Supplementary material

Developing a national mortality surveillance dashboard in Sierra Leone: implementation experience and governance lessons

JIEPH-D-26-00195R4

Supplementary Table S1. Dashboard development process by implementation component

Process dimension	Key activities	Outputs	Phase	Layer
Data integration and architecture	Source mapping; mortality data warehouse; application programming interface connectors to the three priority sources; custom verbal-autopsy module; automated validation and deduplication; role-based access; encrypted transmission	Secure central repository fed by civil registration and verbal autopsy, with the disease-surveillance link live; 1,071 cross-source duplicates resolved and 32,234 unique decedents retained	Design, build and pilot	Technical
Indicators and key performance measures	Specification of rates, ratios and service-delivery measures; ICD-11 cause harmonization; 47 common data elements	Rates-and-ratios framework; place of death, certification and timeliness indicators	Inception through pilot; continuing refinement	Semantic
Functionality and user experience	Multi-tier role-based views (national, geography and equity, district); interactive maps and trend charts; prototype user-acceptance testing; change-request management; offline operation	National overview and geography dashboard plus two district views; 48 of 63 change requests implemented; offline functionality deployed	Design and pilot	Technical / semantic
Testing, training and handover	Requirements review; national scaling workshop; district training; master-trainer development; standard operating procedures, manuals and reporting templates; hosting transfer	Training in both pilot districts; six of ten planned master trainers prepared; materials completed; hosting transferred to HDMU. Trainee proficiency was reported as achieved, but numerator and denominator were not reproduced.	Pilot and institutionalisation	Technical / organizational
Governance and policy enablers	Technical Working Group; source-specific technical collaboration; documentation of existing surveillance authority; governance framework; hosting and maintenance planning	HEAL-SL technical cooperation agreement for dashboard integration concluded; NPHA ownership and existing surveillance use unchanged; governance framework prepared; HDMU hosting	Inception through institutionalisation	Organizational

Phases are descriptive. No phase or milestone establishes complete functional interoperability across all sources.

Supplementary Table S2. Mixed methods evidence, units, analysis and use

Strand	Data source	Participants or units	Sampling	Analysis	Used for
Quantitative	Platform analytics	33,305 integrated death records, deaths 1 Jan 2022 to 18 Jun 2026	Census of records held	Descriptive counts and proportions of records held; denominator 33,305 unless stated. No inferential confidence intervals for complete platform counts; no national representativeness assumption.	Endline performance; service-delivery indicators
Quantitative	Monitoring framework	12 indicators with baselines and targets	All indicators	Achieved, partly achieved or not achieved against target	Adoption, feasibility, fidelity, sustainability
Quantitative	Data quality assessments (Nov 2025, May 2026)	Six key fields; 600 civil-registration records per round (300 per pilot district); 3,600 expected field entries per round	Simple random sampling within district, conducted separately at each assessment round	Six-field composite; 600 sampled records x 6 fields = 3,600 expected entries per round. Identifier structurally complete. No record-level scores or variances available for valid confidence intervals.	Descriptive programme comparison, not a causal effect; samples drawn separately.
Quantitative	Record linkage	Validation samples: 200 flagged pairs and 500 near-miss pairs. These are separate from the 1,438 candidate pairs reviewed and the 1,071 duplicate records removed.	Random samples	Classification agreement, Cohen kappa and missed-match yield among near-miss candidates	Internal validation of linkage classifications, not population-level validation
Quantitative	Milestone log	16 dated milestones	All milestones	Dates and elapsed days from 24 June 2025 where exact dates exist; retain month-only dates without imputing days.	Implementation chronology; not whole-layer closure or a comparative constraint ranking
Qualitative	Program documents	41 documents	All project documents in the period	Framework method	Context, decisions, chronology
Qualitative	Governance records	14 records (minutes, action logs, escalation memoranda)	All Technical Working Group records	Framework method	Technical responsibilities, collaboration and escalation
Qualitative	Routine system-testing observations	2 observation records from programme events (35 and 38 participants); not the total number of observations during daily implementation work	Both stakeholder events	Structured observation guide covering use, resistance, workarounds and decisions; notes charted with other programme documents.	Use, resistance, workaround, decision

Strand	Data source	Participants or units	Sampling	Analysis	Used for
Qualitative	Semi-structured implementer debriefs	22 debrief-note sets across programme constituencies, districts and roles; debriefs lasted 20-40 minutes. Engagement itself occurred daily.	Purposive maximum-variation recruitment to programme debriefs by institutional constituency, district and role; no new codes after debrief 19; three confirmatory debriefs.	English topic guide; contemporaneous notes expanded within 24 hours; framework method and charted matrix. Participation was voluntary. Routine written consent covered use of meeting materials and photographs in documentation and publications; no meeting photographs were used.	Operational experience and explanation
Integration	Joint display	6 implementation outcomes	All outcomes	Quantitative and qualitative evidence set side by side for each outcome; fit classified as confirmation (strands agree), expansion (one strand adds to the other) or discordance (strands disagree)	Merged interpretation

Programme scope: the dashboard is a continuing national surveillance programme designed for real-time integration using agreed common variables. Daily consultation, observation, system testing, data-quality review and performance evaluation support routine programme management and continue independently of publication. June 2025-June 2026 is the manuscript reporting window. Real-time exchange is a design objective, not a measured end-to-end latency result.

Supplementary Table S3. Original programme monitoring framework and targets

#	Indicator	Type	Target	Data source	Maps to
1	Technical documentation available for dashboard integration	Input	3 finalized documents	Internal reports, review logs	Feasibility
2	Secure infrastructure and access controls deployed	Input	Role-based access and encryption in place	IT logs, audit reports	Feasibility; fidelity
3	Budget and resources disbursed to implementing units	Input	≥90% disbursed	Financial records	Resource allocation
4	Functional dashboard infrastructure available	Process	3 dashboards deployed	System verification reports	Adoption
5	Health officials trained in data use and dashboard functions	Process	≥50 trained	Training reports, assessments	Adoption; program implementation
6	Interoperability, deduplication and validation systems implemented	Process	Three source connections live; at least two sources volume-bearing	API logs, test reports	Fidelity
7	Stakeholder engagement sessions held	Process	≥4 sessions	Workshop reports	prioritization
8	Dashboard data used in public health decision-making	Outcome	At least 5 documented uses (original programme target)	Memos, briefs, official records	program implementation; prioritization
9	Improvement in mortality data quality	Outcome	≥30% improvement	Data quality assessment reports	program implementation
10	Service-delivery indicators generated (place of death, certification, timeliness)	Outcome	Indicators reported at national scale	Platform analytics	program implementation
11	Dashboard institutionalized into agency operations	Outcome	SOP adopted; system hosted in operational unit	SOPs, terms of reference	Sustainability; procedures and guidelines
12	Source-specific technical cooperation arrangements for integration completed	Outcome	Technical roles agreed by participating institutions; existing surveillance authority documented separately	Technical cooperation agreement and implementation records	prioritization; sustainability

Supplementary Table S4. Programme indicators: baseline, target and status at June 2026

Domain	Indicator	Baseline	Target	Endline status (June 2026)
Digital systems	Integrated dashboards deployed (national and two districts)	0	3	Achieved: national overview and geography dashboards plus two district views live
	Automated interfaces connecting CRVS, eIDSR, and HEAL-SL	No	Yes	Achieved: three connections live; civil registration and verbal autopsy volume-bearing; disease-surveillance connector carrying three records
	Dashboard availability and offline functionality	0%	95%	Offline functionality deployed in both pilot districts; platform availability was not quantified against the 95% target.
	Common data elements harmonized to ICD-11	0	47	47 common data elements specified with ICD-11 cause mapping; source coding quality remained incomplete.
	National mortality data dictionary developed	No	Yes	Drafted and aligned with common standards; endorsement in progress. Not evidence of complete semantic quality.
Data use	Evidence of data-informed action	No	Yes	Programme documentation describes indicator refinement, district mortality review and cause-of-death coding correction in Western Area Rural.
	Documented uses of dashboard data in decisions	0	5	Monitoring summary recorded 5 uses, without an itemised dated decision register. Do not treat as five independently verified outcome events; see S17.
	NPHA and district workflows using dashboard analysis	0%	75%	Routine review established in both districts and at national HDMU; the proportion of workflows using dashboard analysis was not reported against the 75% target.
	Reporting delay (days)	14	2	Legacy summaries: 14.0-day civil-registration baseline; 5.1-day mixed-source endpoint; 80.4% within 48 hours. Source endpoints are unharmonised; no valid change or target-attainment conclusion is drawn. See S17.
	Improvement in mortality data quality	NA	30%	Six-field completeness 91.4% and 99.9% in separate samples of 600 records. Consistency summaries recorded 412 and 7 violations; distinct affected-record counts are not specified. The composite includes an automatic identifier. The 30% target is not established by these summaries.
Capacity	Health officials trained	0	50	Training completed in both pilot districts; the participant count was not reported in this summary against the target of 50.
	Trainees demonstrating proficiency	0%	85%	Proficiency target reported as achieved on assessment; the percentage was not included in this summary.
	Local master trainers developed	0	10	Partially achieved: 6 developed
	standardized training materials developed	No	Yes	Achieved: manuals and quick-reference guides

Domain	Indicator	Baseline	Target	Endline status (June 2026)
	Dashboard training integrated into NPHA curriculum	No	Yes	Advancing
Governance and sustainability	Written products developed (specifications, manuals, protocols, strategy, templates)	0	6	Achieved
	standardized mortality reporting templates adopted	0	4	Achieved: developed and in use
	Process changes articulated and documented	No	Yes	Achieved: SOPs finalized
	Data governance framework established	No	Yes	Framework finalised and submitted for endorsement; endorsement not established by the reporting summary.
	Dashboard institutionalized into NPHA operations	No	Yes	Achieved: hosted in Health Data Management Unit; ToR prepared
	HEAL-SL technical cooperation agreement for dashboard integration concluded	No	Yes	Agreement concluded in April 2026; integration feed activated afterwards. NPHA already owned and used these government data for surveillance.
	Two planned data quality assessments completed	0	2	Achieved: November 2025 and May 2026 assessments completed

Completeness uses 600 sampled records x six equally weighted fields per assessment. The automatic identifier raises the composite. Rounds are separate samples. Missing field counts in Figure 1 describe the full platform and are not the same measure.

Supplementary Table S5. Implementation milestone log and elapsed-day chronology

Component	Milestone	Planned window	Observed date	Elapsed days from 24 June 2025
Organizational	Technical Working Group constituted; terms of reference endorsed	Month 1	24 June 2025	0
Semantic	47 common data elements and coding specification agreed	Months 1 to 3	12 August 2025	49
Organizational	Drafting of HEAL-SL technical cooperation agreement for dashboard integration begun	Months 1 to 6	July 2025	7-37 (calendar bounds)
Technical	Mortality warehouse and civil registration connector operational	Months 1 to 3	18 September 2025	86
Technical	Surveillance application programming interface link established and tested	Months 4 to 6	6 November 2025	135
Organizational	Technical cooperation agreement entered legal review at partner institutions	Not planned separately	October 2025	99-129 (calendar bounds)
Technical	Prototype user-acceptance testing (35 participants)	Months 4 to 6	27 to 28 November 2025	156-157
Technical	First data quality assessment	Months 4 to 6	November 2025	130-159 (calendar bounds)
Semantic	Indicator framework revised to rates, ratios and service-delivery measures	Months 4 to 6	16 January 2026	206
Organizational	Written escalation to executive leadership, with named owner and target date	Not planned	February 2026	222-249 (calendar bounds)
Technical	Offline district dashboards deployed	Months 4 to 6	4 March 2026	253
Organizational	Standard operating procedures, manuals and four reporting templates completed	Months 7 to 12	March 2026	250-280 (calendar bounds)
Organizational	HEAL-SL technical cooperation agreement for dashboard integration concluded	Months 1 to 6	April 2026	281-310 (calendar bounds)
Organizational	Six master trainers certified (target ten)	Months 7 to 12	April 2026	281-310 (calendar bounds)
Organizational / quality assurance	Data governance framework finalized; second data quality assessment	Months 7 to 12	May 2026	311-341 (calendar bounds)
Operational outcome / organizational	Operational feed activation and hosting handover reported in programme summary (combined entry)	Months 7 to 12	May to June 2026	311-371 (combined reporting window)

Elapsed days = event date minus 24 June 2025 (day 0). For month-only entries, the lower and upper values use the first and last days of the recorded month; these are bounds, not imputed event dates. The approximately four-month legal-review period ends at the February 2026 escalation. The combined May-June entry does not establish a separate feed-activation day.

Supplementary Table S6. Record-linkage rules, adjudication and validation

Element	Specification	Result
Blocking	District of residence and year of death	1,438 candidate pairs entered clerical review
Rule 1	Exact national identification number	Applied where present in both records
Rule 2	normalized surname and given name, sex, exact date of death, district	Applied where no national identification number
Rule 3	normalized names, sex, date of birth or age within 1 year, district, date of death within 3 days	Applied where date of death differed slightly across sources
Name normalization	Punctuation and diacritics removed; spelling variants standardized; phonetic key applied	Required because transliteration varies across the three selected sources
Identifiers available	Every record carried a record identifier assigned by its own source. The sources shared no common person identifier. The national identification number was used where both records carried it (Rule 1).	Where national identification number was absent, Rules 2 and 3 used names, sex, dates and district. Identifiers remained protected. Linkage within this dashboard began after the technical agreement; NPHA's ownership and surveillance authority pre-dated it.
Uncertain matches	Pairs agreeing on 2 or more identifiers without satisfying a complete rule, or with conflicting sex or age difference above 5 years, routed to clerical queue; two officers adjudicated independently, third resolved disagreements	1,071 adjudicated as matches, 352 as non-matches, 15 unresolved and retained as distinct records
Reconciliation of counts	One record was removed for each adjudicated match.	33,305 records held − 1,071 duplicate records = 32,234 unique decedents (96.8% of records held; not national mortality coverage). The 200 flagged pairs and 500 near-miss pairs in the rows below are validation samples, not counts of duplicates.
Classification-agreement check	Random sample of 200 flagged pairs re-reviewed blind to algorithm output	196/200 agreed (98.0%; Wilson 95% CI 95.0-99.2). Programme-reported inter-adjudicator kappa was 0.94 (reported 95% CI 0.88-1.00). Paired-rater classifications are not reproduced.
Sensitivity check	Random sample of 500 near-miss pairs (agreement on at least two identifiers, not classified as matches)	6 true matches; missed-match yield 1.2% of reviewed near-miss pairs (Wilson 95% CI 0.6 to 2.6). This is not a record-level residual-duplication estimate.
Method not used	Probabilistic linkage	Not implemented: transparent deterministic rules with clerical adjudication were selected for operational reproducibility; no validated labeled match set was available for calibration

Element	Specification	Result
Known limitation	Deterministic rules are conservative	True matches may be missed where identifiers are absent or inconsistent; no population-level gold standard was available
Interpretive boundary	Near-miss review estimates missed matches within sampled candidates	Record-level residual duplication requires the size of the full near-miss pool and known sampling probabilities.

Algorithm agreement is not a precision estimate against a population-level gold standard. Near-miss yield applies to reviewed candidates, not all unobserved duplicates. Kappa 0.94 and its reported interval are retained as programme-summary results; no paired-rater contingency table is reconstructed.

Supplementary Table S7. Joint display of quantitative and programme-document evidence

Implementation outcome	Quantitative evidence	Qualitative evidence	Fit
Adoption	National dashboard and two pilot-district views deployed; programme records describe indicator refinement, district mortality review and coding correction.	Programme notes describe early dashboard use of civil-registration outputs while HEAL-SL technical integration arrangements were completed.	Confirmation
Feasibility	Warehouse, connectors and offline deployment milestones; 48 of 63 change requests implemented.	Technical work described as more predictable after specification; a working connector did not guarantee source-data availability.	Confirmation
Fidelity	47 common elements with cause mapping; completeness summaries 91.4% and 99.9%; consistency summaries 412 and 7 violations.	Programme feedback linked validation to data-quality work, but coding problems and duplicate labels persisted. No causal effect is estimated.	Confirmation
Sustainability	Hosting transferred to the Health Data Management Unit; governance framework finalized; six of ten master trainers developed	Sustainability located in protected staff time; trainer shortfall attributed to competing routine duties	Expansion: a determinant no indicator captured
Data flow and connectivity	eIDSR interface tested on 6 November 2025 (135 days); only three mortality records transferred.	District users did not regard the source as functionally connected while it carried negligible volume, and some read the near-empty panel as system failure	Discordance: technical connection and usable data flow used different definitions
organizational interoperability	Technical cooperation agreement concluded in April 2026; integration feed began within two weeks. Excluding that feed reduced the certified/physician-coded share from 30.4% to 0.6%.	Technical collaboration, assigned responsibility and escalation supported integration. The agreement did not establish NPHA ownership, access or surveillance authority.	Sequence illustrates coordination of technical integration; not a causal comparison or an ownership/access restriction

Supplementary Table S8. Source-exclusion summaries for the HEAL-SL feed

Indicator	Full integrated dataset (all sources)	Excluding the verbal autopsy feed
Total records	33,305	23,326
Certified or physician-coded cause	10,124 (30.4%)	145 (0.6%)
Place of death: community share	18,885 (56.7%)	9,405 (40.3%)
Legacy source-date interval within 48 hours (not harmonised)	80.4%	82.1%
Deduplicated versus all-record proportions	Not quantified in the retained aggregate comparison	No equivalence conclusion inferred from a 3.2% duplicate share alone

Source-exclusion fractions describe records held, not national mortality. The timing row reproduces unharmonised programme summaries and should not be read as a comparable timeliness estimate. A small duplicate share alone does not demonstrate unchanged post-deduplication fractions.

Supplementary Table S9. Readiness self-assessment for local adaptation

Layer	Readiness question	Why it matters	Status (mark one)
Organizational (governance)	Is there a designated senior owner and a standing inter-institutional body for mortality data?	Integration requires institutional coordination; a standing body may support shared decisions.	Not started / In progress / In place
Organizational (governance)	Are source custodians, existing surveillance authority and technical collaboration requirements identified separately?	Existing authority may already permit surveillance use. Technical collaboration addresses how systems connect; it should not be confused with data ownership or a new access permission.	Not started / In progress / In place
Organizational (governance)	Is there an agreed escalation pathway to senior leadership for stalled agreements, with target dates?	A named escalation pathway may prevent stalled agreements from remaining unowned; this proposition requires testing.	Not started / In progress / In place
Organizational (governance)	Are data ownership, access, privacy and stewardship roles defined and documented?	Sensitive cause-of-death data require clear stewardship to move between institutions.	Not started / In progress / In place
Organizational (governance)	Are hosting, maintenance financing and institutional placement secured within government?	Government ownership and financing may support continuity after external funding; this proposition requires testing.	Not started / In progress / In place
Semantic	Have common data elements across the sources been identified and mapped?	Shared meaning is required before data can be exchanged.	Not started / In progress / In place
Semantic	Is cause-of-death coding harmonized to a standard such as ICD-11?	Comparability depends on a common classification.	Not started / In progress / In place
Semantic	Does the indicator framework prioritize rates, ratios and service-delivery measures over raw counts?	These measures support comparison and decision-making.	Not started / In progress / In place
Technical	Is there a shared platform and a data warehouse for integration?	A shared platform may reduce duplication of technical work; cost and effort require evaluation.	Not started / In progress / In place
Technical	Are automated connectors, deduplication and validation feasible for each source?	Automation can reduce manual transfer; validation remains necessary to detect errors.	Not started / In progress / In place
Technical	Is offline functionality available for low-connectivity districts?	Use depends on access where connectivity is poor.	Not started / In progress / In place
Technical	Is local technical capacity, including master trainers, in place or planned?	Local technical capacity may reduce dependence on external support; sustainability requires evaluation.	Not started / In progress / In place

This self-assessment is an unvalidated planning aid. Document existing data ownership and surveillance authority separately from technical collaboration. Technical agreements do not themselves create ownership or surveillance authority; applicable access controls and confidentiality safeguards remain necessary.

Supplementary Table S10. Illustrative maturity matrix

Stage	Technical	Semantic	Organizational (governance)
Stage 0: Fragmented	Separate systems; manual or no data transfer	No common data elements or shared coding	No shared integration coordination or technical collaboration arrangements
Stage 1: Emerging	Shared platform identified; pilot connector	Common data elements drafted	Coordinating body convened; technical roles and existing surveillance authority documented
Stage 2: Integrated	Automated connectors, warehouse, deduplication, offline mode	Coding harmonized; rates, ratios and service-delivery indicators	Required arrangements completed for available sources; framework finalized
Stage 3: institutionalized	Government-hosted and maintained; routine use	Endorsed data dictionary; routine analytic use	Required arrangements operating for participating sources; embedded unit and financing

Stages illustrate planning dimensions, not a validated score. No claim is made that Sierra Leone reached every criterion in a stage.

Supplementary Table S11. Planned and observed sequencing of selected milestones

Layer	Milestone	Planned program period	Actual program status
Technical	Mortality data warehouse and civil-registration connector	Months 1 to 3	18 September 2025; day 86
Technical	Offline functionality for district dashboards	Months 4 to 6	4 March 2026; day 253
Semantic	47 common data elements and coding specification	Months 1 to 3	12 August 2025; day 49
Semantic	Rates, ratios and service-delivery indicator framework	Months 4 to 6	16 January 2026; day 206
Organizational	Technical Working Group convened	Month 1	24 June 2025; day 0
Organizational	Data governance framework	Months 7 to 12	May 2026; submitted for endorsement; no exact day recorded
Organizational	HEAL-SL technical cooperation agreement for dashboard integration	Months 1 to 6	April 2026; elapsed-day bounds 281-310. Feed activation reported within 14 days of conclusion. Bounds are not exact execution or transfer dates.

Supplementary Table S12. mERA-related reporting map

#	mERA item	How addressed in this paper
1	Infrastructure	National DHIS2 infrastructure, NPHA servers, and district connectivity described in Dashboard development and integration and Methods.
2	Technology platform	Built on DHIS2 with a mortality data warehouse and application programming interface connectors (Dashboard development and integration; Figure 2).
3	Interoperability with health information systems	Integration of the three priority sources, civil registration, disease surveillance and verbal autopsy, analyzed by interoperability layer (Methods; Figure 2; Supplementary Tables S1 and S5).
4	Intervention delivery	Phased delivery over twelve months across design, pilot and institutionalization (Methods; Supplementary Tables S1 and S5).
5	Intervention content	Integrated dashboard with place of death, certification, timeliness and source-contribution indicators (Dashboard development and integration; Table 1; Figure 1).
6	Usability and content testing	Prototype user-acceptance testing with 35 participants (Results).
7	User feedback	Daily routine engagement, prototype testing and the national scaling workshop (38 participants) informed the indicator framework. User consultation continues as part of routine programme performance evaluation and improvement, independently of publication (Methods; Results).
8	Access of individual participants	Offline functionality addressed connectivity and power constraints in pilot districts (Dashboard development and integration; Results).
9	Cost assessment	No formal economic evaluation was undertaken. The fixed-grant implementation and transfer of hosting to the National Public Health Agency are reported.
10	Adoption inputs and program entry	District training and six local master trainers developed; standard operating procedures and manuals produced (Results).
11	Limitations for delivery at scale	Surveillance feed population and certification gap discussed (Limitations).
12	Contextual adaptability	Designed for partial integration and low-connectivity districts; the framework is presented as a testable proposition rather than validated guidance.
13	Replicability	Architecture, common data elements, coding standard, milestone log and implementation tools support replication (Methods; Supplementary Tables S1, S5, S6, S9 and S10).
14	Data security	Encrypted transmission and role-based access controls (Results; Ethics and permissions; Figure 2).
15	Compliance with regulatory statutes	NPHA routine surveillance mandate and the manuscript's implementation-science analysis are distinguished. SLESRC determination SLESRC-2026-011 (7 October 2026) addresses the described activities and their documentation/reporting. The HEAL-SL agreement concerns technical integration, not ownership or new surveillance authority; access controls remain in place. Routine written consent at programme meetings covered materials and photographs; no meeting photographs were used. Documentation is available to the editor on request.

#	mERA item	How addressed in this paper
16	Fidelity	Indicator framework with baselines and targets and two scheduled data quality assessments (Methods; Table 1; Supplementary Tables S4 and S3).

This is a narrative reporting map, not a reproduced official checklist.

Supplementary Table S13. StaRI-related reporting map

Map row	StaRI-related reporting topic	Location / statement
1	Title	Title identifies dashboard development, implementation experience and governance lessons without claiming completed integration.
2	Abstract	Structured abstract summarising introduction, methods, results and conclusion.
3	Problem, challenge or deficit	Mortality data fragmented across multiple systems and data sources, and the consequences for national integration and decision-making (Background).
4	Scientific background and rationale	Interoperability layers and prior evidence on data silos and governance (Background).
5	Aims and objectives	Background states objectives: describe dashboard and strategy; document operational outputs and quality constraints; examine sequence; derive practical lessons for adaptation.
6	Design	Convergent mixed methods implementation-science analysis of NPHA's continuing national surveillance programme during June 2025-June 2026. The dashboard is designed for real-time integration using agreed common variables; routine consultation and performance evaluation continue beyond the reporting window. The paper documents this experience for other countries (Methods).
7	Context	Sierra Leone mortality systems and institutional setting (Local context).
8	Targeted sites and population	National platform holding records from all 16 districts; district dashboards, offline deployment, district training and data quality assessments in two pilot districts, Western Area Urban and Western Area Rural (Methods, Setting, participants and governance; Local context).
9	Implementation strategy	Coordination, mapping, common standards, source integration, user testing, training and handover; practical ten-step aid in S16.
10	Intervention	Integrated mortality dashboard architecture, security controls, dashboard views and source interfaces (Dashboard development and integration; Figures 1 and 2).
11	Evaluation framework	Interoperability layers and the Consolidated Framework for Implementation Research (Methods).
12	Implementation outcomes and measures	Adoption, feasibility, fidelity and sustainability assessed through the monitoring framework (Methods; Table 1; Supplementary Table S3).

Map row	StaRI-related reporting topic	Location / statement
13	Process and contextual data	Programme and governance documents, two structured observation records and 22 semi-structured debrief-note sets within daily engagement. Purposive maximum-variation recruitment, 20-40-minute duration, topic guide, note preparation and code saturation are described (Methods; S2).
14	Economic evaluation	Not applicable; no economic evaluation was undertaken.
15	Analysis	Framework analysis and joint display; descriptive platform summaries without inferential CI; sampled linkage intervals; elapsed-day milestone chronology (Methods; S2, S5-S7).
16	Ethics	SLESRC determination SLESRC-2026-011 (7 October 2026, after the reporting window) classifies the described programme activities and their documentation/reporting as public-health practice not requiring research ethics approval. This does not depend on avoiding research terminology. Government ownership, existing surveillance authority, technical cooperation and confidentiality controls are distinguished. Participation was voluntary. Written consent at all programme meetings covered use of materials in documentation and publications, including photographs. No meeting photographs were used; consent documentation and meeting records are available to the editor on request.
17	Sites and participants	Engagement with NPHA, Ministry of Health, NCRA, Njala University and the two pilot district health management teams (Methods; Results).
18	Implementation outcomes (results)	Warehouse, three technical links, two useful-volume sources, common specifications, 48/63 changes implemented, two pilot districts and handover. Milestones are not complete-layer closure.
19	Intervention outcomes	Three source connections live, with two volume-bearing sources; national service-delivery indicators generated; sensitivity analysis quantified the information added by verbal autopsy (Results; Table 1; Supplementary Table S8).
20	Harms and unintended consequences	No systematic harms assessment was reported. Sparse source data, coding limitations and operational constraints are described; absence of reported harm is not evidence of safety.
21	Summary of findings	Technical connectivity, useful flow, source quality and institutional responsibilities are distinct. HEAL-SL illustrates technical collaboration under existing government ownership; eIDSR illustrates sparse source reporting.
22	Strengths and limitations	Single setting; routine documentation and author positionality; source ascertainment and coding; linkage validation limits; missing detail for some monitoring summaries (Limitations; S17).
23	Comparison, implications, generalizability	Compared with mortality and digital-health system development in Suriname, Uganda, Ghana and Slovenia, and with a 13-country rapid mortality surveillance evaluation; transferability framed as testable propositions (Discussion; Generalizability).
24	Funding, conflicts, data sharing	Funding and funder role; authors' programme roles as potential non-financial competing interests; controlled access and data availability (Declarations).

Map-row numbers are local navigation labels, not official StaRI item numbers. The map distinguishes the dashboard intervention from the implementation activities used to introduce it.

Supplementary Table S14. GRAMMS reporting map

#	GRAMMS criterion	How addressed
1	Justification for using a mixed methods approach	Quantitative summaries described outputs and timing; analysis of routine programme documents explained operational experience. Integration distinguished connection, useful flow, source quality and technical collaboration.
2	Design, including purpose, priority and sequence	Convergent documentation: evidence from the same reporting window was analysed separately and integrated in interpretation; ongoing surveillance was not terminated by the reporting window.
3	Description of each method	Platform analytics, monitoring, two sampled DQAs and linkage checks; 41 programme documents, 14 governance records, two structured observation records and 22 semi-structured debrief-note sets. Debriefs used purposive maximum-variation recruitment, a topic guide and 20-40-minute discussions; code saturation was assessed. Routine engagement continued daily (Methods; S2).
4	Where integration occurred, who integrated and how	Integration at analysis and interpretation, by the study team, using a joint display of implementation outcomes with a fit judgment (Supplementary Table S7).
5	Limitation of one method associated with the other	Milestones establish sequence but not causal effects; programme notes provide context but may be selective. Their complementary limitations are reported.
6	Insights gained from mixing methods	A working interface did not guarantee useful records. Technical collaboration and source reporting posed different implementation problems. S16 organises these activities into a planning aid for testing.

Supplementary Table S15. Glossary of terms

Term	Plain-language meaning	Where used
Interoperability	The ability of different information systems to exchange data and to use the data exchanged.	Background
Technical interoperability	The infrastructure and software links that move data between systems.	Background; Figure 3
Semantic interoperability	Shared definitions, data elements and codes, so that data mean the same thing in every system.	Background; Figure 3
Organizational interoperability (governance)	Institutional responsibilities, stewardship and coordination needed to connect systems and use information together; distinct from any change in underlying ownership or existing surveillance authority.	Background; Results; Figure 3
Convergent mixed methods design	Quantitative and qualitative evidence are collected over the same period, analyzed separately and then compared.	Methods, Design; Supplementary Table S2
Strand	One of the two bodies of evidence in a mixed methods study: quantitative or qualitative.	Methods
Framework method	A qualitative analysis approach in which coded material is charted into a matrix (sources in rows, themes in columns) so that sources can be compared theme by theme.	Methods, Analysis and integration
Semi-structured implementer debrief	A 20-40-minute programme-feedback discussion using a topic guide. Purposive selection covers different institutional constituencies, districts and roles; notes provide qualitative evidence alongside ongoing daily engagement.	Methods; S2
Joint display	A table that sets quantitative beside qualitative evidence for each outcome. Fit is classified as confirmation (the strands agree), expansion (one strand adds something the other did not capture) or discordance (the strands disagree).	Methods; Results; Supplementary Table S7
Data warehouse	A central database that stores records from all sources in one common format.	Dashboard development and integration; Figure 2
Connector (application programming interface)	A software link that transfers records automatically from a source system to the data warehouse.	Dashboard development and integration; Figure 2
Technically live connection	A connector that has been established and tested, whether or not records flow through it.	Methods; Table 1
Volume-bearing connection	A connection that transfers usable records for routine analysis. Two of the three live connections met this definition at endline.	Methods; Results; Table 1
Common data elements	The 47 fields defined in the same way across the three sources.	Dashboard development and integration

Term	Plain-language meaning	Where used
Deduplication	Identifying records of the same death that appear in more than one source and keeping one of them.	Methods; Supplementary Table S6
Hierarchical deterministic matching	Rule-based matching. Two records are treated as the same death when they agree on a fixed rule; three rules were applied in order.	Methods; Supplementary Table S6
Blocking	Comparing only records from the same district and year of death, to limit the number of comparisons.	Methods; Supplementary Table S6
Candidate pair (flagged pair)	Two records identified as possibly describing the same death.	Methods; Supplementary Table S6
Clerical review	Manual adjudication of candidate pairs by two trained officers, with a third resolving disagreements.	Methods; Supplementary Table S6
Near-miss pair	Two records that agree on at least two identifiers but were not classified as a match.	Methods; Results; Supplementary Table S6
Unique decedents	Records remaining after one record is removed from each confirmed duplicate pair (33,305 − 1,071 = 32,234). The 96.8% is a share of records held on the platform, not national mortality coverage.	Results; Table 1
Six-field completeness	Non-missing entries divided by 3,600 expected entries (600 sampled records × six fields), multiplied by 100.	Methods; Table 1; Supplementary Table S4
Elapsed implementation days	Calendar days from 24 June 2025 (day 0); exact intervals for dated events and lower/upper calendar bounds for month-only entries.	Methods; Table 1; S5
Implementation milestone	Completion of a specified output. It does not establish functional completion of an entire interoperability layer.	Methods; Results; S5
Technical cooperation agreement chronology	Dates of drafting, legal review, escalation, conclusion and activation of dashboard integration; not dates when government acquired ownership or surveillance authority. Exact between-layer intervals are not inferred from month-only dates.	Results; S5; S11
Technical collaboration constraint	Delay or difficulty coordinating joint technical work for integration; not evidence that NPHA lacked ownership or surveillance authority and not a universal ranking of interoperability layers.	Results; Discussion
Wilson 95% confidence interval	Interval used for the sampled linkage proportions; not applied to complete platform counts or correlated field-level completeness entries.	Methods; Table 1
Cohen kappa	A measure of agreement between two adjudicators beyond chance; 1 indicates perfect agreement.	Methods; Table 1

Supplementary Table S16. Practical ten-step implementation pathway

This planning aid translates the Sierra Leone experience into actions for local adaptation, not a tested causal sequence. Steps overlap: technical collaboration starts at inception, and daily engagement and formal testing recur. Existing surveillance authority, technical responsibilities and safeguards are distinct. Scale-up is a planning function, not evidence of completed nationwide district rollout.

Step and timing	Country action	Minimum output / retained evidence	Readiness question
1. Mandate and coordination | inception	Identify the lead public-health body, convene source custodians and establish shared decision and escalation responsibilities.	Mandate, terms of reference, membership and action log.	Who owns implementation decisions and resolves blocked actions?
2. Source mapping | inception	Map source purpose, coverage, fields, identifiers, update frequency and interfaces; document existing data ownership and surveillance authority and inspect actual record availability.	Source inventory, data-flow map and source-readiness assessment.	Does each proposed source contain the records expected of it?
3. Common data standards | early design	Define the minimum dataset, identifiers, geography, source provenance and cause-mapping rules; record missingness explicitly.	Versioned data dictionary and mapping specification.	Do fields mean the same thing across sources, and what remains unmapped?
4. Use cases and indicators | early design, revisited during testing	Specify intended users and decisions; define numerators, denominators, dates and display limits.	Indicator reference sheets and prioritised surveillance use cases.	Can users interpret each output without confusing platform records with national coverage?
5. Architecture and security | design/build	Select a shared warehouse and modular source connections; define access roles, encryption and low-connectivity requirements.	Architecture, access matrix and operating/security procedures.	Can each authorised source connect without exposing identifiers in public outputs?
6. Source integration and validation | build	Test transfer, mapping, validation and duplicate handling; reconcile source and warehouse counts. Apply existing surveillance authority and confidentiality controls; use non-identifiable test records where required.	Test results, reconciliation logs and validation rules.	Is the connection merely live, or does it transfer usable, interpretable records?
7. Technical collaboration | start at inception; run in parallel	Agree technical roles, integration responsibilities, support and escalation. Distinguish these arrangements from pre-existing ownership and surveillance authority; seek additional permissions only where required for the proposed use.	Technical cooperation plan or agreement; record of existing authority and any additional permissions applicable to the proposed use.	Are technical responsibilities agreed and the applicable surveillance authority and safeguards clear, without treating cooperation as ownership transfer?
8. User testing and iteration | prototype/pilot	Embed routine feedback and observation in daily implementation work; test prototypes formally, prioritise requests and verify implemented changes.	Test notes and change register showing request, action and status.	Do users confirm that priority functions and indicator definitions support routine work?
9. Routine-condition pilot | pilot	Deploy in contrasting operating conditions, train users, verify end-to-end use and review source-data problems.	Pilot and training records, support log and dated examples of use.	Does the system function in practice, and which gaps need source-system rather than software action?

Step and timing	Country action	Minimum output / retained evidence	Readiness question
10. Institutionalisation and scale-up planning | continuing operations	Place hosting and stewardship in government operations; plan maintenance, financing, trainers, supervision, quality review and staged expansion.	Handover record, maintenance plan, support arrangements and scale-up criteria.	Who sustains the system, and what evidence supports expansion beyond the pilot?

Supplementary Table S17. Measurement definitions and interpretation of programme summaries

Measure or claim	Definition / available evidence	Interpretive boundary
Platform proportions	All 33,305 platform records; source counts 23,323 NCRA, 9,979 HEAL-SL, 3 eIDSR. Deduplication removes 1,071 and retains 32,234.	Complete platform counts, not a census or established probability sample of national deaths. No inferential CI.
Cause-code denominator	Figure 1C shows 3,299 missing codes, all in NCRA. Therefore 33,305 - 3,299 = 30,006 coded records. Displayed categories are percentages of coded causes.	30,006 is derived by subtraction from displayed totals. It is a reconstructed coded-record total; no original-query denominator or cause-specific numerator is newly inferred.
Civil-registration timing	The recorded endpoint is registration; interval starts at death. Baseline summaries: mean 14.0 days (SD 21.3), median 6 days.	Baseline source mix differs from the mixed-source endpoint.
HEAL-SL and eIDSR timing	Earlier programme summaries describe a registration/entry endpoint but do not identify whether it denotes notification, source entry, interview completion or warehouse ingestion for each source.	Event meaning is not resolved in the retained summaries. The historical values are not labelled as interview latency, platform-availability latency or a harmonised reporting-speed measure.
Mixed-source timing summaries	26,777/33,305 (80.4%) within 48 hours; mean 5.1 days (SD 9.8); median 2 days (IQR 1-5). Excluding HEAL-SL: 82.1% within 48 hours.	Retained as legacy monitoring outputs only. No before-after improvement or interview-within-48-hours claim is made.
Linkage agreement and kappa	Random blinded flagged-pair audit: 196/200 agreement. The programme summary reports inter-adjudicator kappa 0.94 (reported 95% CI 0.88-1.00); 0.94 is retained.	The paired-rater table and analytic denominator are not reproduced. No artificial classification table or independently recalculated kappa interval is supplied.
Sampled completeness	600 records per round; six fields, 3,600 entries. Reported scores: 91.4% and 99.9%. Removing the structurally complete identifier algebraically gives approximately 89.7% and 99.9% for the other five fields; these are derived from rounded means, not a new audit.	Five-field sensitivity = (6 x six-field percentage - 100)/5. This derivation does not supply record-level variance or a valid confidence interval. Fields within a record are not assumed independent.
Internal consistency and register agreement	Each assessment sampled 600 records. Programme summaries report 412 and 7 consistency violations and 98.6% death-date agreement.	Counts are reported per 600-record assessment, not as affected-record prevalence. The 98.6% result remains a reported summary without reconstructed numerator, denominator or interval.
Dashboard uses	Programme monitoring tallied five uses. The earlier implementation narrative explicitly describes indicator refinement, district mortality review and coding correction in Western Area Rural.	Five is the monitoring tally. Examples are categories of routine use, not five independently dated events. Daily engagement is separate from the number of analysed notes and reported decision uses.
Technical integration chronology	Technical cooperation agreement: October 2025 legal review; February 2026 escalation; April 2026 conclusion; integration feed reportedly activated within 14 days. April corresponds to days 281-310 from inception. NPHA ownership and surveillance use pre-date the agreement.	Conditional calendar envelope for activation: 1 April-14 May 2026 (days 281-324), combining the month-only conclusion with the reported 14-day maximum. These are derived outer bounds, not observed signature, effective or transfer dates.
Change requests	User testing and stakeholder review generated 63 requests; 48 were implemented.	The reported completion proportion is 48/63 = 76.2%; 15 requests were not recorded as implemented. Their disposition is not inferred. No change-request register is recreated.