Original Paper

# Sustaining Public Health Surveillance Systems in Thailand: Comparative Qualitative Case Study of 2 National Platforms

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## Abstract

**Background:** Public health surveillance (PHS) systems are essential for routine disease monitoring, early outbreak detection, and emergency response. Although many studies focus on system development and implementation, less attention has been given to factors that sustain surveillance systems over time.

**Objective:** This study aimed to identify stakeholder-perceived conditions associated with the sustainability of PHS systems in Thailand by examining stakeholder experiences across 2 operational national surveillance platforms.

**Methods:** A comparative qualitative case study was conducted using evidence from the Malaria Surveillance System (MIS) and Digital 506 (D506), the national notifiable-disease surveillance platform. In total, 6 individual interviews and 4 small-group interviews were conducted using semistructured guides with 17 participants: IT personnel, project managers, public health officers, and policymakers and funders. Audio recordings were transcribed and analyzed using a deductive-dominant hybrid thematic approach combining deductive and inductive coding, with explicit within-case and cross-case comparison.

**Results:** Thematic analysis identified 7 themes reflecting stakeholder perceptions of PHS sustainability: user needs, collaboration and partnership, human resources, infrastructure, financial sustainability, ownership, and system adaptability. Participants associated continued use with systems that fit routine workflows, reduced duplicate work, and produced actionable outputs. MIS findings highlighted context-adapted design in remote settings, donor transition, and reluctant ownership, while the D506 findings emphasized interoperability, near real-time national reporting, and constraints in domestic budgeting and specialized technical capacity. Shared challenges included infrastructure maintenance and recurrent staffing and financing needs. Participants also distinguished digitization from digital transformation intended to improve efficiency, decision-making, and adaptability to changing needs.

**Conclusions:** Stakeholder perspectives suggest that sustaining PHS systems requires more than technical deployment. For comparable national surveillance systems, the findings suggest prioritizing clear operational ownership and recurrent resources to support routine workflows, maintain human and infrastructure capacity, and enable continuous adaptation to changing public health and technological needs.

***(JMIR Public Health Surveill 2026;12:e106399)*** doi: 10.2196/106399

**KEYWORDS**

public health surveillance; sustainability; health information systems; qualitative study; Thailand



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## Introduction

Public health systems worldwide continue to face emerging health threats that require timely detection and response. Traditional paper-based surveillance systems, which depend on manual reporting and delayed data collection, are increasingly inadequate for addressing the challenges of modern public health. These limitations have driven the adoption of health information systems (HISs) within public health surveillance (PHS) to facilitate timely monitoring, efficient data management, and evidence-based decisions in public health practice [1,2]. By improving data timeliness, PHS systems can enhance public health readiness and support faster responses to outbreaks and emergencies, making them important components of modern public health infrastructure.

As health care demands rise, the importance of sustainable PHS systems has become increasingly apparent. Public health organizations worldwide have implemented PHS systems to address diverse and evolving health risks [3,4]. The integration of PHS systems into the existing HIS framework enables more efficient data collection, analysis, and dissemination, improving disease surveillance and enabling more effective public health responses [5].

Sustainability, which has been conceptualized in environmental science as "meeting present needs without compromising future generations," has been extended to IT topics to describe the ability of systems to remain functional and practical over time despite technological, organizational, or financial changes [6]. In the context of PHS, sustainability refers to the system's capacity to maintain surveillance activities to support continuous disease monitoring and public health decision-making [7,8].

Despite the growing adoption, the long-term sustainability of PHS systems remains a significant challenge and an underexplored area of research. As with other software systems, their viability depends not only on their initial development but also on technical infrastructure, organizational support, and management processes. Without adequate support for sustainability, PHS systems risk becoming inefficient or even obsolete over time [9]. Examining sustainability challenges in operational PHS systems can provide valuable insights into system implementation and maintenance processes throughout their lifecycle to support long-term use.

Studies in Thailand have described the development, implementation, and performance of individual surveillance systems [10-14]. However, comparative qualitative evidence on the sustainability of national PHS platforms with contrasting development, governance, and financing pathways remains limited in the Thai context. Consequently, little is known about which sustainability concerns are shared across systems and which are shaped by their operational contexts.

Accordingly, this study aimed to identify stakeholder-perceived conditions associated with the sustainability of PHS systems in Thailand through a comparative qualitative case study of the Malaria Surveillance System (MIS) and Digital 506 (D506), the national notifiable-disease surveillance platform. These systems were selected as deliberately contrasting cases because they differed in disease scope, development pathways, operational contexts, governance, and financing arrangements, allowing shared and context-specific sustainability concerns to be examined. The study drew on the perspectives of individuals directly involved in system development, implementation, management, routine use, policymaking, or funding. By focusing on sustainability as a central yet underexplored dimension of PHS, this study contributes to understanding how surveillance systems can remain functional and responsive in dynamic public health environments.

## Methods

### Study Design

The study used a comparative qualitative case-study design to investigate stakeholder perceptions of the sustainability of PHS systems in Thailand [15,16]. Semistructured interviews and small-group interviews were used to gather in-depth insights into the experiences and perceptions of stakeholders involved in the development, implementation, routine use, management, policymaking, or funding of these systems. The MIS and D506 were intentionally selected before data collection, with each surveillance system serving as a bounded case and primary unit of analysis. Their contrasting disease scope, development pathways, operational contexts, and funding arrangements were prespecified as the basis for cross-case comparison. This purposeful contrast allowed the study to examine which perceived sustainability conditions were shared across 2 operational systems and which were specific to their institutional, technical, and financing contexts.

Both systems were selected for their continued operation through changes in technology, organizational arrangements, and public health requirements, providing information-rich insights into adaptation and ongoing challenges. Although discontinued systems were not included, these cases allowed examination of difficulties encountered during continued operation.

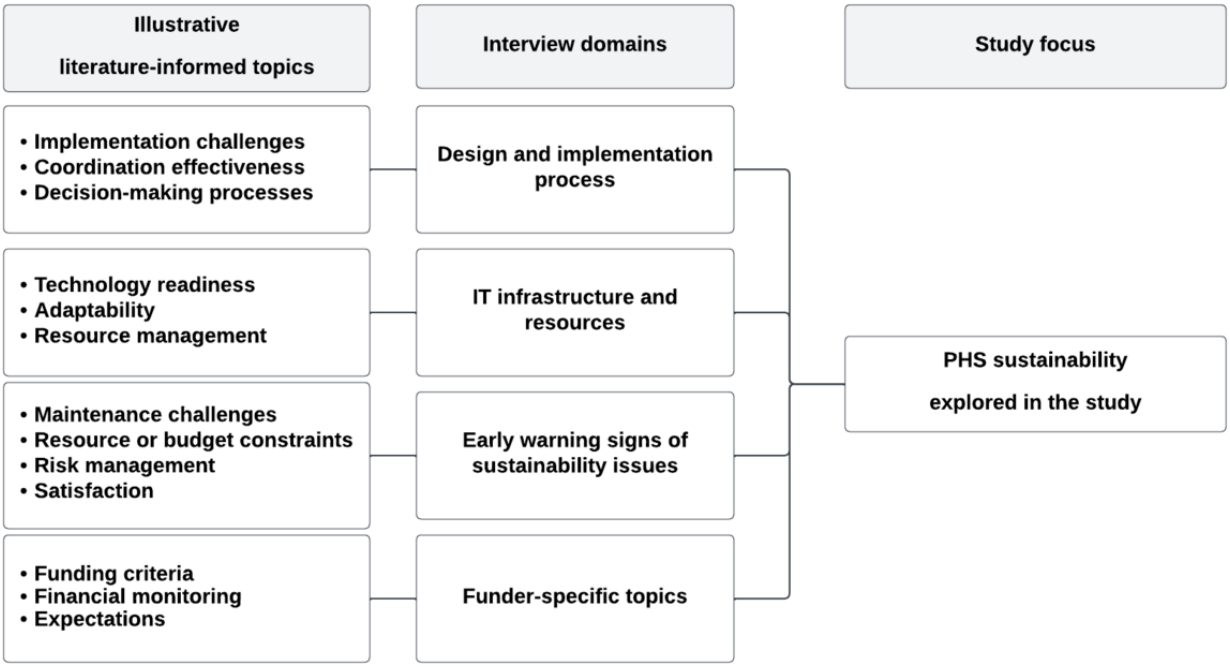
For this study, sustainability was operationalized as the ability of a PHS system to continue functioning and supporting routine surveillance over time despite changes in technology, funding, organizational arrangements, and public health requirements. This included continued routine use, maintenance and support, clear responsibility for ongoing operation, and the capacity to adapt to changing needs [8,17].

An interview guide was developed to ensure consistency across data-collection sessions while permitting open-ended responses. The guide was structured using a literature-informed framework developed by the research team from recurring sustainability considerations reported in HIS and PHS literature [6-8,17]. These considerations were organized into 4 domains: design and implementation process, IT infrastructure and resources, early warning signs of sustainability issues, and funder-specific topics (Figure 1). The framework was used as an organizing structure for data collection and the deductive component of initial coding while allowing additional concepts to emerge from participants' accounts.



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**Figure 1.** A literature-informed interview framework. PHS: public health surveillance.




## Ethical Considerations

The study received approval from the ethics committee of the Faculty of Tropical Medicine, Mahidol University (MUTM2025-015-01). Before participation, participants reviewed the study information and were informed of the study objectives, procedures, rights, and confidentiality risks, including the limits of confidentiality in small-group interviews. Written informed consent was obtained from all participants. Direct identifiers were removed from transcripts before coding. Audio recordings, transcripts, and study materials were stored, with access restricted to the research team. Each participant received THB 500 as compensation for their time. For reporting, quotations and supplementary materials were deidentified and reviewed to reduce the risk of deductive identification for national-level stakeholder groups.

## Study Setting

The study focused on 2 PHS systems in Thailand: the MIS and D506, the national notifiable-disease surveillance platform. MIS is used nationwide for malaria surveillance and supports monitoring and management of malaria transmission, with particular operational requirements in malaria-endemic and border settings. Its development grew from electronic and mobile malaria-surveillance initiatives introduced in 2009 and subsequently expanded in provinces along Thailand's international borders. MIS has been supported by international funding sources, including the World Health Organization, the Bill & Melinda Gates Foundation, and the Global Fund, and received technical support from the Center of Excellence for Biomedical and Public Health Informatics (BIOPHICS), Faculty of Tropical Medicine, Mahidol University [10,11].

D506 evolved from the legacy Report 506 (R506) weekly reporting structure, which has supported national notifiable-disease reporting since 1967. D506 was developed domestically using national budget allocations in 2022 to support more timely electronic reporting and was later incorporated into the broader Digital Disease Surveillance framework in 2024 [12-14].

## Study Population

Participants were selected using purposive sampling to include individuals with relevant roles and experience in PHS systems and the capacity to provide in-depth insight into their long-term sustainability [18]. Eligibility required at least 6 months of relevant involvement in system development, implementation, operation, management, policymaking, or funding. Formal invitations were sent directly to the designated leads responsible for MIS or D506 within participating organizations. These leads were asked to identify and nominate staff whose functional involvement met the eligibility criteria. The recruitment process therefore reflects nominated and participating individuals rather than all staff who may have been considered within each organization.

The study population was categorized into 4 key stakeholder groups based on functional roles. The first group comprised IT personnel, including developers, system analysts, and administrators, responsible for the technical design, deployment, and maintenance of PHS systems. The second group included project managers (PMs) who oversee system planning and implementation and coordinate between technical teams and public health stakeholders. The third group consisted of public health officers (PHs), such as epidemiologists and field practitioners, who are responsible for routine data collection, verification, and the application of surveillance data for disease monitoring. The fourth group included policymakers and funders (PFs), encompassing senior officials and representatives who provide strategic direction, governance, or financial support for PHS systems.



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These categories were selected to capture complementary responsibilities across the surveillance-system lifecycle: technical development and maintenance, implementation coordination, routine public health use, and policy or financial governance. Stakeholder categories were assigned according to participants' primary functional responsibilities in the surveillance system rather than formal organizational job titles.

The initial recruitment plan allowed for up to 10 participants associated with each PHS system and up to 5 policy or funding participants. The plan was informed by the range of technical, operational, governmental, and partner perspectives included in comparable qualitative research on HIS sustainability [19] and by the stakeholder functions relevant to the present study. Final recruitment was guided by informational redundancy in the accumulating interview data rather than by statistical calculation [20].

## Data Collection

Participants took part in either an individual interview or a small-group interview based on their responsibilities, involvement, and availability. Participants involved in closely coordinated technical or operational activities were generally included in small-group interviews to capture shared experiences and complementary perspectives, whereas those with strategic, supervisory, policy, or funding responsibilities were generally interviewed individually to support more detailed insights into governance and decision-making. Small-group interview composition was arranged around related responsibilities and participant availability while seeking to limit hierarchy effects where possible.

Two role-adapted semistructured interview guides were used. The surveillance-system stakeholder guide was used for participants directly involved in MIS or D506, including technical, public health, management, and policy roles. The funder participant was interviewed using a separate guide focused on funding criteria, monitoring, expectations, and sustainability beyond the funding period. Before data collection, WP pilot-tested the interview guides internally with CR and SL through mock administration of the questions. Based on this process, the research team refined the wording and sequencing of questions and incorporated relevant follow-up probes to improve clarity and suitability for the intended participant groups. The pilot testing was conducted as an internal research-team procedure, and no pilot-test data were included in the analysis. The complete English interview guides are provided in Multimedia Appendix 1.

Sessions were conducted in either Thai or English, depending on participants' preferences, and took place on-site or online through the Mahidol University password-protected Zoom environment. CR and WP participated in all data collection sessions as an interviewer or comoderator, asked follow-up and clarification questions, and supported session recording and observation. All sessions were audio-recorded with participants' consent, and recordings were stored, with access restricted to the research team. Handwritten notes were used to capture key points and preliminary observations and to support postsession discussion within the research team.

Data saturation was assessed iteratively during data collection as redundancy in the accumulating information [20]. WP and CR reviewed the accumulating interview content and the evolving codebook as data collection progressed and considered whether subsequent sessions contributed substantively new information relevant to the study objectives. Recruitment concluded when subsequent interviews largely repeated issues already represented in the codebook, while also considering the availability of eligible participants and organizational access. Data collection was completed in a single session per participant; no repeat interviews were scheduled, and transcript return and participant member checking were not part of the study procedures.

## Researcher Characteristics and Reflexivity

The research team was based at an academic institution, with backgrounds in epidemiology and health informatics and experience in PHS and digital health systems. The team has established academic and professional collaborations with the Ministry of Public Health and relevant stakeholders in Thailand. CR and WP led the individual and small-group interviews; CR had formal qualitative research training and interviewing experience, and WP conducted data collection under CR's supervision.

The researchers' familiarity with PHS facilitated access and understanding of the study context. However, none had a direct supervisory relationship with participating PHS personnel or operational responsibility for either surveillance platform. Although the MIS was developed by BIOPHICS within the broader institutional environment, the researchers were not involved in its day-to-day operation or staff supervision. Following each session, CR and WP conducted reflective debriefings to compare interpretations, consider how their assumptions or experiences might influence interpretation, and discuss alternative or divergent perspectives to ensure that findings remained grounded in participants' accounts.

## Data Analysis

Audio recordings were transcribed verbatim in the language used in each session. WP transcribed Thai-language recordings word for word in Thai and used ChatGPT (OpenAI) as a translation-support tool to prepare English translations, whereas English-language recordings were transcribed directly in English. WP checked every English translation against the corresponding Thai transcript and audio recording. CR and SL reviewed the translated material and its use throughout the analysis. The English translations also enabled PH, an English-speaking coauthor, to participate in analytic review and validation. Unclear or culturally and technically specific wording was resolved by replaying the recording, returning to the Thai transcript, and discussing the intended meaning within the research team. Coding and analysis were conducted in English.

Data were analyzed using a deductive-dominant hybrid thematic approach combining deductive and inductive coding [21,22]. Initial coding was structured by the 4 literature-informed framework domains and 13 predefined working codes documented in the qualitative codebook. A common coding framework was used across MIS and D506, with codes applied



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where relevant to each participant's interview material. WP performed the primary coding in Microsoft Excel and recorded material not adequately captured by the initial categories as emerging concepts. WP, CR, and SL iteratively reviewed coded excerpts, emerging concepts, category organization, and candidate themes. Interpretive differences raised during review were addressed by returning to source excerpts and revising category or theme boundaries through discussion. This process consolidated the predefined codes and emerging concepts into the 7 final themes reported in the Results section.

Following theme development, evidence was reviewed within MIS and D506 and compared across the 2 systems to identify convergent, divergent, and case-specific patterns. A structured cross-case evidence matrix was prepared from the existing coded dataset to make these comparisons explicit. The supplementary materials include participant and session characteristics (Multimedia Appendix 2), the qualitative codebook with theme definitions, distinctions, and illustrative coding (Multimedia Appendix 3), and the cross-case evidence matrix (Multimedia Appendix 4). The SRQR (Standards for Reporting Qualitative Research) checklist is provided in Multimedia Appendix 5.

# Results

## Participant and Session Characteristics

Data collection was conducted between February and July 2025 and included 17 unique participants from organizations involved in the development, funding, and implementation of the 2 PHS systems. Participants represented 4 stakeholder categories: IT personnel (n=6), PMs (n=3), PHs (n=4), and PFs (n=4). No participant contributed to more than 1 data collection session.

Data were collected through 6 individual interviews and 4 small-group interviews. The small-group interviews included 2-4 participants. In total, 3 sessions were conducted online via Zoom, and the remaining 7 were conducted onsite. Session durations ranged from approximately 33 to 90 minutes. Participant- and session-level characteristics are provided in Multimedia Appendix 2.

Most participants had substantial experience in PHS systems, with 13 of 17 reporting at least 10 years of relevant experience. Notably, IT personnel were involved in both the development and maintenance phases, providing insights into the full technical lifecycle from system design to long-term sustainability. A summary of participant characteristics is presented in Table 1.

**Table 1.** Participant and session characteristics.

| Session ID | Participant ID[a] | PHS[b] experience (years)[c] | Interview type | Session duration (minutes:seconds)[d] |
|---|---|---|---|---|
| MIS-1 | MIS-PM-01 | 10-15 | Small group | 33:24 |
| MIS-1 | MIS-IT-01 | 10-15 | Small group | 33:24 |
| MIS-2 | MIS-IT-02 | >15 | Individual | 53:21 |
| MIS-3 | MIS-PM-02 | >15 | Individual | 79:25 |
| MIS-4 | MIS-IT-03 | 10-15 | Individual | 56:04 |
| PF-1 | PF-01 | >15 | Small group | 77:04 |
| PF-1 | MIS-PH-01 | >15 | Small group | 77:04 |
| D506-1 | D506-PM-01 | >15 | Small group | 80:31 |
| D506-1 | D506-IT-01 | 10-15 | Small group | 80:31 |
| D506-1 | D506-IT-02 | 10-15 | Small group | 80:31 |
| D506-2 | D506-PH-01 | 5-10 | Small group | 71:44 |
| D506-2 | D506-PH-02 | 5-10 | Small group | 71:44 |
| D506-2 | D506-PH-03 | 10-15 | Small group | 71:44 |
| D506-2 | D506-IT-03 | <5 | Small group | 71:44 |
| PF-2 | PF-02 | 5-10 | Individual | 90:31 |
| PF-3 | PF-03 | >15 | Individual | 76:29 |
| PF-4 | PF-04 | 10-15 | Individual | 49:11 |

[a]IDs indicate case and functional role. MIS: Malaria Surveillance System; D506: Digital 506; IT: information technology personnel; PM: project manager; PH: public health officer; PF: policymaker and funder. All 4 PF participants had responsibilities relevant to both systems and were therefore not assigned exclusively to either case.

[b]PHS: public health surveillance.

[c]Experience refers to PHS work generally, not exclusively to the named platform. The experience bands are retained from the participant records.

[d]Durations refer to sessions, not individual speaking time.



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## Summary of the Themes

### Overview

The 4 literature-informed interview domains shown in Figure 1 structured data collection and initial deductive coding but were not treated as final themes. Through iterative review, the predefined codes and emerging concepts were consolidated into 7 final themes reflecting participants' perceptions of PHS sustainability: user needs, collaboration and partnership, human resources, infrastructure, financial sustainability, ownership, and system adaptability. These themes describe technical, organizational, and policy dimensions of continued surveillance-system operation. Table 2 summarizes the principal cross-case findings.

**Table 2.** Summary of final theme findings and cross-case interpretations.

| Theme | Key findings | Cross-case interpretation | |
|---|---|---|---|
| | | MIS[a] | D506[b] |
| User needs | Participants associated continued use with systems that fit routine workflows, reduced reporting burden, and provided immediately useful outputs. | Emphasis on field usability despite unstable connectivity and on case follow-up. | Emphasis on timeliness, dashboards, interoperability, and national-scale information use. |
| Collaboration and partnership | Participants described sustainability as requiring ongoing coordination among technical, public health, managerial, vendor, and policy stakeholders. | Long-term collaboration between malaria staff and developers. | Broader network with greater interoperability and vendor-coordination demands. |
| Human resources | Continuity was perceived as vulnerable when technical or operational knowledge depended on a small number of people and more resilient when internal capability and training were strengthened. | Emphasis on field training and transfer of system-specific technical knowledge. | Emphasis on recruitment and retention of specialized engineering capability. |
| Infrastructure | Infrastructure was described as a lifecycle issue involving connectivity, maintenance, capacity, upgrading, procurement, and continuity. | Emphasis on resilience to weak connectivity and older hardware. | Emphasis on centralized processing, interoperability, and increasing data volume. |
| Financial sustainability | Participants described sustainability financing as extending beyond development to recurrent personnel, infrastructure, maintenance, training, and governance costs. | Donor-to-domestic transition concerns. | Domestic budgeting and procurement constraints despite stronger institutional embedding. |
| Ownership | Participants associated continued operation with a responsible entity that had authority, resources, and accountability for system continuity. | Reluctant or nominal ownership emerged most explicitly in MIS. | More institutionalized government responsibility through departmental roles and budget allocation. |
| System adaptability | Participants viewed sustainability as dynamic and dependent on continued relevance under changing epidemiological, organizational, technological, policy, and user conditions. | Adaptability to disease context, organizational change, remote operations, and technology. | Adaptability through interoperability, evolution from prior reporting systems, and broader digital transformation. |

[a]MIS: Malaria Surveillance System.

[b]D506: Digital 506.

### User Needs

Participants associated the perceived sustainability of PHS systems with their ability to meet user needs by integrating into routine workflows and providing immediate, tangible value. Across both cases, continued use was associated with whether the system supports daily operations rather than imposing additional reporting burdens. Participants perceived that useful tools for decision-making and service delivery encouraged continued engagement and long-term use.

Despite this shared principle, user needs differed according to the operational context of each system. In the MIS, the primary requirement was to facilitate the transition from paper-based and spreadsheet-based processes to a digital platform suitable for use in remote and resource-constrained settings. MIS participants highlighted the importance of retaining functionality that accommodates unstable internet connectivity, such as offline data entry and delayed synchronization:

> *... Users often said their internet was unstable ... so we switched to an online-offline model ... which allows users to input data offline and then syncs it to the central system when internet is available.* [MIS-IT-03]

> *... They had specific workflows, including report forms, data collection templates, and required reporting formats ... We used them to design the computerized system accordingly ...* [MIS-PM-01]

In contrast, D506 participants described how the COVID-19 pandemic increased demand for timely, useful outputs,



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prompting a shift from legacy weekly reporting (R506) to near real-time data availability. They described the development of interoperable components, including APIs and dashboards, to support timely monitoring and national-level decision-making. These developments were accompanied by consultation with field users about which information to display:

> *The factor that led from R506 to D506 came during the COVID period. ... We realized we needed real-time data ... to get timely information ... During COVID, we were using Excel to report daily data and were still struggling with just Excel.* [D506-PH-03]

> *If we only develop based on what we want to see, without actually asking field users what they need, then it is not useful.* [D506-PH-01]

Across both systems, participants associated immediate, actionable outputs for routine supervision and decision-making with motivation to continue using the system. Thus, both cases emphasized practical fit and visible value, while the specific user requirements differed: MIS centered on field usability under unstable connectivity, whereas D506 centered on timeliness, dashboards, interoperability, and national-scale information use.

### *Collaboration and Partnership*

Across both systems, participants emphasized that sustainability depends on continuous coordination to align system design and implementation with routine public health practices. They described collaboration as a way to integrate policy priorities, technical requirements, and field realities into usable digital workflows and resolve problems as the systems evolved. They perceived that systems developed without such alignment, particularly those driven solely by central-level requirements, were less likely to be sustained.

> *There were so many stakeholders involved, and even gathering requirements was tough. We came from the center and did not really know how they operated in practice, ... we had to go into the field ... so they could explain what they encountered and how things worked.* [MIS-PM-02]

> *... If the system is designed only for central programs, it won't be sustainable. If it's designed to be used by the field, for real work, it becomes sustainable.* [PF-01]

In the MIS, participants described a focused, long-term partnership between disease control programs, subnational implementation teams, and an academic development partner. This relationship was described as complementary, combining domain-specific expertise in malaria elimination with technical capacity for system development. They associated continued collaboration with mutual trust, shared problem-solving, and a strong understanding of local workflows and operational contexts:

> *The disease program has elimination expertise, while the development partner has developer and digital expertise ... we both have something the other lacks. When we come together, it works.* [MIS-PH-01]

In contrast, D506 participants described coordination across a broader and more complex institutional network, including multiple disease programs, regional health offices, public and private health facilities, and HIS vendors. They identified a key challenge in achieving interoperability across diverse systems while transitioning from weekly reporting to near real-time, API-based data exchange. They described ongoing engagement with vendors, structured technical guidance, and collaborative problem-solving intended to support consistent data reporting nationwide:

> *... we organize meetings ... with vendors and provide development guidelines on how they need to develop, what user and password they'll need, what kind of access rights to use, and how to send data ...* [D506-PM-01]

Although MIS relied on a more concentrated partnership with accumulated domain knowledge, D506 required sustained coordination across a larger and more heterogeneous interoperability network. Across both systems, participants nevertheless emphasized the importance of continuous communication and practical support rather than one-time agreements. Participants described mechanisms such as standard operating procedures, data standards and mappings, help-desk services, messaging platforms, and routine review processes as important for maintaining alignment as systems evolved.

### *Human Resources*

Human resources were described as a key constraint affecting the sustainability of both PHS systems. Participants emphasized that sustainable operation depended not only on system design but also on the availability and continuity of personnel capable of developing, maintaining, and adapting the systems over time. A common concern was the gap between workforce capacity and the increasing technical and operational demands of modern surveillance systems.

> *I think training people within the organization to sustain it is very important ... Having in-house people who can solve these issues makes the system more user-centric and ... move much faster.* [PF-02]

In the MIS, participants described challenges in building operational capacity among field staff, supporting the transition from paper-based to digital workflows and transferring technical knowledge to the institutions expected to maintain the system. Participants highlighted the need for iterative, task-based training to address varying levels of digital literacy and ensure routine system use after handover:

> *... They do not really have people who specialize in databases or development ... taking over this system requires them to look into the database and development side.* [MIS-IT-02]

> *... the core was still the same ... just converted into electronic format ... so the learning curve took quite a while to overcome.* [MIS-PM-02]

In contrast, D506 participants described difficulties in recruiting and retaining specialized technical personnel, particularly shortages in data engineering and system integration. These



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challenges were linked to public-sector compensation constraints, limiting the ability to attract highly skilled staff:

> *The challenge is about personnel ... We need people with additional knowledge in computer engineering ... each person is basically handling one dashboard on their own.* [D506-PH-03]

> *... we are really lacking in Data Engineers ... we cannot hire them due to budget constraints.* [PF-03]

Across both systems, participants perceived continuity as more vulnerable when important knowledge or technical capacity depended on a small number of people. MIS emphasized training and handover of system-specific knowledge, whereas D506 emphasized recruitment and retention of specialized technical capability for a national data platform.

### *Infrastructure*

Infrastructure was described as one factor shaping the extent to which PHS systems could support routine operations. Across both systems, participants emphasized that infrastructure must enable continuous functionality without disrupting surveillance workflows. This included not only software capabilities but also reliable systems for data synchronization, server management, and user support.

> *... If we have the right tools for data entry, everything will be faster ... and help us clean up data more efficiently.* [D506-IT-03]

In the MIS, participants linked infrastructure challenges to hardware limitations and the operational realities of remote settings. Participants highlighted the need for systems that support offline functionality and reliable synchronization under unstable connectivity. They also described delays in hardware procurement and server replacement under complex administrative processes as a concern for continued operation:

> *... they're trying to replace the server ... it's been a year, and they still haven't finalized it ... there are many issues with procurement ...* [MIS-IT-03]

In contrast, D506 participants emphasized centralized infrastructure to support nationwide interoperability, including data pipelines, dashboards, and integration across multiple reporting platforms. Participants also described how reusing the underlying infrastructure developed during the COVID-19 response made D506 development easier and faster:

> *... we already have a model from COVID-19 reporting ... we used this system to build upon for the new system ... helped us develop and build further.* [D506-PM-01]

Whereas MIS participants emphasized connectivity resilience and legacy hardware constraints, D506 participants focused on centralized processing, interoperability, and increasing data volume. Across both systems, participants associated continued operation with maintaining core system components and minimizing disruption to users.

### *Financial Sustainability*

Participants across both systems described a financial sustainability challenge in the mismatch between short-term development funding and the recurrent costs of operating and maintaining a surveillance platform. These costs extended beyond initial development to include infrastructure, personnel, system upgrades, training, technical support, and governance. Participants noted that budgets often prioritized system development, while long-term operational needs were addressed through ad hoc solutions rather than structured financial planning.

> *Sustainability is really about who supports [financially] the work moving forward ... because these systems don't run for free. Someone has to take responsibility for funding it.* [PF-04]

In the MIS, financial sustainability was closely tied to reliance on external donor funding, particularly from the Global Fund. Participants identified this as a key vulnerability, as future continuity was linked to a credible pathway for transferring financial and operational responsibilities to domestic structures beyond grant periods. This included sustaining technical personnel and disease-specific expertise beyond externally funded positions:

> *... if the Global Fund didn't support it, this project would have failed ... What we really need are personnel and funding ...* [MIS-PM-02]

In contrast, D506 was supported by domestic government funding, providing a different initial financial foundation. However, participants noted ongoing constraints in allocating limited resources across competing priorities, such as staffing, infrastructure, and system improvements, which affected long-term planning:

> *The real challenge is: how do we use this money in a sustainable way?... Most of the time, we have to find funding on our own because the internal budget is not sufficient.* [PF-02]

MIS faced a clear donor-to-domestic transition challenge, whereas D506 faced constraints within domestic budgeting and procurement despite stronger institutional embedding.

> *... If they don't value the system, it ends. But now they realize it's essential and necessary. When they realize that, it will keep going even without money ... In the end, a way will be found ...* [MIS-PH-01]

Participants also reported that continued funding was more likely when systems demonstrated clear value and operated within well-coordinated organizational structures. These descriptions suggest that financial sustainability depended not only on the available resources but also on credible pathways for ongoing funding, capacity transfer, and gradual system scaling.

### *Ownership*

Ownership emerged most explicitly in the MIS case. Participants indicated that the central ownership challenge was not simply identifying a responsible organization, but ensuring that the designated owner had the authority, resources, and willingness to manage the system throughout its lifecycle. They associated effective ownership with decision-making authority and dedicated resources for ongoing functions such as system



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maintenance, monitoring, and upgrades. Participants noted that when ownership was perceived as unclear or weak, systems would be vulnerable to delayed updates, reliance on workarounds, and declining user trust over time.

> *One of the biggest challenges ... is ownership—who takes responsibility.* [MIS-PM-02]

MIS participants also described a "reluctant ownership" dynamic as a challenge, in which organizations recognized the benefits of the system but were hesitant to assume full operational responsibility. They linked this reluctance to limited technical capacity, procurement constraints, and concerns about accountability for system performance. They described a gap between nominal ownership and responsibility for continued operation:

> *We're the developers but not the owners of the systems or the data. ... once it's handed over, there isn't always clear responsibility for ongoing maintenance ...* [MIS-IT-02]

Perceptions of ownership were also shaped by funding and governance structures. In the MIS, participants described challenges in transferring financial responsibility and technical expertise from external partners to domestic institutions. In D506, participants used the language of ownership less directly, discussing institutionalized government responsibility and the allocation of departmental roles and budgets. Across both cases, participants associated continued operation with a responsible entity that had the authority and capacity to assume long-term accountability:

> *... if funding ends, it comes down to ownership ...* [MIS-PM-02]

> *Instead of just one division being responsible, since this is a national task, we assign it to the department so the budget and data can be shared across divisions.* [PF-03]

Beyond institutional responsibility, MIS participants also highlighted the importance of developing a sense of shared ownership among users. They described actively involving users in providing feedback and adapting the system to reflect their field workflows and operational needs. Participants noted that when users saw that their input led to practical system improvements, they were more likely to regard the system as a tool developed with them rather than merely a reporting requirement imposed on them. Participants associated this sense of involvement with active engagement, routine use, and perceived long-term sustainability:

> *... we try to make users ... feel like they own the system ... that's why it has been sustainable ...* [MIS-IT-02]

### *System Adaptability*

Participants described sustainability as dynamic rather than as the preservation of a static system. They associated continued relevance with the ability of surveillance platforms and their governance arrangements to respond to changing epidemiology, organizational structures, reporting requirements, technology, and user needs.

In MIS, participants linked the system's continued relevance to changing disease patterns and surveillance needs. They also noted that, as disease burdens changed, surveillance data could retain value for future research and that the platform would need to adapt to organizational and technical changes:

> *... if the disease is gone ... the data may still be useful for something else ... I believe it will still be valuable for future research.* [MIS-IT-02]

For D506, participants described adaptability as requiring more than the electronic reproduction of legacy reporting processes. They emphasized that changes were intended to improve reporting timeliness, workflows, interoperability, data use, and decision-making. One participant summarized this broader pattern by distinguishing simple digitization from meaningful digital transformation:

> *The goal is to truly transform the system and the efficiency of the work, not just to store things digitally ... that's not enough.* [PF-03]

Across both cases, participants therefore viewed adaptability as the capacity to remain useful as conditions changed. MIS findings centered on disease context, organizational change, remote operations, and technology, whereas D506 findings centered on interoperability, reuse of earlier reporting infrastructure, and broader digital transformation.

## Discussion

### Principal Findings

This study suggests that stakeholders perceived PHS sustainability as depending not only on technical design but also on the extent to which systems were embedded within real-world implementation contexts. Prior research has examined surveillance-system integration, development, and implementation [23-25]; however, sustaining routine use remains a complex implementation challenge. The findings suggest that participants understood sustainability through interacting technical, organizational, and governance factors, consistent with established health information and surveillance frameworks [26,27]. The results particularly highlight operational ownership and the capacity for continuous adaptation to evolving technologies. The cross-case comparison showed that these dimensions took different forms: MIS findings emphasized online-offline field functionality, donor-to-domestic transition, and reluctant ownership, whereas D506 findings emphasized nationwide interoperability, specialized technical capacity, and domestic budgeting and procurement constraints. These findings reflect participant perceptions rather than objectively measured or causal determinants of sustainability. The contribution lies in explaining how shared sustainability concerns take different forms across 2 Thai platforms with contrasting development and financing pathways.

In many countries, multiple PHS systems operate across different contexts. While standard system architectures may provide a common foundation, identifying context-specific users and functional requirements is critical for sustainability [27,28]. Participants associated long-term system use with how well systems integrate into existing operational practices without



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increasing user burden and frustration. MIS participants emphasized resilient design for remote settings with unstable connectivity, consistent with evidence from southern Africa that infrastructure constraints affect system use [17,24,28]. In contrast, D506 participants emphasized workflow redesign to support near real-time reporting and interoperability across multiple platforms, with integration into existing HISs to reduce duplicated workload. At the national level, aligning stakeholder interests, roles, and responsibilities remains a key challenge [6,17,29]. Our findings also suggest that sustained collaboration, supported by continuous communication and practical coordination mechanisms rather than one-time agreements, is important for long-term system continuity. The comparison suggests that a common commitment to user-centered design can require different technical and organizational responses rather than a single architecture for every setting.

Participants associated long-term PHS sustainability with how financial, infrastructure, and human resources are managed across the system lifecycle. Prior work similarly identified limited technical capacity and staff turnover as common challenges in sustaining surveillance systems [17,23,25]. Although participants did not describe turnover as a uniformly high concern, they emphasized the need for continuous skill development to keep pace with evolving technologies and increasing system complexity [25]. Participants also associated reliable IT infrastructure with the ability to sustain routine surveillance workflows. These findings suggest that incremental adaptation and reuse of existing infrastructure can support continued operation and development. In MIS, this involved connectivity resilience and the modernization of legacy components, whereas D506 participants emphasized scalable data pipelines, interoperability, and capacity for increasing national data volumes.

Financial factors were prominent in participants' descriptions of sustainability. Participants described budgets that prioritized system development, while long-term operational needs were addressed through ad hoc solutions rather than structured planning. This concern is consistent with prior research on sustaining donor-supported HISs [17]. These findings suggest that sustainability depends not only on resource availability but also on establishing credible pathways for ongoing funding, capacity transfer, and gradual system scaling. Clear postgrant transition plans were also highlighted as critical for maintaining long-term value within national health systems. The comparison nevertheless indicated that domestic funding did not remove perceived sustainability concerns: MIS faced uncertainty during donor-to-domestic transition, while D506 participants described constraints in routine budgeting, procurement, infrastructure, and technical staffing.

These findings also draw attention to the political economy of surveillance systems. Participants' descriptions suggest that the organizations and users who benefit from timely, decision-useful information are not always the same actors who bear the costs of hosting, maintenance, technical personnel, training, and future upgrades. In MIS, donor-supported development and external technical expertise were expected to transition toward domestic responsibility. In D506, government responsibility was more institutionalized, but central teams continued to manage resource competition and coordination with other divisions and vendors. Sustainability therefore involves not only the amount of funding available but also how costs, authority, expertise, and accountability are distributed over time. This interpretation suggests that assigning responsibility without corresponding budget authority and technical capacity may leave the receiving organization reluctant or unable to assume operational commitments. Political economy was therefore an important cross-cutting consideration connecting financial sustainability with operational ownership in both cases.

The ownership findings highlighted a gap between formal designation and operational capacity. Participants described functional ownership as requiring institutions to have the authority, resources, and willingness to undertake system maintenance, monitoring, and continuous improvement. In this interpretation, ownership identifies who can authorize and resource continued operation, while collaboration describes how the relevant actors coordinate, and adaptability concerns how the system responds to change. This challenge was particularly evident in MIS, where participants described reluctant or nominal ownership during handover, while D506 reflected more institutionalized departmental responsibility.

In this context, D506 participants collectively described digital transformation as improving reporting workflows, efficiency, interoperability, data use, and decision-making, rather than simply converting paper-based processes into electronic storage. These findings suggest that sustainable systems should remain adaptable and capable of supporting emerging health threats or broader public health needs.

Leadership and legal constraints were less prominent in the interviews. This may reflect the established institutional settings of the 2 systems, although limited emphasis in these interviews does not establish that these factors were unimportant. Compared with the emphasis on enduring champions in the proposed genomic-surveillance operating model [25], these findings suggest that the salience of leadership may differ by institutional context and system maturity.

In resource-constrained settings, we suggest first addressing the most immediate threat to routine surveillance by aligning operational responsibility, recurrent resources, and technical support. For MIS, priorities could include maintenance responsibilities and knowledge transfer during donor transition; for D506, specialized integration capacity and support for data exchange. Expanding system functions may provide additional value but also increase maintenance and staffing demands. A staged approach could therefore protect essential operations while revisiting longer-term financing and development. These are author-derived implications of the 2 cases rather than an empirical ranking of the 7 themes.

### Strengths and Limitations

This study has several strengths. First, it examined 2 operational national PHS systems with different development histories, technical architectures, financing pathways, and operational demands. This enabled the study to examine stakeholder perspectives on sustainability over time and to compare how similar concerns were expressed in different implementation



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contexts. Second, many participants had been involved since the development phase and remained responsible for system maintenance, providing detailed insights across the system lifecycle. Third, the qualitative design, using both individual interviews and small-group interviews, captured perspectives from technical, operational, managerial, and policy-level stakeholders. Finally, the study extends beyond broad technical and financial barriers by explaining how ownership, user-centered adaptation, collaboration, and system adaptability were experienced across the 2 cases. The explicit cross-case analysis and supplementary materials also increased the transparency of the study and strengthened the interpretation of the findings.

These strengths should be considered alongside several study boundaries. Purposive, organization-facilitated recruitment and the inclusion of 2 operational systems may have favored more engaged participants and relatively sustainable cases, while remote frontline users were less represented. Consequently, the findings may give greater prominence to managerial and technical concerns than to the everyday reporting burdens and support needs of remote frontline users. Data saturation was assessed through redundancy across the overall dataset rather than separately for every case-role subgroup. In addition, the findings reflect stakeholder perceptions rather than objective measures of system performance or sustainability. Transferability may therefore be greatest for comparable national surveillance systems. Application to decentralized, laboratory, event-based, community, or One Health surveillance requires consideration of their different governance and operational arrangements.

## Conclusions

Stakeholders across 2 operational national surveillance systems in Thailand perceived that sustaining PHS requires more than successful technical development or initial implementation. They associated long-term sustainability with the extent to which systems were aligned with user needs, embedded within routine workflows, supported by sustained collaboration, and backed by adequate human, financial, and infrastructure resources. Clear operational ownership and the ability to adapt to evolving technologies and public health priorities were also perceived as important for maintaining system relevance over time. The comparison showed that these dimensions were expressed differently across cases: MIS highlighted remote field operation, donor transition, and reluctant ownership, whereas D506 highlighted nationwide interoperability, specialized technical capacity, and constraints within domestic budgeting and procurement.

For comparable systems, these findings suggest that sustainability should be planned across the full system lifecycle, with operational ownership and recurrent resources considered during initial development, feedback and knowledge transfer supported during routine use, and technical and governance arrangements revisited as needs change. These implications are not tested prescriptions; they are context-sensitive lessons from 2 surviving systems that require examination in other surveillance models and in discontinued or less-sustained cases.

## Acknowledgments

The authors thank all study participants for generously sharing their time, experiences, and perspectives. Their contributions were essential to understanding the sustainability of public health surveillance systems in Thailand. This research was conducted as part of a thesis for the Master of Science Program in Biomedical and Health Informatics, Mahidol University.

## Funding

This study was supported by the Rockefeller Foundation (grant 2021 PPI 005). The grant supported this research and did not provide operational funding for the Malaria Surveillance System, Digital 506, or the participating organizations in relation to the surveillance systems examined. PH was partially supported by a fellowship from the Hanse-Wissenschaftskolleg Institute for Advanced Study. Neither the Rockefeller Foundation nor the Hanse-Wissenschaftskolleg Institute for Advanced Study had a role in the study design, data collection, analysis, interpretation of findings, or preparation of the manuscript.

## Data Availability

The datasets generated and analyzed during this study are not publicly available due to participant confidentiality and the potentially identifiable information about participants and their organizations. Requests for access to deidentified data may be directed to the corresponding author and will be assessed individually in accordance with the study's ethics approval, participant consent, and confidentiality requirements. Deidentified excerpts and supporting materials, including participant and session characteristics, interview guides, a qualitative codebook, and a cross-case evidence matrix, are included in this article and its multimedia appendices.

## Generative AI Use

The authors declare that generative AI was used in the creation of this manuscript. Generative AI (ChatGPT) was used for proofreading, editing, or language polishing, and reference formatting. The authors verified all outputs of the tool(s) used in the preparation of this manuscript. The authors used ChatGPT (OpenAI) to support Thai-to-English translation of interview transcripts, English language editing, wording refinement, and formatting support. Thai-to-English translations were reviewed by the authors against the original Thai transcripts and audio recordings to preserve the intended meaning. ChatGPT was not used to generate



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data, conduct analysis, or interpret findings. All AI-assisted suggestions were reviewed and verified by the authors, who take full responsibility for the final manuscript.

## Authors' Contributions

WP contributed to conceptualization, data curation, methodology, formal analysis, visualization, and writing the original draft. CR contributed to conceptualization, data curation, methodology, formal analysis, and validation. PH contributed to conceptualization, methodology, formal analysis, and validation. TB contributed to conceptualization, methodology, and validation. SL contributed to conceptualization, methodology, validation, funding acquisition, supervision, and writing the original draft. All authors critically reviewed and approved the final manuscript.

## Conflicts of Interest

None declared.

## Multimedia Appendix 1

Semistructured interview guides for surveillance-system stakeholders and the funder participant.
[DOCX File , 23 KB-Multimedia Appendix 1]

## Multimedia Appendix 2

Participant and session characteristics.
[XLSX File (Microsoft Excel File), 13 KB-Multimedia Appendix 2]

## Multimedia Appendix 3

Qualitative codebook and theme development.
[XLSX File (Microsoft Excel File), 19 KB-Multimedia Appendix 3]

## Multimedia Appendix 4

Cross-case evidence matrix.
[XLSX File (Microsoft Excel File), 12 KB-Multimedia Appendix 4]

## Multimedia Appendix 5

Standards for Reporting Qualitative Research (SRQR) checklist.
[DOCX File , 21 KB-Multimedia Appendix 5]

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## Abbreviations

**BIOPHICS:** Center of Excellence for Biomedical and Public Health Informatics
**D506:** Digital 506
**HIS:** health information system
**MIS:** Malaria Surveillance System
**PF:** policymaker and funder
**PH:** public health officer
**PHS:** public health surveillance
**PM:** project manager
**R506:** Report 506
**SRQR:** Standards for Reporting Qualitative Research

*Edited by T Hanjahanja-Phiri; submitted 06.Jul.2026; peer-reviewed by J Loureiro, B Shaikh; comments to author 23.Aug.2026; revised version received 14.Oct.2026; accepted 18.Oct.2026; published 11.Nov.2026*

*Please cite as:*
*Pipithruengkrai W, Lawpoolsri S, Rotejanaprasert C, Haddawy P, Barkowsky T*
*Sustaining Public Health Surveillance Systems in Thailand: Comparative Qualitative Case Study of 2 National Platforms*
*JMIR Public Health Surveill 2026;12:e106399*
*URL: https://publichealth.jmir.org/2026/1/e106399*
*doi: 10.2196/106399*
*PMID: 43013340*

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