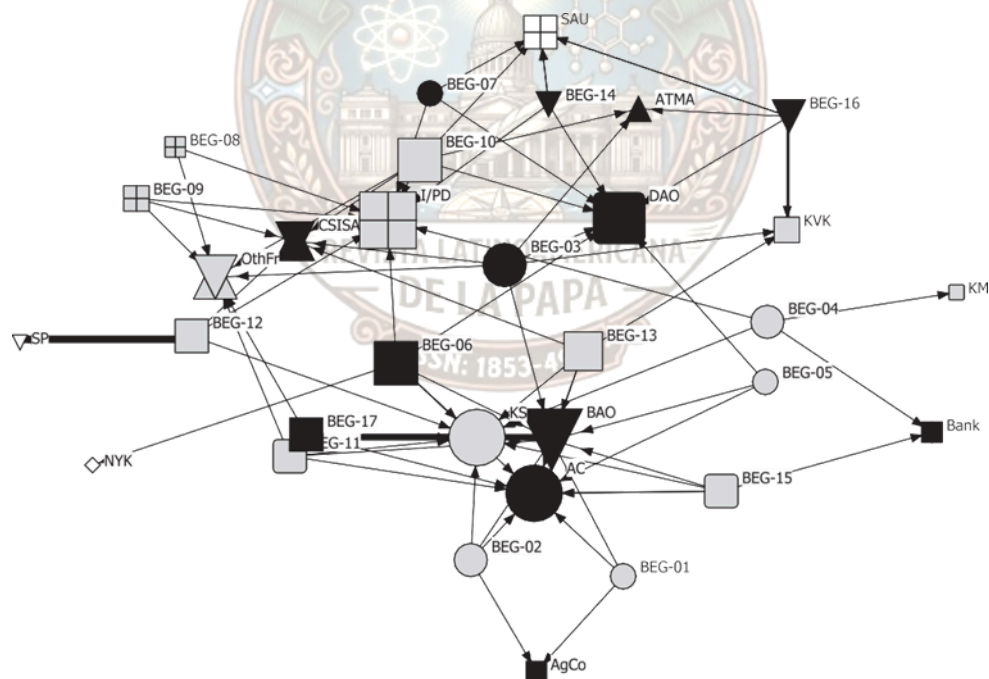


Figure 4.3: Agricultural knowledge network map in Begusarai district (N = 17)

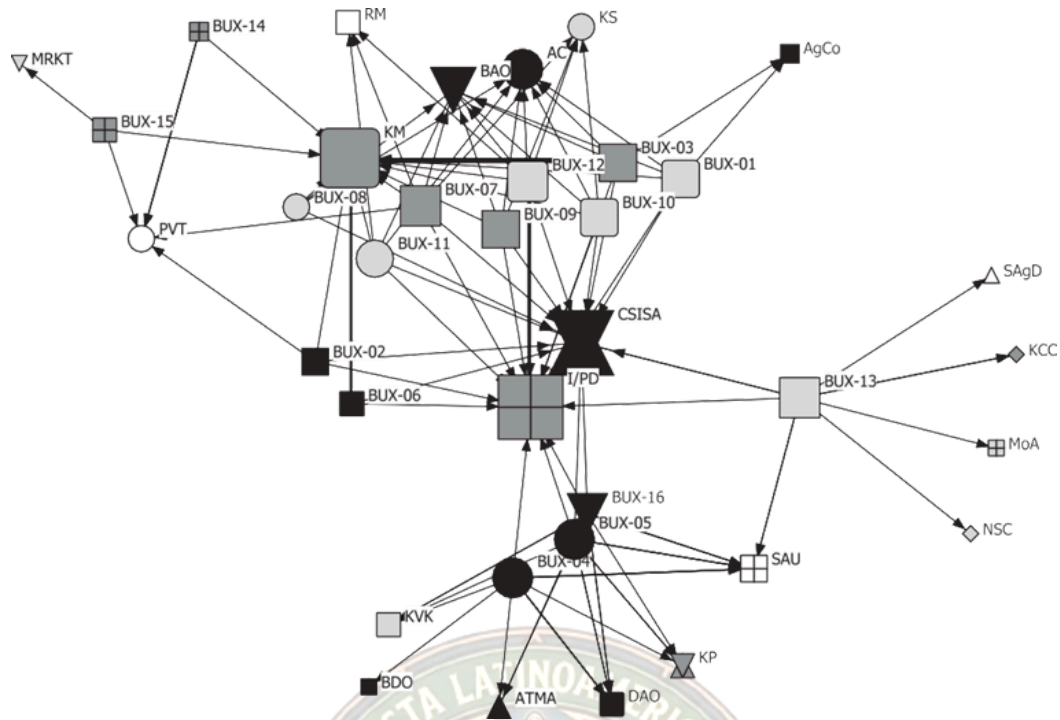


Figure 4.4: Agricultural knowledge network map in Buxar district (N = 16)

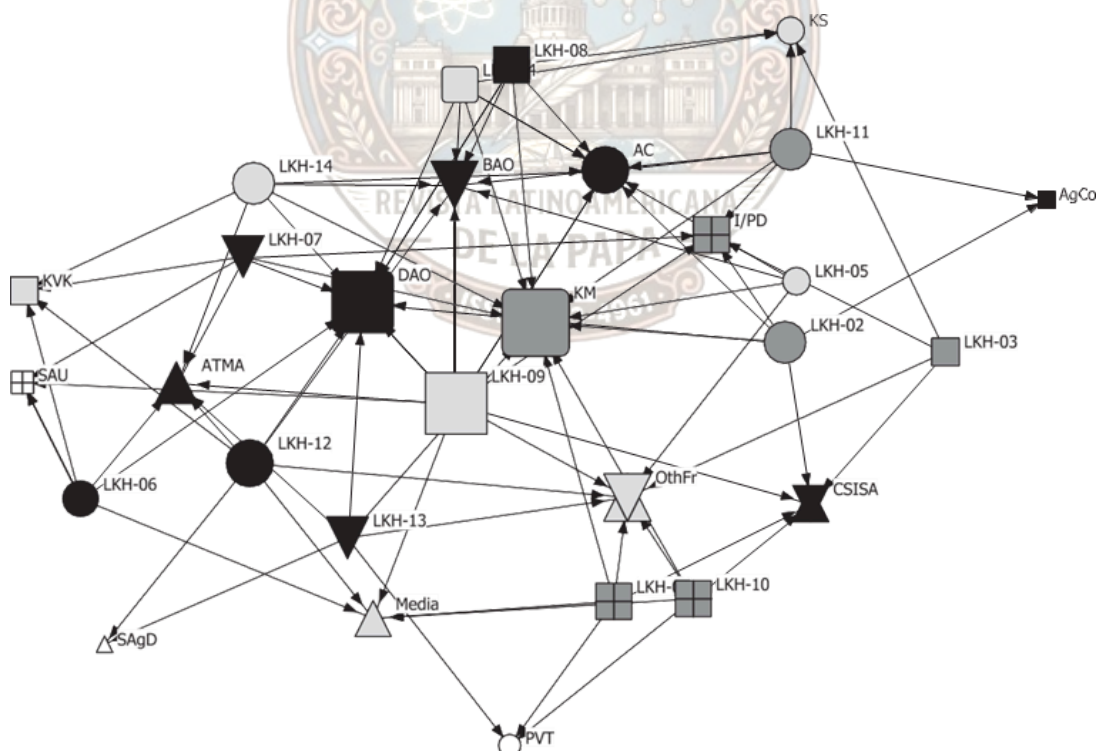


Figure 4.5: Agricultural knowledge network map in Lakisarai district (N = 14)

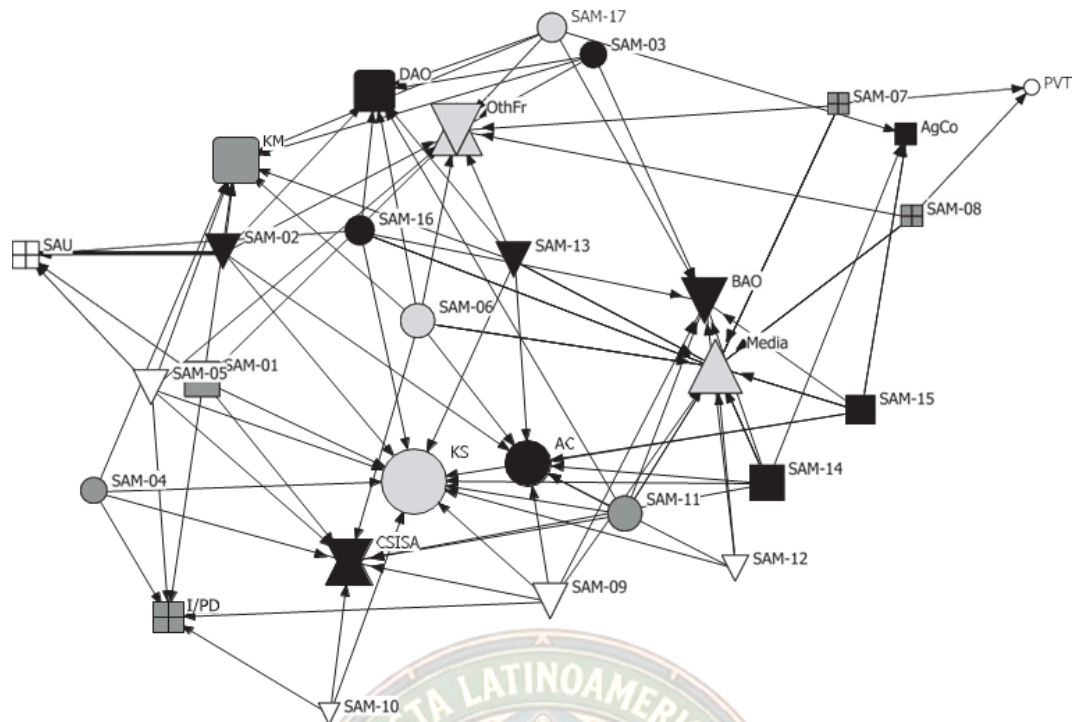


Figure 4.6: Agricultural knowledge network map in Samastipur district (N = 17)



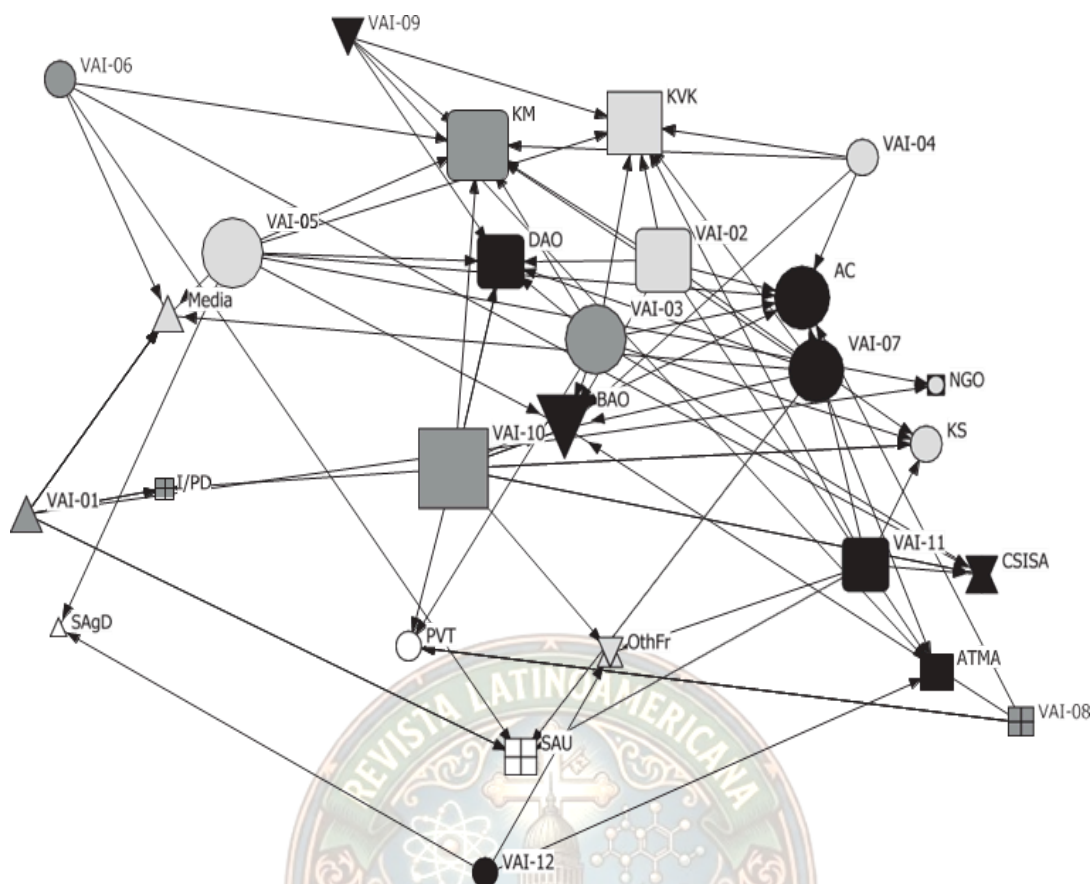


Figure 4.7: Agricultural knowledge network map in Vaishali district (N = 13)

Legends for reading network maps and centrality analysis

Table 4.2: Legend for Network Maps:

				Color		
	Shapes	Black	Dark Gray		Light Gray	White
1	Circle	AC	F		KVK	SA

						gD
2	Square	AgCo	F/SP		Media	SA U
3	Up triangle	ATMA	GS		MoA	SP
4	Box	Bank	I/PD		MRKT	TD C
5	Down triangle	BAO	ICAR		NGO	
6	Circle in box	BDO	JDA		NSC	
7	Diamond	BRBN	KCC		OthFr	
8	Plus	Co	KM		P	
9	Thing	CSISA	KP		PVT	
10	Rounded square	DAO	KS		RM	

Table 4.3: Full form of Abbreviations

Abbreviations	Key people/teams/organization	Abbreviations	Key people/teams/organization
AC	Agricultural Coordinator	KM	Krishi Mela

	(AC)		
AgCo	Agriculture Cooperative	KP	Kisan Pathshala
ATMA	ATMA	KS	Krishi Salahakar
Bank	Bank	KVK	Krishi Vigyan Kendra
BAO	Block Agricultural Officer	Media	Media
BDO	Block Development officer	MoA	Ministry of Agriculture
BRBN	Bihar Rajya Beez Nigam	MRKT	Market
Co	Cooperative	NGO	Non-Government Organization
CSISA	CSISA, CGIAR, CIMMYT, IRRI	NSC	National Seed Corporation
DAO	District Agricultural Officer	OthFr	Other Farmers
F	Farmer	P	Progressive Farmer
F/SP	Farmer & Service provider	PVT	Private

GS	Gram Sevak	RM	Rabi Mahotsav
I/PD	Input Dealers	SAgD	State Agricultural Department
ICAR	Indian Council of Agriculture Research	SAU	State Agricultural University
JDA	Joint Director of Agriculture	SP	Service Providers
KCC	Kishan Call Centre	TDC	Tarai Development Corporation

Visual data interpretation of network maps provides valuable insights into the relationships and dynamics within information networks among various actors. These maps visually depict the connections between different nodes, representing actors such as government institutions, cooperatives, NGOs, agricultural officers, and farmers. The relationships are illustrated through lines or arrows, where the positioning of nodes within the map indicates their importance as sources of information. Nodes positioned centrally are considered more critical and influential, as they are heavily interconnected with other nodes in the network. Conversely, nodes towards the periphery or isolated indicate less centrality and interaction. Assigning colors and shapes to nodes based on their attributes helps in grouping and distinguishing different types of actors within the network maps. For instance, circles might represent agricultural coordinators (AC), squares could denote agricultural cooperatives (AgCo), and triangles might signify government agencies like Block Agricultural Officers (BAO). This visual differentiation aids in understanding the composition and structure of the network, highlighting clusters or groups of actors with similar roles or affiliations.

The density of each district's network map varies based on the number of respondents and the predominant information networks within that geographic area. Nodes representing less frequently mentioned sources of information, listed by only one actor, may not appear on the map. This selective representation ensures that the focus remains on the most influential and interconnected nodes in the network. District-specific variations in network maps reflect the unique interaction patterns and information dissemination strategies among local actors. For example, in districts like Ara (ARA), Buxar (BUX), Samastipur (SAM), Lakhisarai (LAK), Begusarai (BEG), and Vaishali (VAI), each map may exhibit different shapes, colors, and abbreviations depending on the actors interviewed and their specific interaction networks. The nodes' size within these maps corresponds to their degree centrality, visually highlighting major actors that play crucial roles in the information exchange network. A quick glance at these network maps provides initial insights into the prominent information sources and their connectivity. Nodes positioned centrally with larger sizes and surrounded by numerous connections signify their significance as primary sources of information. The spatial arrangement of nodes also reveals how closely related actors interact with different information sources, indicating clusters of similar actors collaborating closely within the network.

Visual interpretation of network maps offers a comprehensive view of information flow dynamics, highlighting key actors, their interconnections, and the overall structure of information networks in Bihar's agricultural sector. These insights are pivotal for understanding information dissemination patterns, identifying influential actors, and optimizing strategies to enhance agricultural knowledge sharing and innovation adoption.

Based on the analysis of network maps from various districts in Bihar, several key insights can be drawn regarding the structure and dynamics of information dissemination among agricultural actors:

In Ara district (Figure 4.2), key informants such as Krishi Mela (Agricultural fair), Block Agricultural Officers (BAO), Agricultural Coordinators (AC), and input dealers play central roles in the information network. These actors are positioned centrally within the network map, indicating their importance in knowledge dissemination. Peripheral sources like CSISA

(a research for development project), ATMA, State Agricultural Universities, media, fellow farmers, KVK, and BRBN (seed agency) have less connectivity and influence compared to the central actors. Krishi Mela stands out as a frequently utilized and well-connected source of information. In Begusarai district (Figure 4.3), the network appears scattered, indicating limited interaction between different actors. This suggests a fragmented information dissemination landscape in this district, where no major clusters or central actors dominate the network. In Buxar district (Figure 4.4), the network shows three distinct clusters of actors. Krishi Mela serves as a prominent networking hub for many actors, particularly in the first cluster. CSISA and input dealers are centrally located and well connected with other clusters, indicating their significant role in bridging information across different groups within the district. In Lakhisarai district (Figure 4.5), Krishi Mela emerges as a central node, along with other key actors like Block Agricultural Officers, State Agriculture Department, and Agricultural Coordinators. Additionally, fellow farmers are noted to be part of the knowledge network, which distinguishes this district from others where farmer-to-farmer interactions are less prominent. In Samastipur district (Figure 4.6), no single actor emerges as a dominant information provider, indicating a more evenly distributed network structure where no central actor plays a pivotal role in information dissemination. In Vaishali district (Figure 4.7), Block Agricultural Officers (BAO), District Agricultural Officers (DAO), Krishi Mela, and Krishi Vigyan Kendra (KVK) are identified as key information sources. These actors are centrally located within the network map, suggesting their critical role in facilitating information flow across the district.

To further understand the significance of these observations, quantitative measures such as centrality measures (e.g., degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality) are calculated. These measures will provide numerical insights into the importance and influence of each actor within their respective networks. By combining visual analysis with quantitative metrics, a comprehensive understanding of the information networks in Bihar's agricultural sector can be achieved, enabling targeted interventions to enhance knowledge dissemination and improve agricultural practices. Centrality analysis offers valuable insights into the structure and dynamics of information networks among key actors in different districts of Bihar. This analysis, based on measures such as degree

centrality, betweenness centrality, closeness centrality, and eigenvector centrality, helps identify pivotal actors and understand their roles in facilitating information flow and influence within the networks.

In Ara district, for instance (Figure 4.2), the District Agricultural Officer (DAO) emerges as a central figure with significant betweenness centrality. This indicates that DAO has a crucial role in controlling and altering information flows within the network, leveraging its position as a district-level agricultural authority. Input dealers also exhibit considerable betweenness centrality, suggesting their strong connections across various actors in the network, including farmers and both public and private entities. Interestingly, Krishi Salahakars, who work closely with farmers at the grassroots level, have a higher eigenvector centrality than DAO. This reflects their influence and popularity within local agricultural communities, despite DAO's broader administrative reach. Moving to Begusarai district (Figure 4.3), Block Agricultural Officers (BAO) are highlighted as important information sources, supported by high degrees of closeness and eigenvector centrality. BAO's central role underscores their effectiveness in disseminating information widely and being perceived favorably among key informants. Krishi Salahakars also exhibit notable betweenness and closeness centrality, indicating their pivotal role as intermediaries in information transmission between various agricultural actors. In Buxar district (Figure 4.4), CSISA emerges as a prominent player with significant centrality scores across different measures. This research project's strong network presence suggests its effective engagement in agricultural development initiatives and knowledge dissemination. Input dealers, SAU (State Agricultural University), and private sector entities like IFFCO also demonstrate substantial betweenness and closeness centrality, emphasizing their crucial role in bridging information gaps between different clusters of actors within the district. Lakhisarai district (Figure 4.5) showcases Krishi Mela as a central information source, with District Agricultural Officers (DAO), other farmers, and Block Agricultural Officers (BAO) also playing pivotal roles. BAO, in particular, exhibits higher closeness and eigenvector centrality, indicating their effectiveness in spreading information efficiently and being highly regarded within the local agricultural network. Samastipur district (Figure 4.6) illustrates KS (Krishi Salahakars) as a major information source, followed closely by Media. Here, centrality measures align closely with degree centrality,

suggesting a straightforward distribution of influence among key actors where KS and Media hold significant sway in information dissemination. In Vaishali district (Figure 4.7), Krishi Mela stands out prominently as a key information source, complemented by high betweenness scores for State Agricultural University (SAU). This indicates SAU's strategic position in facilitating information exchange between different actors within the district. Other farmers and NGOs also exhibit noteworthy betweenness and closeness centrality, underscoring their roles as important intermediaries and contributors to the information network.

The centrality analysis provides a nuanced understanding of how different actors are positioned within their respective networks in Bihar. It reveals not only who the key players are but also their specific roles in influencing information flow and network dynamics. By integrating visual network maps with quantitative metrics, this approach enables policymakers and agricultural stakeholders to identify opportunities for enhancing communication channels, improving knowledge dissemination strategies, and fostering more effective agricultural development interventions across the region. Therefore, the State Government and its extension agencies emerge as pivotal players in the dissemination of agricultural information within this knowledge network. Their central role highlights the critical importance of coordinating with these agencies to enhance the accessibility and adoption of modern agricultural technologies.

Krishi Mela stands out prominently as the primary node facilitating farmers' access to new technologies. Its central position underscores its effectiveness in serving as a platform for disseminating agricultural innovations and practices directly to farmers. To strengthen the overall network and improve closeness among different nodes, it is essential to implement effective feedback mechanisms. These mechanisms would facilitate ongoing interactions with farmers, allowing for real-time adjustments and improvements in the usability and relevance of the disseminated information. By addressing feedback and understanding constraints faced by farmers in utilizing information, the network can enhance its responsiveness and efficacy in promoting agricultural advancements. Fostering collaboration and feedback loops between state agencies, extension services, and farmers is crucial for optimizing the spread and adoption of modern agricultural technologies across Bihar. This approach not only

strengthens existing nodes like Krishi Mela but also ensures that all actors within the network are effectively connected and empowered to contribute to agricultural development in the region.

Table 4.4: Network centrality measures in the district of Bihar (arranged in descending order of degree)

Information source	Degree	Betweenness	Closeness	Eigen vector	Information source	Degree	Betweenness	Closeness	Eigen vector
	Ara					Lakhisarai			
KM	25	306.08	74	0.257	KM	10	78.53	58	0.303
BAO	23	200.10	84	0.240	DAO	9	66.50	58	0.307
AC	16	58.41	98	0.193	OthFr	7	38.67	66	0.205
I/PD	15	71.38	98	0.169	BAO	7	35.29	64	0.244
DAO	14	77.44	100	0.129	AC	7	25.51	68	0.237
KS	12	34.05	106	0.138	ATMA	6	17.11	72	0.210
Media	10	44.76	108	0.106	CSISA	5	17.10	74	0.139
CSISA	10	33.78	110	0.112	Media	5	16.24	74	0.156
OthFr	8	38.97	110	0.060	KS	4	8.76	84	0.109
ATMA	7	17.88	116	0.057	KVK	4	5.94	80	0.132

KVK	6	15.21	120	0.049	I/PD	3	3.42	88	0.073
SAU	3	1.11	126	0.039	SAU	3	2.47	84	0.102
MKT	3	0.82	148	0.015	PVT	3	1.97	90	0.081
PVT	3	0.82	148	0.015	SAGD	2	1.12	88	0.069
BRBN	2	0.20	146	0.015	IFFCO	2	0.84	86	0.077
	Beg usar ai					Samasti pur			
BAO	9	78.84	71	0.342	KS	12	79.38	55	0.296
KS	8	109.35	69	0.280	Media	10	62.54	59	0.234
AC	8	47.36	75	0.305	OthFr	9	51.13	63	0.192
DAO	7	69.43	77	0.810	KM	8	29.37	65	0.191
OthFr	6	58.53	79	0.165	CSISA	8	28.36	65	0.198
CSISA	5	46.07	79	0.137	BAO	8	26.57	65	0.192
IFFCO	4	22.77	85	0.098	AC	8	16.48	67	0.217
I/PD	4	20.89	101	0.054	DAO	7	16.45	69	0.175
SAU	4	9.04	105	0.068	I/PD	5	8.35	75	0.112
KVK	3	11.09	89	0.095	SAU	4	5.73	75	0.101

ATMA	3	5.32	95	0.079	AgCo	3	2.11	81	0.070
AgCo	3	2.29	111	0.106	PVT	2	0.33	101	0.021
Bank	2	4.01	105	0.055					
	Buxar					Vaishali			
CSISA	13	293.59	66	0.330	KM	8	56.92	64	0.323
KM	12	117.00	84	0.31	AC	7	36.65	68	0.282
BAO	8	11.16	106	0.259	BAO	7	36.40	68	0.294
I/PD	7	8.09	102	0.234	KVK	7	33.79	68	0.285
AC	7	7.28	104	0.227	DAO	6	23.54	70	0.270
									(Continued)
IFFCO	6	70.67	90	0.077	SAU	4	48.00	72	0.103
SAU	4	21.65	104	0.043	Media	4	38.88	76	0.119
PVT	4	18.08	104	0.068	CSISA	4	17.04	78	0.154
KS	4	1.78	110	0.136	ATMA	4	15.75	82	0.128
ATMA	3	4.15	114	0.032	KS	4	7.40	80	0.183
DAO	3	4.15	114	0.032	OthFr	3	15.20	80	0.088
KP	3	4.15	114	0.032	PVT	3	3.23	94	0.122

KVK	3	4.15	114	0.032	NGO	2	12.29	88	0.055
RM	3	0.94	112	0.102	SAgD	2	6.24	90	0.054
AgCo	2	0.17	118	0.064					

The feedback channels and constraints in the efficiency of the information dissemination system highlight crucial aspects of the network's functionality. According to the key informants interviewed, several channels serve as avenues for receiving feedback from farmers, with personal visits, mobile phone calls, and Krishi Mela emerging as the primary channels (Figure 4.8). These interactions are critical for gathering insights directly from farmers regarding their needs, challenges, and the effectiveness of information provided. Personal visits to farmers' fields are considered vital by many informants, often supplemented or followed up by mobile phone communications. Farmers also provide feedback through interactions with agricultural extension officers during training sessions. However, the reliance on personal visits, accounting for 31.7% of feedback, reveals potential inefficiencies. Given the substantial ratio of agricultural households to extension personnel (roughly 1500–2000 households per extension worker based on 2011 census data), many farmers may not have the opportunity to give feedback promptly due to logistical challenges.

A notable suggestion is to centralize the feedback collection process locally, potentially through farmers' cooperatives, input dealers, or service providers. This decentralized approach could improve accessibility for farmers to provide feedback more regularly and effectively. It addresses the current limitations of relying solely on personal visits, ensuring that feedback loops are more inclusive and responsive to farmer needs. Another critical issue highlighted by informants is the inadequate incorporation of feedback into the information network system (Figure 4.9). There appears to be dissatisfaction among respondents regarding the formalization and effectiveness of processes to integrate feedback received from farmers. This gap suggests that while feedback is collected through various channels, its utilization to improve information dissemination or address farmer concerns remains inconsistent or insufficient.

To enhance the efficiency of the information network, it is imperative to establish robust mechanisms for systematically incorporating farmer feedback. This entails developing formalized procedures that ensure feedback loops are closed effectively, enabling continuous improvement in the relevance and utility of information provided. Addressing these feedback-related challenges is crucial for optimizing the impact and responsiveness of agricultural extension services and information networks in Bihar.

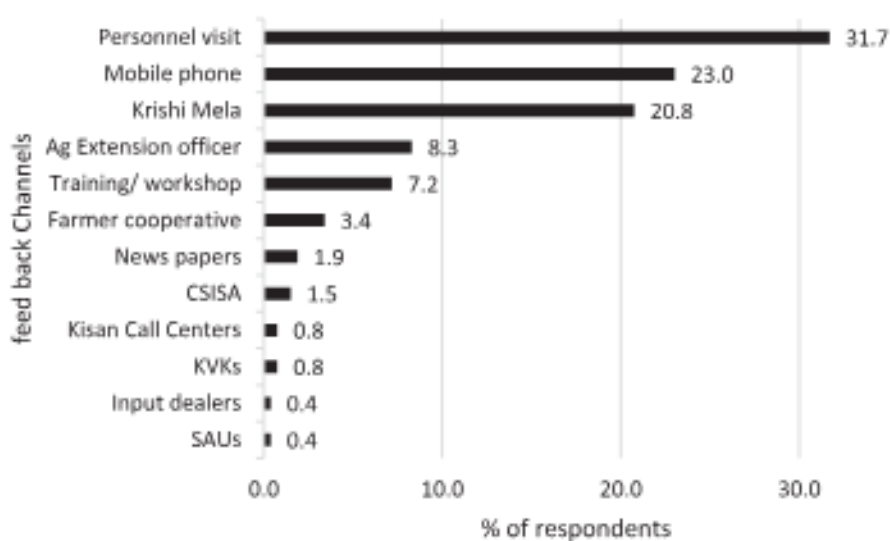


Figure 4.8: Feedback channels that connect key informants with farmers

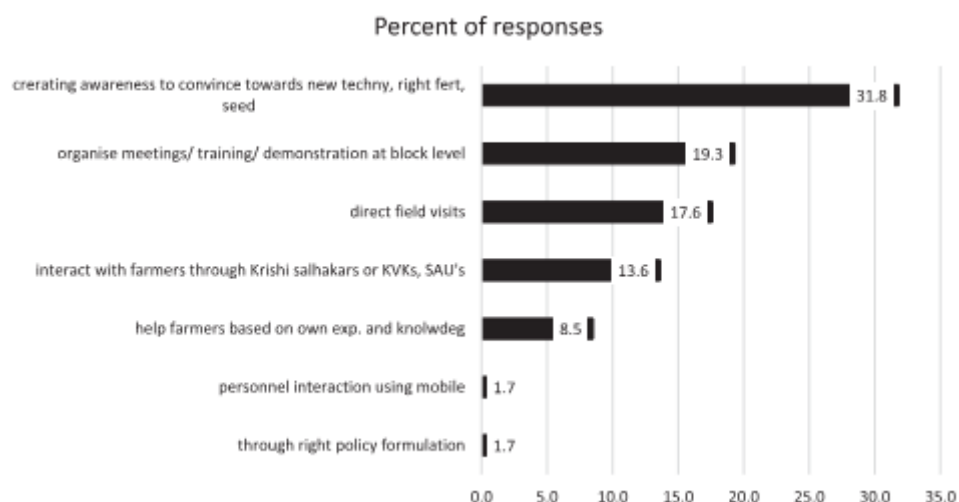


Figure 4.9: Mechanisms to incorporate feedback

The challenges faced during awareness campaigns and workshops highlight key concerns regarding the efficiency and effectiveness of information dissemination and utilization within the agricultural network. One of the primary issues identified is the heavy reliance on personal visits for addressing farmer concerns related to new technologies and pest management. When farmers report issues such as pest infestation, for instance, the process often involves initial reporting to local Kisan Salahkars, who may not always have the expertise or resources to provide immediate solutions. This information then moves up through various bureaucratic channels, involving Agricultural Coordinators (AC), Block Agricultural Officers (BAO), and District Agricultural Officers (DAO) before a definitive solution is relayed back to the farmers. This bureaucratic route can be time-consuming, diminishing the timeliness and relevance of the solutions provided. However, the increasing penetration of mobile phones has expedited information flow, bypassing some unnecessary layers in the hierarchy and improving responsiveness to farmer needs. This shift underscores the potential for technology to streamline communication and enhance the relevance of solutions delivered to farmers.

Another critical issue highlighted is the adequacy of the information provided by key actors in the network and its utilization by farmers. Key Informant Interviews (KII) revealed that the most common information disseminated to farmers includes details about seed varieties,

fertilizers, advanced agricultural techniques such as zero tillage (ZT), System of Rice Intensification (SRI), and Direct Seeded Rice (DSR), as well as guidance on weed and pest management, agricultural machinery, and government agricultural programs. Stakeholders generally perceive this information as relevant to farmers' needs (Table 4.8). However, despite the perceived relevance, there are concerns about the actual utilization of this information by farmers. Only 55–60% of respondents believe that farmers effectively utilize information related to seeds, inputs, and zero tillage practices (Table 5). This indicates a gap between the dissemination of information and its practical application on the ground. Factors contributing to this gap may include the complexity of technologies introduced, inadequate farmer training, and limited follow-up mechanisms to ensure effective adoption.

Addressing these challenges requires enhancing the efficiency of feedback mechanisms, reducing bureaucratic delays in information dissemination, and strengthening support for technology adoption through targeted training and practical assistance. By improving these aspects, the agricultural information network can better serve the needs of farmers, facilitate informed decision-making, and foster sustainable agricultural practices in Bihar. Further exploration into why certain information is underutilized by farmers revealed two significant reasons. Firstly, there is a notable absence of a supportive infrastructure to translate information into practical application. This includes essential components such as seed certification, soil testing, irrigation facilities, post-harvest technologies (PHT), land laser levelers (LLL), and access to weather information. These are critical for farmers to implement new practices effectively. Secondly, some information lies beyond the control of individual farmers, such as output and input prices, which significantly influence agricultural decisions.

Information network actors identified several constraints contributing to farmers' incomplete utilization of available information. These constraints are categorized into five main areas: institutional, infrastructure, policy-related, poor access to inputs, and knowledge barriers (see Table 4.6). Actors within the information network expressed concerns that the current system lacks sufficient manpower to meet the demands of farmers effectively. Moreover, existing personnel often lack the technical skills required to provide efficient service within the knowledge network. This gap is crucial as farmers typically seek immediate solutions rather

than reporting problems and waiting for responses. Additionally, there is a lack of incentives for extension workers at the farm level, which further hampers their motivation and performance. Bureaucratic obstacles also pose challenges to extension agents' work. Insufficient infrastructure, including inadequate roads, electricity supply, communication networks, and storage facilities, further exacerbates these challenges. These limitations impede the extension agents' access to farmers and their ability to deliver timely and effective services. Policy-level constraints, such as inadequate subsidies for finance, seeds, and machinery, are another significant barrier identified by actors in the information network. This limitation directly affects the availability of essential resources like fertilizer and water, crucial for agricultural productivity and innovation.

Table 4.5: Knowledge network actors' perspective on relevance and usability of information

Type of information	In your opinion how relevant do farmers find this information		Are farmers able to use this information appropriately?
	% of respondents saying 'Somewhat relevant'	% of respondents saying 'very high relevance'	% of respondents saying yes
Seed varieties	26.1	63.1	56.8
Other inputs (fertilizer, pesticides, herbicides)	11.7	70.3	63.3
Zero Tillage	19.8	64.0	57.6
DSR/MTR/SRI	20.7	56.8	51.1
Agriculture related govt. schemes and programs	20.7	55.0	49.5
Weed and insect pest management	20.7	54.1	48.7
Irrigation	25.2	42.3	38.1
Machinery/implements	14.4	41.4	37.3
Micro nutrients/nutrient management	11.7	35.1	31.7
Soil testing	21.6	21.6	19.5
Credit and insurance	24.3	23.4	21.1
Land preparation	13.5	20.7	18.7
Post-harvest technologies	18.0	18.0	16.2
Land laser levelers	13.5	13.5	12.2
Weather Information	15.3	8.1	7.3
Crop residue management	12.6	3.6	3.2
Animal husbandry/livestock management	6.3	9.0	8.1
Cooperatives/organizations	8.1	7.2	6.5
Seed certifications	3.6	8.1	7.3
Input prices	8.1	1.8	1.6
Producers price/MSP	2.7	0.9	0.8

Table 4.6: Constraints in Utilization of information by the farmers

Constraint	Number of responses	In Percent
Institutional systems	14	9.7
Infrastructure – Road and electricity	14	9.7
Policy issue	7	4.8
High cost of inputs and lack of credit	28	19.3
Non availability or timely availability of inputs	48	33.1
Lack of awareness	34	23.4
Total	145	100

Note: Multiple constraints cited.

Source: Authors calculations from Key informant survey.

Addressing the specific needs of farmers effectively. Additionally, there is a call for establishing better coordination between different departments and agencies involved in agricultural extension services. This includes creating platforms for regular interactions and collaboration to ensure that information dissemination aligns with ground realities and farmer needs. Respondents emphasized the need for infrastructure development, particularly improving roads and communication networks, to enhance the mobility of farmers, extension staff, and input dealers. Better infrastructure would facilitate easier access to markets, information, and agricultural inputs, thereby fostering convergence between farmers and extension services. There is a strong recommendation to review and tailor government policies and subsidy programs to better suit local agricultural conditions. This entails promoting technologies that are suitable for specific agro-climatic zones and ensuring that incentives do not inadvertently distort farmers' decision-making processes. Moreover, there is a need to mitigate the impact of recurring natural disasters such as droughts and floods through resilient farming practices and timely support mechanisms.

To strengthen feedback mechanisms and improve the utilization of information, key informants suggested several measures. These include establishing centralized local platforms (e.g., farmer cooperatives, input dealers) for efficient feedback collection and dissemination. They also underscored the importance of integrating farmer feedback into decision-making processes at all levels of the agricultural extension system. This involves developing formalized systems to incorporate farmer inputs and ensuring that responses to farmer queries and issues are prompt and effective. Addressing these constraints requires a multi-faceted approach involving infrastructure development, policy alignment, capacity building of extension personnel, and enhanced coordination among stakeholders. By implementing these recommendations, it is anticipated that the efficiency of information transmission and

adoption of agricultural technologies will be significantly improved, thereby benefiting farmers and enhancing agricultural productivity in the region.

Table 4.7: Suggestions by Farmers to Improve the Knowledge Networks

Suggestion	Number of Responses	Percent
Improve skill sets	50	19.8
Improve work efficiency and ethics	47	18.7
Improve infrastructure (computers, electricity, etc.)	23	9.1
Improve information dissemination	40	15.9
Improve quality check parameters	7	2.8
Improve farmers' information and knowledge base	23	9.1
Improve inputs supply (fertilizer, seed, etc.)	18	7.1
Improve ways to interact with farmers	22	8.7
Improve the process of policy implementation	18	7.1
Improve function of farmer cooperatives	4	1.6
Total	252	100

A significant recommendation from respondents to enhance the effectiveness of agricultural knowledge networks is to improve the skill sets of personnel involved. Approximately 19.8% of respondents emphasized the need for better training and competency among extension workers and agricultural officials. They highlighted that current staff, particularly those on contract, often lack motivation due to inadequate incentives and job security. Conversely, permanent staff are sometimes criticized for their lack of punctuality and work ethics, posing challenges to efficient information dissemination. Another crucial suggestion, voiced by 15.9% of respondents, is to prioritize timely information delivery. This is closely linked to improving the ways information is communicated to farmers, as highlighted by 8.7% of respondents. They recommended leveraging modern communication tools such as video-based clips and mobile phones to ensure efficient and effective interaction with farmers. Regular field visits by information network actors were also deemed essential for understanding farmers' information needs firsthand and providing tailored solutions promptly.

The need to raise awareness among farmers about new agricultural technologies and provide training on their implementation was underscored by 9.1% of respondents. They stressed that merely providing technological information is insufficient without accompanying efforts to educate and empower farmers. This necessitates improvements in infrastructure, including reliable electricity, irrigation facilities, soil testing capabilities, and efficient marketing channels. Quality and timely availability of inputs like seeds and fertilizers were also highlighted as critical factors influencing farmers' ability to adopt new technologies. 7.1% of respondents pointed out shortcomings in policy implementation processes. They cited examples where subsidies and support programs intended to benefit farmers, such as timely availability of fertilizers and seeds, often fail due to bureaucratic delays and misalignment with ground realities. Respondents suggested adopting a more inclusive approach to policy formulation, involving feedback from farmers, district-level agricultural workers, and Krishi Salahakars (village-level agriculture advisors), to ensure policies are practical and responsive to local needs. Addressing these recommendations could significantly enhance the efficiency and impact of agricultural knowledge networks. By improving human resource management, adopting modern communication technologies, enhancing farmer education and infrastructure, and refining policy implementation processes, stakeholders aim to bridge the

gap between information dissemination and effective utilization at the grassroots level of agriculture.

The implications of this study underscore the critical role of information and knowledge networks in agricultural information dissemination. While some studies have explored the roles of actors and social networks in this context, this study uniquely highlights the heterogeneous and complex nature of these networks across different districts. This diversity must be considered when designing extension strategies, as a one-size-fits-all approach may not be effective across regions. Social Network Analysis (SNA), a tool used extensively in this study, proves invaluable in eliciting insights into farmers' agricultural information networks. While Bihar served as the case study here, the SKA tool can be easily adapted and replicated in other states of India or even in different parts of the world. Extension professionals can benefit greatly from understanding the dynamics revealed in network maps, gaining insights into the pivotal roles played by key nodes and actors within these networks. This study sensitizes extension professionals to the significant role of small-scale and resource-poor farmers in the diffusion of agricultural technologies. This awareness can inform strategies aimed at accelerating technology adoption and effectively targeting influential nodes and actors within the network. It also highlights the importance of prioritizing investments to strengthen weaker nodes or develop crucial network points to enhance overall efficiency.

Understanding the structure of these networks also serves as a strategic entry point for introducing new agricultural technologies and facilitating connections with diverse farming communities. This knowledge can inform the design and implementation of government programs and policies aimed at reaching farmers in the most efficient and impactful manner possible. Beyond agriculture, insights from network analysis can be extrapolated to inform the design of other development and welfare programs. For instance, insights gleaned from network analysis can enhance efforts to promote the adoption of certified seeds or encourage the utilization of soil health card information. By understanding how different actors interact and influence information flow within these networks, policymakers can tailor interventions more effectively to address specific needs and constraints at the grassroots level. This study not only advances our understanding of agricultural information networks but also

underscores their relevance in shaping effective strategies for agricultural development and welfare. It provides a framework for enhancing the adoption of agricultural innovations and optimizing the impact of policies aimed at improving rural livelihoods and agricultural productivity.



CHAPTER-5**CONCLUSION**

Based on the comprehensive analysis above, it is evident that key information and knowledge actors in Bihar are intricately connected, fulfilling crucial roles in generating, disseminating, and utilizing agricultural information. Government institutions, represented prominently by Krishi Salahakars, exhibit robust networking primarily within similar governmental setups, with limited interactions observed across non-governmental sources. To optimize the efficiency of the information and knowledge network, it is recommended that Krishi Salahakars, alongside service providers and progressive farmers, be strategically leveraged as focal points for knowledge creation and dissemination. While they currently play pivotal roles in transmitting knowledge, these roles could be formalized within a systematic framework to enhance the delivery of information on new agricultural technologies and practices. Krishi Mela emerges as another critical platform where farmers converge with service agencies and institutions to exchange information, seek solutions to queries, and explore new technologies. Enhancing the stature of Krishi Mela as a pivotal meeting and networking hub could significantly bolster the adoption of modern agricultural practices on a broader scale. Input dealers, known for their role in transmitting information about essential farm inputs like seed varieties, herbicides, and pesticides, are highly regarded by farmers due to their direct involvement with critical agricultural inputs. Elevating input dealers to nodal points within the information delivery chain could establish an effective channel for educating farmers about advanced crop varieties and agricultural chemicals.

Efforts to enhance the extension system's efficiency should focus on developing the skill sets of key stakeholders, particularly in addressing local farming challenges, imparting knowledge on locally adaptable technologies, and familiarizing them with relevant government programs beneficial to farmers. Establishing a local agricultural knowledge repository in vernacular languages, accessible to farmers, supplemented by remote consultations with pertinent authorities, could streamline information dissemination. This approach promises to minimize information lag and enhance accessibility to solutions, thereby fostering broader adoption of improved agricultural technologies. Strategic utilization of Krishi Salahakars, amplification

of Krishi Mela's role as a networking platform, and empowering input dealers as information nodes are crucial steps toward optimizing Bihar's agricultural information network.



REFERENCES

1. Alam, S., & Dwivedi, Y. K. (2017). Digital government initiatives and citizen engagement in India: A conceptual framework and empirical investigation. *Government Information Quarterly*, 33(3), 322-333.
2. Athique, M., & Zhang, X. (2020). E-government and citizen satisfaction in developing countries: A case study of India. *Information Systems Frontiers*, 22(3), 1223-1238.
3. Gupta, M., & Jana, D. (2018). E-governance and service delivery in India: A state-of-the-art review. *International Journal of Public Sector Management*, 31(2), 222-243.
4. Baruah, A., & Bhuyan, M. H. (2016). Land records management system: A review of existing practices and future directions. *International Journal of Computer Applications*, 141(11), 21-26.
5. Bhagat, S., & Nagarajan, V. (2018). Land titling, land records, and access to finance in rural India. *World Development*, 104, 222-237.
6. Roy, S. (2020). Challenges and opportunities in land record management in India: A case study of West Bengal. *Land Use Policy*, 99, 105083.
7. Agarwal, A., Dey, P., & Kohli, R. (2017). Digital transformation for rural development: A conceptual framework and empirical analysis from India. *Information Technology for Development*, 23(4), 572-594.
8. Chandrasekhar, C. P., & Muralidharan, K. (2017). Information technology for poverty alleviation: Ten years later. *Journal of Economic Perspectives*, 31(4), 165-186.
9. Gavali, V., & Patadia, S. (2021). Impact of digital technologies on rural livelihoods in developing countries: A systematic review. *Sustainability*, 13(19), 11062.
10. Cao, Y., Zhao, P., & Li, N. (2019). A user-centered design approach for promoting technology adoption in rural areas. *Sustainability*, 11(18), 5072.

11. Gregor, S., & Lyytinen, K. (2015). Design for use: A perspective on design research in information systems. *Information Systems Research*, 26(3), 657-678.
12. Rogers, Y. (2016). User-centered design in everyday life. *Interactions*, 23(3), 24-27.
13. Eswaran, S., & Rai, A. (2017). E-governance and its challenges in India. *International Journal of Information Technology and Management*, 16(2), 233-248.
14. Goyal, A., & Mittal, S. (2018). Challenges in implementation and adoption of e-governance in India. *International Journal of Computer Applications*, 178(11), 18-23.
15. Ahmed, S. A., & Tiwari, A. K. (2020). Land administration reforms in India: A critical analysis of the use of information technology. *Land Use Policy*, 99, 105102.
16. Iqbal, M. A., Athar, M., & Abbas, F. (2016). Land information systems in developing countries: A case study of Pakistan. *Land Use Policy*, 57, 744-753.
17. Yuan, W., Shen, L., & Gong, P. (2018). Land administration systems and their modernization in developing countries: A comparative study. *Land Use Policy*, 70, 56-67.
18. Heeks, R. (2018). Digital inclusion: Conceptualizing the problem of user inequalities in the digital age. *Social Science Computer Review*, 36(2), 156-176.
19. Melhuish, T. (2020). Digital literacy and social inclusion: A review of the literature. *Journal of Include Practice Research*, 13(2), 1-16.
20. Alajarmeh N. Evaluating the accessibility of public health websites: an exploratory cross-country study. *Univ Access Inf Soc*. 2021:1–19.
21. Sik-Lanyi C, Orban-Mihalyko E. Accessibility testing of European health-related websites. *Arab J Sci Eng*. 2019;44(11):9171–90.
22. Ross AS, Zhang X, Fogarty J, Wobbrock JO. Epidemiology as a framework for large-scale Mobile application accessibility assessment. In: *Proceedings of the 19th*

International ACM SIGACCESS Conference on Computers and Accessibility. Baltimore: Association for Computing Machinery; 2017. p. 2–11.

23. Vazquez A, Jenaro C, Flores N, Bagnato MJ, Perez MC, Cruz M. E-health interventions for adult and aging population with intellectual disability: a review. *Front Psychol*. 2018;9:2323.
24. Jones M, Morris J, Deruyter F. Mobile healthcare and people with disabilities: current state and future needs. *Int J Environ Res Public Health*. 2018;15(3):515.
25. Yu D, Parmanto B, Dicianno B. An mHealth app for users with dexterity impairments: accessibility study. *JMIR Mhealth Uhealth*. 2019;7(1):e202.
26. Patrick PA, Obermeyer I, Xenakis J, Crocitto D, O'Hara DM. Technology and social media use by adult patients with intellectual and/or developmental disabilities. *Disabil Health J*. 2020;13(1):100840.
27. Jones ML, Morris J, DeRuyter F, Miesenberger K, Kouroupetroglou G. Mobile healthcare and people with disabilities: Results from a preliminary survey, vol. 2018. Virginia C: Crawford Research Institute, Shepherd Center, Atlanta, United States Department of Surgery, Duke University Medical Center, Durham, United States: Springer Verlag; 2018. p. 457–63.
28. De Oliveira GAA, De Bettio RW, Freire AP. Accessibility of the smart home for users with visual disabilities: An evaluation of open source mobile applications for home automation, vol. 2016: Dept. of Computer Science, Federal University of Lavras, Lavras MG, Brazil: Association for Computing Machinery; 2016.
29. David EJ. Internalized oppression. In: *The psychology of marginalized groups*: Springer Publishing Company; 2013.
30. Mheta D, Mashamba-Thompson TP. Barriers and facilitators of access to maternal services for women with disabilities: scoping review protocol. *Syst Rev*. 2017;6(1):99.

31. Chiwandire D, Vincent L. Wheelchair users, access and exclusion in south African higher education. *Afr J Disabil.* 2017;6:353.
32. United Nations. Convention on the rights of persons with disabilities (CRPD) 2007. Available from: <https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html>.
33. Brett J, Staniszevska S, Mockford C, Herron-Marx S, Hughes J, Tysall C, et al. Mapping the impact of patient and public involvement on health and social care research: a systematic review. *Health Expect.* 2014;17(5):637–50.
34. Williams AS, Moore SM. Universal design of research: inclusion of persons with disabilities in mainstream biomedical studies. *Sci Transl Med.* 2011;3(82):82cm12.
35. Rios D, Magasi S, Novak C, Harniss M. Conducting accessible research: including people with disabilities in public health, epidemiological, and outcomes studies. *Am J Public Health.* 2016;106(12):2137–44.
36. Johansson S, Gulliksen J, Lantz A. User participation when users have mental and cognitive disabilities. In: *Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility - ASSETS '15*. Lisbon: Association for Computing Machinery; 2015. p. 69–76.
37. Poli A, Kelfve S, Motel-Klingebiel A. A research tool for measuring non-participation of older people in research on digital health. *BMC Public Health.* 2019;19(1):1487.
38. Carroll P, Witten K, Calder-Dawe O, Smith M, Kearns R, Asiasiga L, et al. Enabling participation for disabled young people: study protocol. *BMC Public Health.* 2018;18(1):712.
39. Peters M, Godfrey C, McInerney P, Munn Z, Tricco A, Khalil H. Chapter 11: Scoping Reviews (2020 version). In: *JBİ manual for evidence synthesis: The Joanna Briggs institute*; 2020. Available from: <https://wiki.jbi.global/display/MANUAL/Chapter+11%3A+Scoping+reviews>.

40. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev*. 2016;5(1):210.
41. Peters MD, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. *Int J Evid Based Healthc*. 2015;13(3):141–6.
42. DeForte S, Sezgin E, Huefner J, Lucius S, Luna J, Satyapriya AA, et al. Usability of a Mobile app for improving literacy in children with hearing impairment: focus group study. *JMIR Hum Factors*. 2020;7(2):e16310.
43. Hill AJ, Breslin HM. Refining an asynchronous Telerehabilitation platform for speech-language pathology: engaging end-users in the process. *Front Hum Neurosci*. 2016;10:640.
44. Kerkhof Y, Bergsma A, Graff M, Droes RM. Selecting apps for people with mild dementia: identifying user requirements for apps enabling meaningful activities and self-management. *J Rehabil Assist Technol Eng*. 2017;4:2055668317710593.
45. Lu MH, Lin W, Yueh HP. Development and evaluation of a cognitive training game for older people: a design-based approach. *Front Psychol*. 2017;8:1837.
46. Malu M, Findlater L. Toward accessible health and fitness tracking for people with mobility impairments. In: 10th EAI international conference on pervasive computing Technologies for Healthcare; 2016. Cancun: ICST Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering; 2016.
47. Winberg C, Kylberg M, Pettersson C, Harnett T, Hedvall PO, Mattsson T, et al. The use of apps for health in persons with multiple sclerosis, Parkinson's disease and stroke - barriers and facilitators. *Stud Health Technol Inform*. 2017;242:638–41.
48. Zafeiridi P, Paulson K, Dunn R, Wolverson E, White C, Thorpe JA, et al. A web-based platform for people with memory problems and their caregivers (CAREGIVERSPRO-MMD): mixed-methods evaluation of usability. *JMIR Form Res*. 2018;2(1):e4.

49. Madrigal-Cadavid J, Amariles P, Pino-Marin D, Granados J, Giraldo N. Design and development of a mobile app of drug information for people with visual impairment. *Res Soc Adm Pharm.* 2020;16(1):62–7.
50. Singanamalla S, Potluri V, Scott C, Medhi-Thies I. PocketATM: understanding and improving ATM accessibility in India. 10th international conference on information and communication technologies and development; 2019. India: Association for Computing Machinery; 2019.
51. Zhou L, Saptono A, Setiawan IMA, Parmanto B. Making self-management Mobile health apps accessible to people with disabilities: qualitative single-subject study. *JMIR Mhealth Uhealth.* 2020;8(1):e15060.
52. Thirumalai M, Rimmer JH, Johnson G, Wilroy J, Young HJ, Mehta T, et al. TEAMS (tele-exercise and multiple sclerosis), a tailored Telerehabilitation mHealth app: participant-centered development and usability study. *JMIR Mhealth Uhealth.* 2018;6(5):e10181.
53. Bhattacharjya S, Stafford MC, Cavuoto LA, Yang Z, Song C, Subryan H, et al. Harnessing smartphone technology and three dimensional printing to create a mobile rehabilitation system, mRehab: assessment of usability and consistency in measurement. *J Neuroeng Rehabil.* 2019;16(1):127.
54. Groussard PY, Pigot H, Giroux S. From conception to evaluation of mobile services for people with head injury: a participatory design perspective. *Neuropsychol Rehabil.* 2018;28(5):667–88.
55. Furberg RD, Ortiz AM, Moultrie RR, Raspa M, Wheeler AC, McCormack LA, et al. A digital decision support tool to enhance decisional capacity for clinical trial consent: design and development. *JMIR Res Protoc.* 2018;7(6):e10525.
56. Lazar J, Woglom C, Chung J, Schwartz A, Hsieh YG, Moore R, et al. Co-design process of a smart phone app to help people with Down syndrome manage their nutritional habits. *J Usability Stud.* 2018;13(2):73–93.

57. Ferati M, Babar A, Carine K, Hamidi A, Mörtberg C. Participatory design approach to internet of things: co-designing a smart shower for and with people with disabilities. In: Antona M, Stephanidis C, editors. Universal access in human-computer interaction virtual, augmented, and intelligent environments; 2018. Springer: Springer Verlag; 2018. p. 246–61.
58. Blair J, Abdullah S. Understanding the Needs and Challenges of Using Conversational Agents for Deaf Older Adults. In: Conference Companion Publication of the 2019 On computer supported cooperative work and social computing; 2019, vol. 2019. Austin: Association for Computing Machinery. p. 161–5.
59. Lam MY, Tatla SK, Lohse KR, Shirzad N, Hoens AM, Miller KJ, et al. Perceptions of technology and its use for therapeutic application for individuals with hemiparesis: findings from adult and pediatric focus groups. *JMIR Rehabil Assist Technol*. 2015;2(1):e1.
60. Glaser NJ, Schmidt M, Wade SL, Smith A, Turnier L, Modi AC. The formative design of epilepsy journey: a web-based executive functioning intervention for adolescents with epilepsy. *J Form Des Learn*. 2017;1(2):126–35.
61. Albouys-Perrois J, Laviole J, Briant C, Brock AM. Towards a multisensory augmented reality map for blind and low vision people. In: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. Montreal QC: Association for Computing Machinery; 2018. p. 1–14.
62. Stearns L, Findlater L, Froehlich JE. Design of an augmented reality magnification aid for low vision users. Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility; 2018. Galway: Association for Computing Machinery, Inc; 2018. p. 28–39.
63. Daveler B, Salatin B, Grindle GG, Candiotti J, Wang H, Cooper RA. Participatory design and validation of mobility enhancement robotic wheelchair. *J Rehabil Res Dev*. 2015;52(6):739–50.
64. Leporini B, Buzzi M. Home automation for an independent living. Proceedings of the internet of accessible things. Lyon: Association for Computing Machinery; 2018. p. 1–9.

65. Kim WJ, Kim IK, Kim MJ, Lee E. Effect of UX Design Guideline on the information accessibility for the visually impaired in the mobile health apps. In: 2018 IEEE international conference on bioinformatics and biomedicine (BIBM); 2018. Madrid; 2018. p. 1103–6.
66. Arnott J, Malone M, Lloyd G, Brophy-Arnott B, Munro S, McNaughton R. Involving people with cognitive and communication impairments in Mobile health app design. In: Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility. Galway: Association for Computing Machinery; 2018. p. 367–9.
67. Schmutz S, Sonderegger A, Sauer J. Effects of accessible website design on nondisabled users: age and device as moderating factors. *Ergonomics*. 2018;61(5):697–709.
68. Horton S, Sloan D. Accessibility in practice: a process-driven approach to accessibility: Inclusive Designing: Springer; 2014. p. 105–15.
69. Fuglerud KS. Inclusive design of ICT: the challenge of diversity: University of Oslo, Faculty of Humanities; 2014.
70. van der Kleij R, Kasteleyn MJ, Meijer E, Bonten TN, Houwink EJP, Teichert M, et al. SERIES: eHealth in primary care. Part 1: concepts, conditions and challenges. *Eur J Gen Pract*. 2019;25(4):179–89.
71. Were MC, Sinha C, Catalani C. A systematic approach to equity assessment for digital health interventions: case example of mobile personal health records. *J Am Med Inform Assoc*. 2019;26(8–9):884–90.
72. Veinot TC, Mitchell H, Ancker JS. Good intentions are not enough: how informatics interventions can worsen inequality. *J Am Med Inform Assoc*. 2018;25(8):1080–8.