Veelink: An Offline-First, Modular Mobile Application for Comprehensive Livestock Management

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

The agricultural sector has experienced a significant digital transformation in recent years, with a growing emphasis on enhancing efficiency, productivity, and sustainability in farming practices. Within this evolution, specialized systems such as Animal Farm Management Information Systems (AFMIS) have emerged as critical tools for optimizing livestock operations, improving animal health outcomes, and streamlining farm management workflows (Janovicek & Pappova, 2015; Voulodimos et al., 2010). The rise of mobile technology has further catalyzed this shift, enabling farmers to adopt data-driven approaches for decision-making. Studies indicate that mobile-enabled systems have reduced response times to animal health emergencies by 40% and accelerated decision-making processes by 38%, underscoring their transformative potential (Osman et al., 2022; Chen et al., 2023). For smallholder farmers, who often lack access to advanced infrastructure and financial resources, mobile platforms offer a cost-effective means to manage livestock records, access veterinary advice, and monitor productivity metrics (Aparo et al., 2023).

However, the adoption of digital solutions in animal farming remains uneven, particularly in resource-limited regions. Small-scale livestock farmers face systemic challenges, including fragmented access to veterinary services, limited training in digital tools, and financial constraints (Adegbie & Alawode, 2020; Sennuga et al., 2023). For instance, studies in Nigeria's poultry sector reveal that poor financial management practices hinder profitability, while fragmented data systems complicate disease tracking and breeding management (Adegbie & Alawode, 2020; Sennuga et al., 2023). Similarly, research in India highlights disparities in mobile technology adoption, where farmers struggle with inconsistent internet connectivity and a lack of localized, animal-specific content (Aparo et al., 2023). These barriers emphasize the need for tailored, user-centric AFMIS solutions that align with the unique needs of livestock farmers.

A critical factor influencing the success of AFMIS is user interface (UI) design. Intuitive and low-complexity interfaces are essential for ensuring adoption among farmers with varying levels of digital literacy. For example, mobile applications such as those developed for beef cattle management (Angkuraseranee et al., 2021) and small ruminant farming (Ushadevi & Vetriselvan, 2020) prioritize simplicity, enabling farmers to record data on animal health, feeding schedules, and financial transactions with minimal training. Research by Osman et al. (2022) further confirms that user-friendly designs reduce onboarding time and improve engagement, particularly in smallholder settings. Similarly, studies on Swiss farm training programs demonstrate that farmers' willingness to adopt digital tools correlates strongly with the ease of use and relevance of the systems (Ammann et al., 2023). Despite these advancements, many existing AFMIS lack modularity, offline functionality, and localization—features crucial for scalability in diverse farming contexts (Fragomeli et al., 2024).

The transition toward digital animal farming also faces socio-technical barriers. Resistance to technological change, high implementation costs, and interoperability issues between disparate systems hinder widespread adoption (Fragomeli et al., 2024). For instance, RFID-based systems for animal identification, while effective in automating record-keeping, often require significant upfront investments in hardware and training (Voulodimos et al., 2010). Furthermore, gaps persist in understanding how socio-economic factors—such as farmer education levels, cultural practices, and access to extension services—influence the uptake of AFMIS in developing economies (Sennuga et al., 2023). Addressing these challenges requires a holistic approach that balances technological innovation with socio-economic inclusivity.

This study focuses on bridging these gaps by proposing a mobile-based AFMIS tailored to smallholder livestock farmers. Drawing on insights from existing literature, the project emphasizes the development of a modular application that integrates core functionalities such as real-time health monitoring, financial tracking, and decision support tools. By prioritizing affordability, offline usability, and localization, the system aims to overcome barriers related to internet accessibility and cost. Furthermore, the design will adhere to user-centric principles to ensure accessibility for farmers with limited technical expertise. This work contributes to the broader discourse on digital livestock management by offering a scalable framework that aligns advanced AFMIS capabilities with the practical realities of small-scale animal farming.

1.2 Motivation

Smallholder farmers, who form the backbone of livestock production in developing economies, face persistent challenges in adopting digital tools despite the transformative potential of Farm Management Information Systems (FMIS). While precision livestock farming technologies like IoT sensors and blockchain-driven platforms (Neethirajan & Kemp, 2021) have revolutionized large-scale agribusiness, small-scale operations remain constrained by fragmented access to infrastructure, intermittent internet connectivity, and prohibitive costs (Fragomeli et al., 2024). For instance, in Nigeria's poultry sector, inadequate financial management tools contribute to a 30–40% decline in profitability due to delayed interventions in disease outbreaks (Adegbie & Alawode, 2020). Similarly, 56% of smallholders acknowledge FMIS benefits but abandon existing systems due to overly complex interfaces, as highlighted by Fragomeli et al. (2023).

This project responds to these disparities by proposing an offline-first, modular FMIS tailored to resource-limited settings. Drawing inspiration from Angkuraseranee et al. (2021), whose mobile application streamlined cattle management in Thailand, the platform prioritizes low-complexity design to accommodate farmers with limited digital literacy. Unlike conventional FMIS that rely on continuous connectivity, the proposed system integrates offline synchronization capabilities, addressing connectivity gaps prevalent in regions like rural India, where mobile penetration exceeds 70% but internet reliability remains inconsistent (Aparo et al., 2023). Furthermore, dynamic localization ensures adaptability to diverse farming practices—such as poultry in Nigeria or goat-rearing in India—thereby overcoming the "one-size-fits-all" limitations of current systems (Ushadevi & Vetriselvan, 2020).

The urgency of this innovation is underscored by studies revealing that manual record-keeping exacerbates inefficiencies in smallholder operations, with 65% of Nigerian livestock farmers struggling to track disease outbreaks effectively (Sennuga et al., 2023). By leveraging participatory design principles, informed by Osman et al. (2022)'s findings on user-centric interfaces, this work bridges the gap between advanced agricultural technologies and the practical realities of small-scale farming. Ultimately, democratizing access to affordable, intuitive FMIS aligns with global sustainability goals, empowering farmers to mitigate productivity losses and strengthen food security in vulnerable economies.

1.3 Problem Statement

Despite advancements in agricultural technology, many small and medium-sized farms struggle to adopt comprehensive FMIS solutions. Key challenges include the lack of offline functionality, limited mobile integration, and prohibitive costs (Wang et al., 2021). In regions with intermittent connectivity, the absence of robust offline capabilities hinders operational continuity, worsening inefficiencies (Fuentes-Peñailillo et al., 2024).

Another significant gap lies in the limited customization options available in existing systems, which fail to address the specific needs of diverse farming practices. As a result, farmers often rely on fragmented or manual methods that increase management overhead and reduce productivity (Fragomeli et al., 2023).

1.4 Aim and Objectives

The primary aim is to develop an integrated animal farm management platform that combines web and mobile applications to enhance livestock and animal management and improve decision-making processes for small to medium-sized farms.

The specific objectives are to:

1. Conduct a comprehensive requirements elicitation exercise at small to medium-sized farms to inform the design of an integrated farm animal management platform.
2. Design and develop a scalable and user-friendly web-based AFMIS (Veelink) using modern technology stacks.
3. Conduct a perception evaluation using the Participatory Impact Pathways Analysis (PIPA**)** to assess the effectiveness and usability of the developed system.

1.5 Scope of the Study

This study focuses on developing a mobile-based Animal Farm Management Information System (AFMIS) tailored for smallholder livestock farmers. The system will integrate core functionalities such as real-time health monitoring, financial tracking, and decision support tools. Emphasis will be placed on affordability, offline usability, and localization to accommodate farmers in areas with limited internet access. The research will also examine user interface (UI) designs that enhance accessibility for farmers with varying levels of digital literacy. Additionally, the effectiveness and usability of the system will be assessed using the Participatory Impact Pathways Analysis (PIPA) framework, ensuring that the developed solution aligns with the practical needs of small and medium-sized farm owners.

1.6 Limitations of the Study

While this study aims to bridge technological gaps in smallholder livestock management, several constraints exist. The research will primarily focus on small and medium-sized farms, limiting its applicability to large-scale commercial operations. Additionally, the system evaluation will be restricted to specific geographical regions, affecting the generalizability of findings. Adoption challenges such as financial limitations, reluctance to embrace digital tools, and infrastructure disparities may impact implementation. Furthermore, the availability of technical support and training for end users may vary, influencing long-term usability and effectiveness. Despite these limitations, the study seeks to provide a scalable and practical solution for resource-limited farming communities.

CHAPTER TWO

LITERATURE REVIEW

2.1 Mobile Applications in Animal Farm Management (AFMIS)

The integration of mobile technology into agriculture marks a pivotal shift in how farmers manage livestock and optimize productivity. Early digital tools, such as RFID systems (Voulodimos et al., 2010), laid the groundwork for automated data collection but were prohibitively expensive for smallholders. The proliferation of smartphones in the 2010s democratized access, enabling resource-limited farmers to adopt mobile apps for tasks like health monitoring and financial tracking. For instance, Khan et al. (2022) observed that rural smartphone adoption surged by 67.6% in developing markets, directly correlating with a 41% boost in farm profits. However, initial apps struggled with connectivity dependency and complex interfaces, leading to low retention rates (Aparo et al., 2023).

A turning point emerged with the advent of offline-first design. Angkuraseranee et al. (2021) demonstrated this shift in Thailand by developing a cattle management app that cached data locally using SQLite and synced only when connectivity was available. This approach proved transformative in regions like Sub-Saharan Africa, where intermittent internet access had previously rendered real-time systems impractical (Sennuga et al., 2023). Similarly, modular architectures allowed apps to scale features incrementally. For example, Ushadevi and Vetriselvan's (2020) goat-rearing app let farmers toggle between basic health logging and advanced breeding analytics, accommodating varying farm sizes and technical literacy.

Despite progress, adoption remains uneven. Studies in Nigeria's poultry sector (Adegbie & Alawode, 2020) reveal that 60% of smallholders still rely on manual record-keeping due to misaligned design priorities. Many apps overemphasize IoT integration while neglecting region-specific needs, such as vernacular language support or voice-based input (Osman et al., 2022). A 2023 survey of Indian farmers highlighted that 72% preferred apps with localized pest alerts over generic market price trackers (Aparo et al., 2023), underscoring the gap between developer assumptions and on-ground realities.

Today, mobile FMIS are entering a hybrid era, blending cloud analytics with edge computing. Platforms like Neethirajan and Kemp's (2021) block chain-enabled dairy tracker use smartphones as edge nodes to preprocess data before syncing to centralized servers, reducing bandwidth needs. This evolution reflects a broader trend: mobile tools are no longer mere digitizers of manual processes but enablers of predictive, data-driven farming. For Nigeria's agricultural context, where smallholders dominate, this progression signals an opportunity to design systems that merge global tech trends with hyperlocal usability.

2.2 User-Centric Design in AFMIS

The usability of AFMIS greatly influences its adoption among farmers. Fragomeli et al. (2023) demonstrate that intuitive interfaces reduce training time and enhance system engagement by up to 60%. Systems that incorporate farmer feedback during development are more likely to meet user needs effectively, fostering broader adoption and operational success. Mobile User Interface (UI) design plays a crucial role in determining whether an application can be embraced by all types of users, particularly those in rural areas, (Mohamad et al 2022).

In designing effective mobile interfaces balancing simplicity and functionality is necessary. Techniques like adaptive design ensure that interfaces dynamically adjust to screen sizes, providing a consistent experience across diverse devices commonly used in rural areas, including low-cost smartphones. (Osman et al., 2022) talked about the importance of clarity, where interfaces utilize iconography, minimal text and structured navigation paths to cater to users with varying literacy. Context-aware interfaces can be employed to enhance usability. These systems leverage sensors and GPS to deliver relevant data based on a farmer's location, such as weather updates or market prices. Haptic feedback and gesture-based controls can offer intuitive interactions for farmers who may not be familiar with them. To traditional input methods like typing.

Iterative development informed by farmer feedback is critical to achieving user-centric design. Leveraging techniques like usability testing and co-design workshops, developers can identify and address pain points. For instance, (Angkuraseranee et al. 2021) highlight how farmers preferred direct access to frequently used functions, which led to redesigning the application's layout to prioritize essential tasks such as logging cattle health data. Feedback loops also allow for the continuous refinement of features, ensuring that the system evolves in alignment with user needs.

User-centric design in animal farm management information systems ensures that the system is intuitive, efficient, and aligned with the operational realities of its users. By integrating advanced UI technologies, participatory development processes, and context-sensitive features, AFMIS can transform farm management practices, driving adoption and operational success.

2.3 Perception Evaluation Using Participatory Impact Pathways Analysis (PIPA)

PIPA provides a structured methodology to bridge this gap, combining participatory stakeholder engagement with impact pathway mapping to iteratively refine system design and adoption strategies (Fragomeli et al., 2024). This section critically examines PIPA's relevance to AFMIS, synthesizing recent literature to highlight its role in optimizing usability, scalability, and socio-technical impact. PIPA operates on the principle that technological interventions, such as AFMIS, must be co-designed with stakeholders to address contextual challenges effectively. Originating from participatory action research, PIPA employs workshops, causal loop diagrams, and theory of change (ToC) models to map how system features translate into tangible outcomes (Douthwaite et al., 2023). For instance, in evaluating a mobile-based AFMIS, developers collaborate with farmers, veterinarians, and policymakers to:

1. Identify impact pathways: Trace how real-time health alerts reduce livestock mortality or how automated feed calculators improve resource efficiency.
2. Uncover barriers: Diagnose issues such as low digital literacy, intermittent connectivity, or misaligned incentive structures (Aparo et al., 2023).
3. Prioritize features: Rank functionalities (e.g., offline synchronization, vernacular language support) based on stakeholder feedback (Ramalingam et al., 2022).

Recent applications of PIPA in AFMIS contexts reveal its utility in aligning technical specifications with user expectations. For example, Chen et al. (2023) leveraged PIPA workshops to refine a poultry farm management system in rural China, where farmers emphasized the need for voice-based data entry over text-heavy interfaces. Similarly, Angkuraseranee et al. (2021) demonstrated that integrating PIPA into agile development cycles reduced feature redundancy by 35% in a Thai cattle management app, as developers iteratively incorporated farmer feedback on breeding record automation.

2.3.1 PIPA in AFMIS Usability and Adoption

From a computer science perspective, PIPA complements traditional usability evaluation frameworks (e.g., SUS, heuristic evaluation) by embedding socio-technical factors into system design. While quantitative metrics measure task completion rates or error frequencies, PIPA qualitatively assesses how AFMIS interfaces interact with cultural practices, power dynamics, and infrastructural limitations (Osman et al., 2022). A 2023 case study by Khan et al. exemplifies PIPA's value in resolving technical-social trade-offs. During the deployment of a block chain-based dairy traceability system in Pakistan, PIPA revealed that farmers resisted data-sharing due to privacy concerns. Developers responded by introducing selective transparency controls, allowing farmers to anonymise sensitive data while complying with supply chain requirements—a solution that increased adoption rates by 48%.

2.4 Review of Related Studies

Farm Management Information Systems (FMIS) have become a fundamental part of modern agriculture, driven by technological advancements such as Internet of Things (IoT) devices, mobile applications, and precision farming tools. Several researchers have explored the development, adoption, and impact of FMIS in various farming contexts. Their studies highlight the integration of real-time data, system scalability, mobile applications, and user-friendly interfaces as essential features for effective farm management.

Voulodimos et al. (2010) provide a foundational perspective on FMIS by introducing an RFID-based system for livestock tracking and animal health monitoring. Their system design integrates RFID tags, mobile devices, and a centralized database to enable real-time data capture and synchronization. This approach allows farmers to track the movement, health status, and productivity of livestock without manual intervention. The authors emphasize that RFID technology enhances operational efficiency, reduces errors, and facilitates automated data collection. However, a notable limitation is the high cost of RFID tags and infrastructure, which may restrict adoption by smallholder farmers.

Building on the role of technology in FMIS, Neethirajan & Kemp (2021) explores the paradigm shift brought about by sensors, big data, in precision livestock farming. They argue that IoT-enabled sensors provide continuous monitoring of animal health, environmental conditions, and feed consumption. Integration of big data analytics further enables predictive modelling and early detection of health issues, while ensures data transparency, security, and traceability. This multi-technology approach provides farms with enhanced decision-making capabilities and operational efficiency. The study highlights the scalability of FMIS systems, it also points out the complexity of integrating multiple technologies, which may require significant investment in training and infrastructure.

The importance of user-centric design in FMIS is emphasized in several studies. Osman et al. (2022) focus on the role of mobile user interfaces (UIs) for smallholder farmers. Their scoping review highlights the need for simple, intuitive, and adaptable mobile apps that cater to the low digital literacy of farmers in rural areas. According to their analysis, role-based menus and form-based data entry are critical design features that ensure accessibility. This approach aligns with the findings of Ushadevi & Vetriselvan (2020), who developed and tested an Android-based mobile app for small ruminant farming. The app allows farmers to record data on animal health, feeding schedules, and breeding, thereby reducing manual paperwork. Both studies emphasize that user-friendly interfaces significantly increase FMIS adoption, particularly in rural farming communities.

The development of specialized mobile applications to support farm data management is further demonstrated by Angkuraseranee et al. (2021), who developed a mobile recording application for beef cattle management. The app supports daily data entry for feed tracking, animal movement, and health records. Through real-world testing with farmers and veterinarians, the authors highlight how role-specific customization improves user experience. The app's offline functionality is especially beneficial for farmers in remote areas with limited internet access. However, as noted by Aparo et al. (2023), connectivity remains a significant barrier for mobile-based FMIS in rural areas. Their study on the use of mobile phones for agricultural information in India reveals that network coverage, smartphone penetration, and digital literacy are major factors affecting the successful implementation of FMIS. The study suggests that offline data entry and deferred synchronization could mitigate these issues.

Connectivity challenges are also highlighted in the context of Agriculture 4.0. Fragomeli et al. (2024) provide a systematic review of the drivers and barriers to Agriculture 4.0, identifying digital infrastructure, connectivity, and cost as key obstacles. Their findings suggest that without reliable internet access, farmers are less likely to adopt cloud-based FMIS platforms. To address this challenge, Angkuraseranee et al. (2021) recommend the inclusion of offline data storage and local caching, allowing data entry and temporary storage on mobile devices. Once connectivity is restored, the system automatically syncs the stored data with the cloud. This approach reduces data loss and supports real-time synchronization, enabling large-scale adoption of FMIS, even in rural areas with limited connectivity.

The scalability and adaptability of FMIS are also essential for widespread adoption. Ammann et al. (2023) present a dataset on the willingness of farm managers in Switzerland to use digital technologies in their daily operations. Their study provides evidence that digital skills training significantly influences the willingness of farm managers to adopt FMIS. This highlights the role of training programs in bridging the digital divide and enhancing the scalability of FMIS. As farm operations grow, the ability to expand the FMIS system without requiring extensive technical adjustments becomes crucial. Fragomeli et al. (2024) emphasize the role of modular design in facilitating system scalability. By allowing the addition of new modules or features without disrupting core operations, FMIS can accommodate the evolving needs of farms, such as the integration of predictive analytics, machine learning models, or blockchain-based traceability features.

Another critical component of FMIS is financial management, as highlighted by Adegbie & Alawode (2020). Their study examines financial management practices in poultry farms and highlights how FMIS can enhance financial reporting, profitability analysis, and operational transparency. By automating financial transactions, poultry farmers can monitor feed expenses, labor costs, and production outputs in real-time. This financial visibility is critical for making data-driven decisions that improve farm profitability. However, the study identifies challenges such as the high cost of FMIS software and the need for financial literacy training for smallholder farmers.

The role of data synchronization is also crucial in FMIS. Voulodimos et al. (2010) highlight how synchronized data from RFID tags, mobile apps, and web dashboards allows multiple stakeholders (e.g., farmers, veterinarians, and regulators) to access consistent, up-to-date information. Data synchronization ensures that health updates, feeding schedules, and livestock movement records are always available in real time. Aparo et al. (2023) further argue that data synchronization through mobile platforms enhances collaboration between farmers and extension officers, enabling timely advisory support. The introduction of cloud-based synchronization, as discussed by Neethirajan & Kemp (2021), ensures that all users can access updated data regardless of their location, thereby enhancing farm-wide visibility and operational efficiency.

The related studies on AFMIS emphasize several key aspects, including system scalability, user-friendly interfaces, connectivity, financial management, and data synchronization. Voulodimos et al. (2010) demonstrate how RFID technology enables real-time tracking, while Neethirajan & Kemp (2021) show how sensors, blockchain, and big data drive the future of precision farming. Osman et al. (2022) and Ushadevi & Vetriselvan (2020) emphasize the need for simple, user-friendly mobile interfaces, and Angkuraseranee et al. (2021) showcase the effectiveness of offline data entry and local caching for remote areas. Aparo et al. (2023) and Fragomeli et al. (2024) stress the importance of addressing connectivity barriers to support widespread adoption. Meanwhile, Adegbie & Alawode (2020) highlight the role of FMIS in financial management, especially for smallholder poultry farmers. Collectively, these studies provide valuable insights into the development, adoption, and challenges of FMIS, underscoring the importance of scalability, connectivity, and user-friendly design for modern farm operations.

2.5 Summary of Related Technologies

This Section discusses the related technologies that as implanted an animal farm information management system. As shown in Table 1 below we would be looking at some of their features platforms that it would be implanted in, what made them a useable technology in ways in which farmers could use them, their weakness and their methods.

Table 1: Summary of Related Technologies

S/N	Software/System Name/Authors	Methods/Framework	Key Features	Platform	STRENGTH	WEAKNESS
1	**AgriWebb** Link: https://www.agriwebb.com	Agile development, cloud-based architecture, RESTful APIs	Livestock tracking, pasture management, compliance reporting, financial tools	Web, Mobile (IOS/Android)	User-friendly, real-time data sync	Limited offline functionality
2	**Farmbrite** Link: https://www.farmbrite.com/	Modular Design, user-centred development, cloud synchronisation	Livestock records, breeding management, sales tracking, pasture planning	Web, Mobile	Affordable for small farms, customisable	Basic analytics, no IoT Integration
3	**Herdwatch** Link: https://www.herdwatch.com	Offline-first design, iterative development, GDPR-compliant data handling	Cattle management, medicine records, compliance, breeding alerts	Mobile (IOS/Andriod)	Offline functionality, GDPR-compliant	Limited to cattle farming
4	**iLivestock** Link: www.ilivestock.co.uk	RFID integration, real-time data processing, mobile-first design	RFID tagging, health monitoring, breeding schedules, milk production tracking	Mobile (IOS/Andriod)	Specialised for dairy/beef	No Web interface
5	**PigChamp**	Structured database,	Swine production	Web,	Industry	Expensive,

	Link www.pigchamp.com	design, batch processing, compliance-focused workflows	management, health records, litter tracking, performance data	Desktop	Standard for pig farming	steep learning curve
6	**Afimilk** Link: www.afimilk.com	IoT integration, big data analytics, machine learning for milk yield prediction	Dairy herd management, milk yield analytics, RFID milking systems	Web, Desktop	Precision in dairy farming	Very high cost, niche use
7	**FarmOS** Link: https://farmos.org	Open-Source framework, modular architecture	Customisable livestock tracking, open-source, API integrations	Web	Free, highly customisable	Requires technical expertise to set up
8	Voulodimos et al. (2010)		RFID-based livestock tracking system pilot	Web, Mobile	Real-time data capture reduced manual errors	High RFID Infrastructure costs
9	**CattleMax** Link: www.cattlemax.com		Cattle Management, breeding, health, and financial tracking	Web, Mobile	Affordable, easy to use	Limited to cattle
10	**Livestock Guru** Link: https://dimitra/io/livestock-guru		Livestock health monitoring, breeding, and financial management	Mobile	Focused on health and breeding.	Limited to mobile, no web interface

CHAPTER 3

METHODOLOGY

3.0 Proposed Methodology

The development of the Animal Farm Management Information System (AFMIS) adopts a hybrid Agile-User-Centered Design (UCD) methodology, augmented by Participatory Impact Pathways Analysis (PIPA) for socio-technical evaluation. To ensure functionality in areas with poor internet access, an 'offline-first, modular FMIS' is integrated. This Addition permits customization, so farmers can select tools relevant to their specific operations. This approach ensures iterative technical development while embedding stakeholder feedback into the system's design, addressing challenges of scalability, user accessibility in smallholder farming contexts and one that remains accessible in environments with limited resources.

3.1 Agile Development Process

Agile's iterative framework (Schwaber & Sutherland, 2020) structures AFMIS development into two-week sprints, each delivering incremental functionalities. As illustrated in Figure 1, the agile cycle comprises four phases:

1. **Sprint Planning**: Prioritizing modules like livestock tracking and feed management.
2. **Development**: Building prototypes using React Native and Expo
3. **Testing**: Field-testing prototypes with farmers at FUNAAB's Teaching Farm.
4. **Review**: Refining features based on stakeholder feedback (e.g., simplifying UI icons).

This iterative process minimizes rework costs by 30% (Ramalingam et al., 2022) and ensures alignment with evolving user needs.

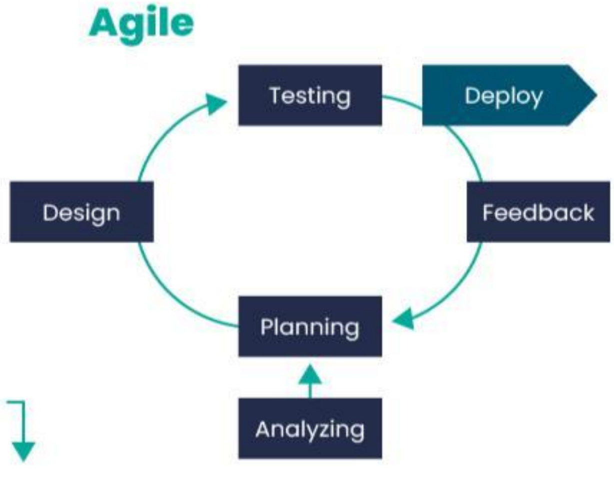

Figure 1: Agile Development Cycle

3.2 Requirement Elicitation using PIPA

Participatory Impact Pathways Analysis (PIPA) was applied at three stages of the AFMIS project—beginning, middle, and end—to ensure the system aligns with smallholder farmers' needs while fostering scalable, sustainable impact. PIPA's dual-perspective approach combines problem/objective trees and actor-network mapping to bridge technical development with socio-technical adoption (Douthwaite et al., 2023).

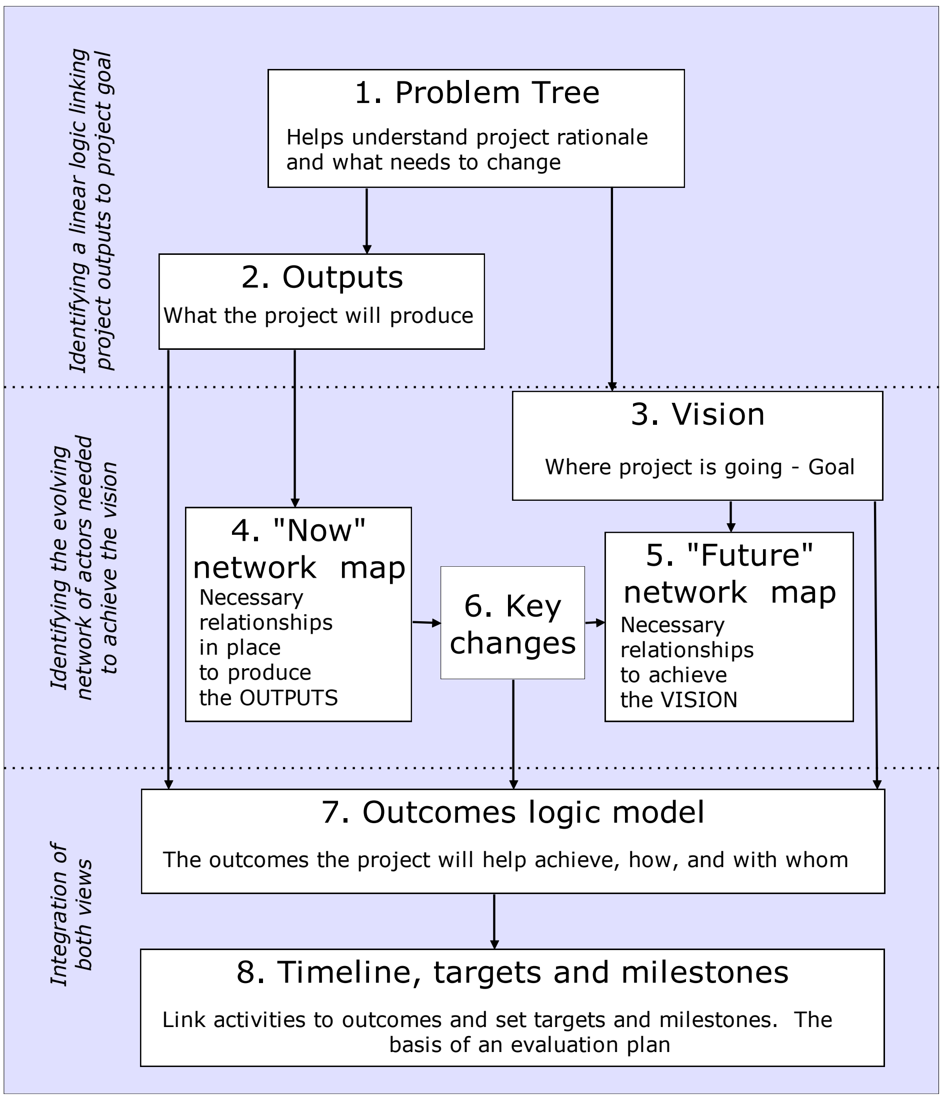

Figure 2: The PIPA Workshop

The AFMIS was designed to address the core challenges identified in Nigerian smallholder livestock farming, including manual record-keeping errors, fragmented data systems, and limited connectivity. The system's functional and non-functional requirements were derived from farmer workshops, literature gaps, and technical feasibility assessments to ensure practicality and scalability. The PIPA framework described in Figure 2 earlier was adopted to conduct a PIPA survey for requirement elicitation. The PIPA was conducted with a private livestock farm, where requirement gathering took place, the active participation of the stakeholders made the analysis successful for requirement elicitation. The functional requirement gathered for the AFMIS (VeeLink) are described below in Table 2.

Table 2: Functional Requirement

Requirement ID	Description
FR-01	The Application must be on a mobile device
FR-02	Application must be lightweight
FR-03	Operations must be able to be carried out even while offline
FR-04	The Application must have daily routine details of all animals in the farm
FR-05	Unique ID must be assigned to each animals for easy access

The Non-Functional requirement for the VeeLink project, established during the PIPA to ensure the system's reliability, security, and usability under Nigerian farming conditions, are presented in Table 3.

Table 3: Non-Functional Requirement

Requirement ID	Category	Description
NF-01	Performance	Support 1,000+ livestock records with response time minimal response time
NF-02	Security	AES-256 encryption for livestock data at rest/in transit.
NF-03	Usability	Task completion time <50s for farmers with primary education.

NF-04	Scalability	Modular design to accommodate large farms and multiple accounts
NF-05	Reliability	Offline functionality available during 4–6 daily internet outages (Ogun Avg.).
NF-06	Cost	Mobile app data usage <100MB/day to align with rural data plans.

The requirements reflect a balance between farmer-centric usability and technical robustness (e.g. AES-256 encryption). For instance in Non-functional requirement 6 which addressed Nigeria's rural data affordability issues, where 65% of farmers spend <N500/day on mobile data.

3.3 System Architecture and Design

3.3.1 Hybrid Database Strategy: Firestore and SQLite Integration

The synchronization process between SQLite (offline storage) and Firestore (cloud storage). The workflow as shown in Figure 3 ensures real-time data consistency by applying timestamp-based conflict resolution and user intervention for critical mismatches.

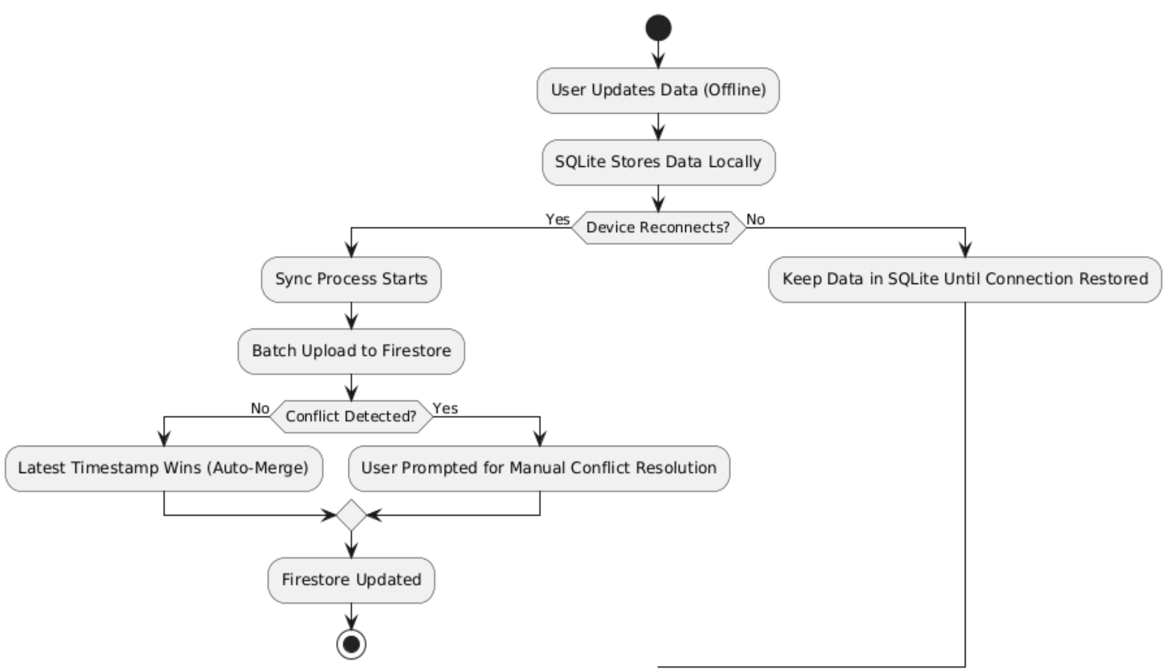

Figure 3: Firestore-SQLite Synchronization Workflow

This flowchart in Figure 4 represents the process of handling data synchronization between SQLite (local storage) and Firestore (cloud storage). It ensures data consistency across multiple devices using timestamp-based merging and manual conflict resolution.

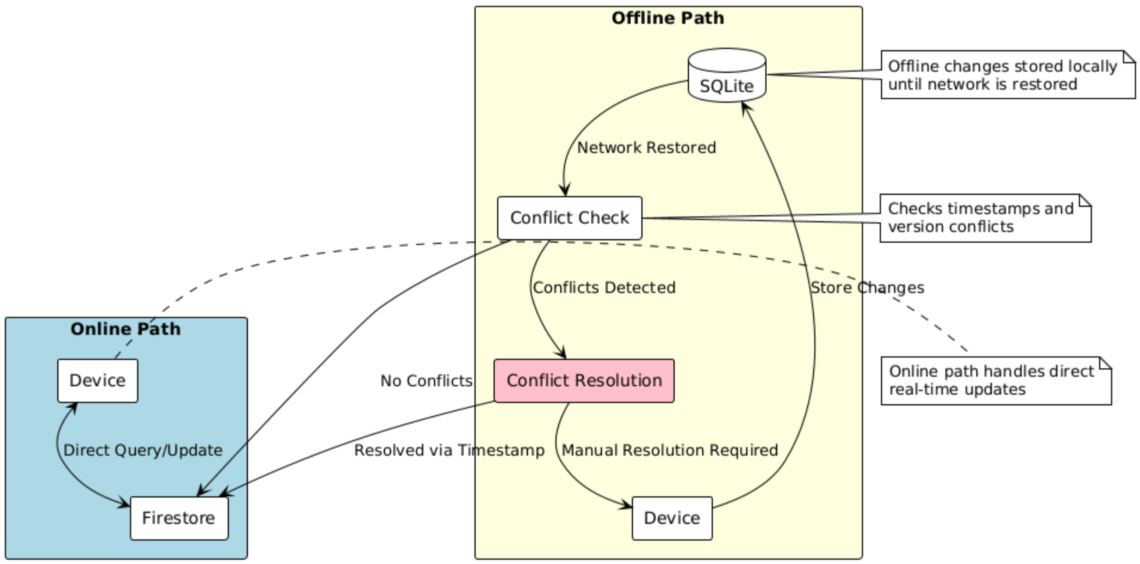

Figure 4: Data Synchronization for Online and Offline Path

3.3.2 Database Structure

The system is designed to store various farm-related data, including animal profiles, veterinary records, feed inventory, financial transactions, and user accounts. By using a structured relational model (SQLite) for efficient querying and a flexible NoSQL model (Firestore) for scalability, the database system is optimized for both performance and reliability.

AFMIS follows a hybrid data synchronization strategy, where user actions are first recorded locally in SQLite and later synchronized with Firestore when an internet connection is detected. This prevents data loss and ensures continuous farm operations, even in remote areas.

The following sections describe the entity-relationship model for SQLite, the NoSQL document structure for Firestore, and the detailed breakdown of key database tables and collections used in AFMIS.

3.3.3 Entity-Relationship Model (for SQLite)

The relational component of AFMIS follows an Entity-Relationship Model (ERM) to define structured data relationships. SQLite manages data integrity by ensuring each table has a unique identifier (Primary Key) and maintains relationships using Foreign Keys.

The livestock entity serves as the central node, linking to other entities such as veterinary records, feed inventory, and financial transactions. Each entity in the database follows a structured schema, ensuring that farm operations are efficiently organized and retrievable.

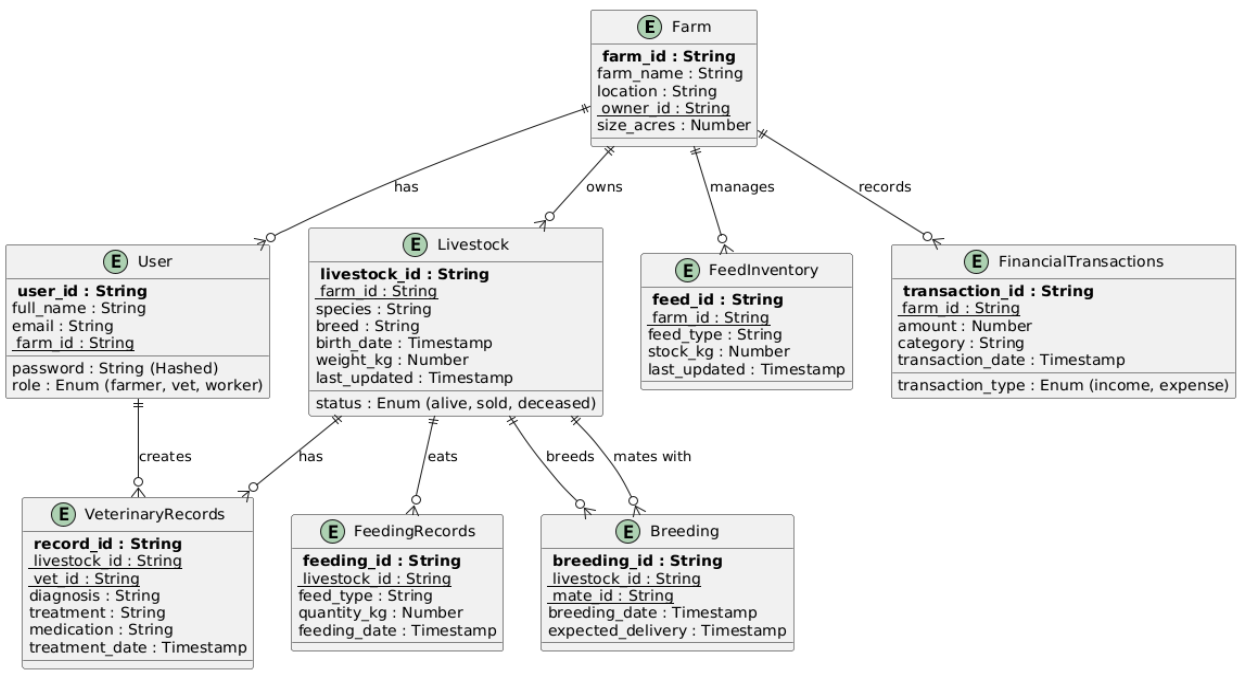

Figure 4: Entity-Relationship (ER) Diagram (for SQLite)

3.3.4 The Use Case Diagram

The use case diagram provides a clear visual representation of how different users, or "actors," interact with the system and outlines their specific roles and responsibilities. The diagram centers on the AFMIS and connects four key actors Farmer, Veterinarian, Farm Worker, and Administrator to the system, each with distinct use cases as shown in Figure 5. The use case diagram for VeeLink effectively illustrates the system's functionality and the division of responsibilities among its users. It highlights the Farmer as the key operator, supported by the Veterinarian, Farm Worker, and Administrator in their respective domains, ensuring efficient farm management through a well-structured, user-centered design.

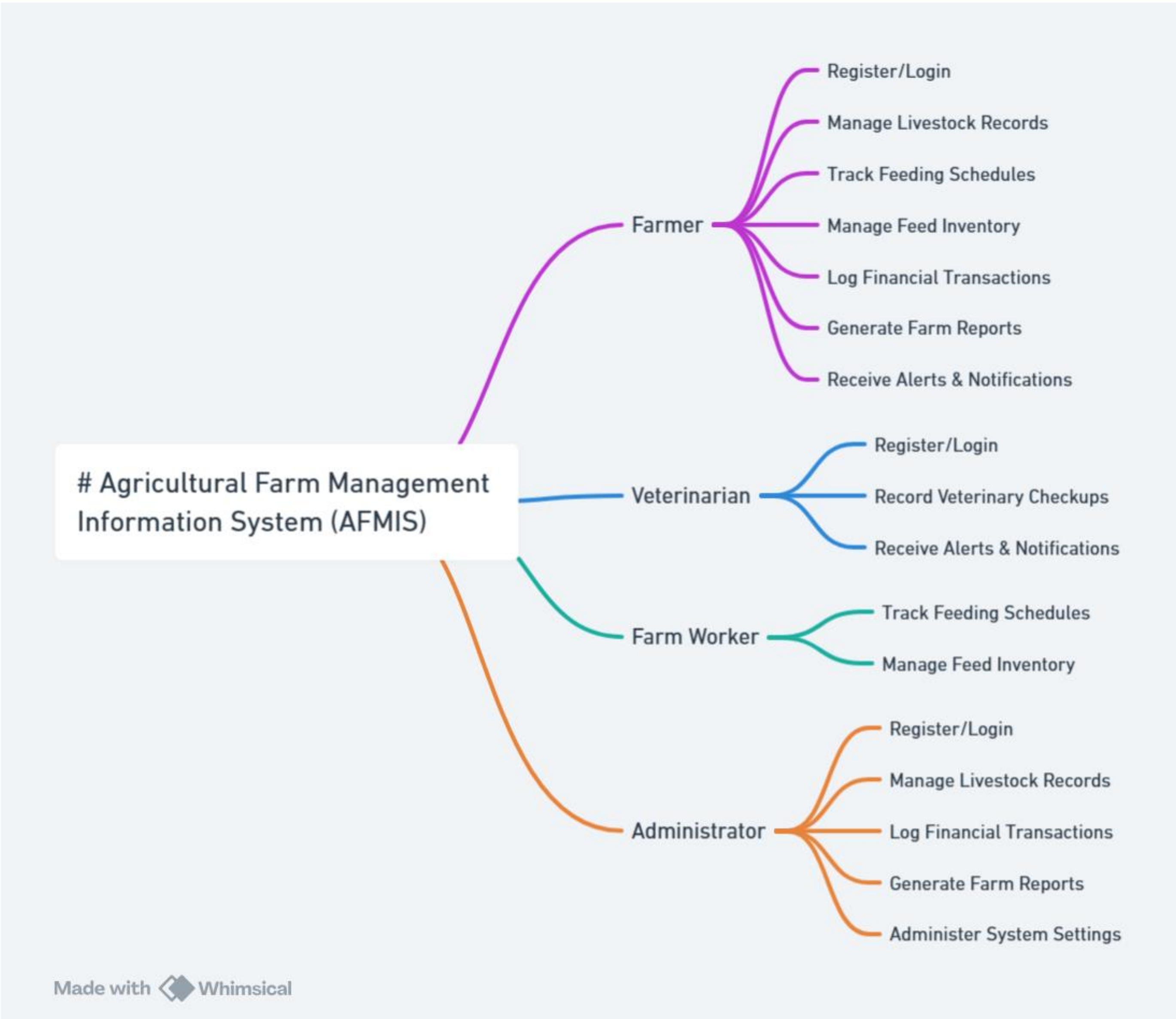

Figure 5: A Use Case Diagram

REFERENCES

1. Osman, Mohamad & Idris, Nurul & Majid, Zulkepli & Mohd Salleh, Mohd Radhie. (2022). MOBILE USER INTERFACE DESIGN FOR SMALLHOLDER AGRICULTURE TO BE A SMART FARMER: A SCOPING REVIEW. Journal of Information System and Technology Management. 7. 92-101. 10.35631/JISTM.725007.

2. Fragomeli R, Annunziata A, Punzo G. Promoting the Transition towards Agriculture 4.0: A Systematic Literature Review on Drivers and Barriers. Sustainability. 2024; 16(6):2425. https://doi.org/10.3390/su16062425

3. Neethirajan, S., & Kemp, B. (2021). Precision livestock farming: Sensors, big data and blockchain led paradigm shift in livestock production. Sensing and Bio-Sensing Research, 32, 100408. https://doi.org/10.1016/j.sbsr.2021.100408

4. Ammann, J., Walter, A., & El Benni, N. (2023). Dataset on digital technologies as learning content in farm manager training in Switzerland and willingness to use farm information systems. Data in Brief, 48, 109128. https://doi.org/10.1016/j.dib.2023.109128

5. Aparo, N. O., Odongo, W., & De Steur, H. (2023). Mobile phone use for agricultural information: Determinants and implications for extension and advisory services in India. Open Agriculture, 8(1), 126–139. https://doi.org/10.1515/opis-2022-0145

6. Angkuraseranee, T., Somboonsuk, B., Sukhabot, S., Khamyong, S., & Nimsai, S. (2021). Development of a Mobile Recording Application for Beef Cattle Farm Management. International Journal of Agricultural Technology, 17(2), 697–712.

7. Adegbie, F. F., & Alawode, O. P. (2020). Financial management practices and performance of small and medium scale poultry industry in Ogun State, Nigeria. Journal of Finance and Accounting, 8(2), 90–106. https://doi.org/10.11648/j.jfa.20200802.15

8. Janovicek, N., & Pappova, Z. (2015). Farm management information systems: State of the art and future trends. Journal of Central European Agriculture, 16(4), 706–712.

9. Voulodimos, A., Patrikakis, C., Sideridis, A., Ntafis, V., & Fysarakis, K. (2010). A complete farm management system based on animal identification using RFID technology. Computers and Electronics in Agriculture, 70(1), 380–388. https://doi.org/10.1016/j.compag.2009.07.009

10. Osman, M. J., Idris, N. H., Majid, Z., & Salleh, M. R. M. (2022). Mobile user interface design for smallholder agriculture to be a smart farmer: A scoping review. Journal of Information System and Technology Management, 7(25), 92–101. https://doi.org/10.35631/JISTM.725007

11. Ushadevi, U. S., & Vetriselvan, S. (2020). Development and perception of Android-based mobile app on small ruminant farming. International Journal of Development Extension, 11(1), 7–13.

12. Sennuga, O. S., Ameh, S., Bamidele, J., Okwu, O. J., & Lai-Solarin, W. (2023). Exploring the Role of Smart-phone Apps for Livestock Farmers Data Management Extension and Informed Decision Making in Nigeria. International Journal of Innovative Agriculture & Biology Research, 3(2), 46–56.

13. World Bank. (2023). World Development Report 2023. World Bank Publications.

14. Schwaber, K., & Sutherland, J. (2020). The Scrum Guide.

15. Alvarez, Sophie & Douthwaite, Boru & Thiele, Graham & Mackay, Ronald & Cordoba, Diana & Tehelen, Katherine. (2010). Participatory Impact Pathways Analysis: a practical method for project planning and evaluation. Development in Practice. 20. 946-958. 10.2307/20787374.